XXXII.—*Note on Ectocarpus.* By JOHN RATTRAY, M.A., B.Sc., Scottish Marine Station, Granton, Edinburgh. Communicated by JOHN MURRAY, Esq., Ph.D. (Plates CXLVII., CXLVIII.)

(Read 2nd February 1885.)

The group of the Phæosporeæ was first recognised by THURET* in 1850. It includes algæ that vary greatly in size, habit, external appearance, and mode of branching, some possessing a flat thalloid appearance with or without a long stalk (*e.g.*, *Laminariæ*), others being filamentous and much branched (*e.g.*, *Ectocarpus*, *Sphacelaria*, *Chordaria*, &c.). The great majority of the genera included in the group are marine or brackish water forms, but recently E. FLAHAULT† has described, under the name of *Lithoderma fontanum*, a fresh water species from the neighbourhood of Montpellier.

All the forms included under the genus *Ectocarpus* are filamentous, and usually much branched, *E. crinitus* being one of the simplest types, and *E. siliculosus* one of the most complex. The primary branches again may be straight or present gentle undulations (*e.g.*, *E. siliculosus*), or may exhibit well-marked geniculations at the points of origin of the ramuli (*e.g.*, *E. distortus* and *E. Landsburgii*). In some the central filament is of greater diameter than the secondary branches, and so remains a prominent feature in the plant, but in others this occurs to a much less degree, both being of approximately equal size (*e.g.*, *E. crinitus*, &c.).

The particular zone in which the *Ectocarpi* flourish is that extending from high to low water mark, some being found over the whole bathymetrical extent of this belt (*e.g.*, *E. brachiatus*, *E. tomentosus*, *E. littoralis*, *E. siliculosus*, *E. sphærophorus*), others occurring chiefly at the level of half tide (*e.g.*, *E. crinitus*), while yet others are especially obtained near that of low water (*e.g.*, *E. fasciculatus*). Their mode of attachment, too, varies very greatly. They are to be found adhering to mud-covered rocks and stones in the shade (*e.g.*, *E. crinitus*) or in exposed situations (*e.g.*, *E. littoralis*), as well as epiphytically on other algæ in shaded pools (*e.g.*, *E. brachiatus*), or in open places (*e.g.*, *E. sphærophorus*).

The great majority of the species of this genus are found to grow epiphytically on other seaweeds, some being apparently confined to a limited number of host plants, others being less restricted in this respect. Thus *E. brachiatus* is only found associated with *Rhodomenia palmata*, just as *Polysiphonia fastigiata* almost exclusively occurs on *Ascophyllum nodosum*, while *E. fasciculatus* and *E.*

* Thuret, "Recherches sur les zoospores des Algues," *Ann. des Sci. Nat.*, series iii. vol. xiv. 1850.

† *Comptes Rendus*, xcvi. (1884), pp. 1389–91.

tesselatus chiefly occur on *Laminaria digitata* and *L. saccharina*. On the other hand, the host plants of *E. littoralis* and *E. siliculosus* are very numerous, the latter, up to the present time, having been found on *Cladophora rupestris*, *Corallina officinalis*, *Chorda lomentaria*, *Chordaria flagelliformis*, *Ceramium Deslongchampsii*, *Asperococcus echinatus*, *Halidrys siliquosa*, *Polysiphonia elongata*, *P. urceolata*, *Myriotrichia clavaeformis*, and *Rhodymenia palmata*, in the Firth of Forth.* Next to *E. siliculosus* and *E. littoralis*, *E. sphærophorus* is that which is least restricted in its range of host plants, being chiefly found associated with Rhodosperms (*e.g.*, *Callithamnia* and *Ptilotæ*). From this peculiar habit the entire genus might be conveniently divided into two groups—a smaller containing the non-epiphytic species, and a larger including all those found growing on other algæ.

Ectocarpus siliculosus (Lyngb.), upon which my present observations are founded, is an annual plant occurring chiefly from May to September, or, according to HARVEY,† from “spring to autumn.” As already indicated, this species is found between the highest and lowest limits of the tide, and even extends to depths varying from three to four fathoms.

In general habit *E. siliculosus* is most closely allied to *E. littoralis*, but may be distinguished from the latter by its more slender and somewhat softer growth, and by the fact that its ramuli, which may be either alternate or subsecund, are never opposite—an arrangement which may occur in young branches of *E. littoralis*. The multilocular sporangia, moreover, of the two species may be readily distinguished, those of *E. littoralis* being placed in the middle of the ramuli, while those of *E. siliculosus* are lanceolate and terminal.

In addition to the ordinary multilocular sporangia (=Trichosporangia, Nob.) upon whose true reproductive significance all observers are agreed, various species of *Ectocarpus* have from time to time been found to possess so-called “unilocular sporangia” (=Oosporangia, Nob.) with regard to which there has not been the same consensus of opinion among algologists.

THURET,‡ when discussing the fructification of the Phæosporeæ, says:—“La seule fructification que l'on signale dans ces plantes consiste en sporanges ovoïdes (Oosporangia, Nob.), qui ont d'ailleurs été toujours décrits comme des spores simples, quoique en réalité ils soient remplis de nombreux zoospores. Cet organe est le plus visible, et c'est ce qui explique pourquoi il a surtout attiré l'attention des observateurs. L'autre forme de sporanges consiste en filaments cloisonnés.

“(Trichosporangia, Nob.), fort étroits et généralement assez courts, composés d'une série de petites cellules, dans chacune desquelles est renfermé un zoospore.

* Traill, *Monograph of the Algæ of the Firth of Forth*, 1885.

† Harvey, *Phycologia Britannica*.

‡ Thuret, *loc. cit.*, pp. 235–236.

Ces filaments sont très nombreux, et occupent la même place que les sporanges ovoïdes, qu'ils accompagnent parfois: plus ordinairement néanmoins, on ne trouve à la même époque que l'une ou l'autre forme de fructification sur le même individu. Les zoospores issus de ces deux organes offrent une parfaite ressemblance. Seulement ceux qui proviennent des sporanges filamenteux sont un peu plus grands que ceux qui s'échappent des sporanges ovoïdes. J'ai vu d'ailleurs germer les uns et les autres, ce qui prouve suffisamment leur complète identité."

J. E. ARESCHOUG* finds "Oosporangia" and Trichosporangia in *Ectocarpus littoralis*, Harv., and in *E. fasciculatus*, Harv.

J. G. AGARDH† describes the fruits of *Ectocarpus* as consisting of (1) spherical or ovate sessile sporæ or sporidia, enclosed within a hyaline perisporium, and (2) of motile sporidia—the sporidia being spherical or ovato-ellipsoidal capsules. He also describes pod-like propagula.

KÜTZING‡ figures in *Ectocarpus fasciculatus* unilocular forms of fruit as "spores," and multilocular as "spermatoidia," the latter, according to Professor PERCEVAL WRIGHT, being very like parasitic Chytridial growths. He also represents, according to Professor MAGNUS, Chytridial parasites as "intercellular spores" of various *Callithamnia*.

C. GOBI§ figures "Oosporangia" and Trichosporangia in *Ectocarpus approximatus* v. *balticus*, Kütz.

W. G. FARLOW|| notes that the so-called "oosporangial" fruit of *Ectocarpus* has not hitherto been observed in America, although the trichosporangial form is well known.

HARVEY,¶ as pointed out by Professor WRIGHT, represents the round or elliptical sessile "utricles" or "spores," which have been recognised as "oosporangia," as outgrowths of cells in *Ectocarpus crinitus*, *E. pusillus*, *E. granulatus*, and *E. sphærophorus*.

PRINGSHEIM,** while figuring (Taf. ix. fig. 7) the terminal portion of a branch of *Sphacelaria olivacea* v. *cæspitosa*, Dillw., which has become invaded by parasitic Chytridial cells, also represents (Taf. ix. fig. 9, c) certain cells which have enlarged into a rounded ball-shaped form, which he calls "Brutzelle," but the exact interpretation of these structures he leaves undecided. "Die sonder-

* J. E. Areschoug, *Algæ Scandinavice exsiccatae, seriei novæ*, Feb. 4, 1862.

† J. G. Agardh, *Species, Genera, et Ordines Fucoidearum*, Lundæ, 1848, p. 14.

‡ Kützing, *Tab. Phyc.*, vol. v. pl. 50, ii.

§ C. Gobi, "Die Brauntange des Finnischen Meerbusens," *Mem. de l'Acad. Imp. des Sci. de Petersbourg*, sept. serie, tome xxi. No. 9, 1874.

|| W. G. Farlow, "List of the Marine Algæ of the United States," in *Proc. Amer. Acad. of Arts and Sciences*, vol. x. 2nd series, p. 351, 1875.

¶ Harvey, *loc. cit.*

** Pringsheim, "Ueber den Gang der morphologischen Differenzirung in der Sphacelarien-Reihe," *Abhandl. d. Königl. Akad. der Wiss. zu Berlin*, 1873.

bare Umwandlung ihres Inhaltes, die sich von der der endständigen Sphacelen wesentlich unterscheidet, *gestattet noch keine sichere Deutung*. Entschiedene Parasiten sind mir in ihnen nicht aufgefallen. Es ist mir nicht fraglich, dass es diese Bildungen sind, welche einige ältere Algologen als sitzende Sporen beschrieben und abgebildet haben."

The parasitic or non-parasitic nature of the much swollen club-shaped cells represented in plate ix. fig. 9, *d*, and in plate x. figs. 5, 6, and 7, the contents of which escape as free swimming ciliated swarmspores, a more or less definitely defined network of the mother cell walls being left behind, this author also leaves undecided, remarking—"Ich habe diese Bildung, die sich, wenn sie nicht in den Entwicklungsgang der Pflanze selbst gehört, an keine bekanntere Parasitenform anschliesst, bisher nur an der *Sphacelaria olivacea* von Helgoland aufgefunden; an anderen Sphacelarien ist sie mir nicht aufgestossen. Sie verlangt eine weitere, eingehende Berücksichtigung."

COHN,* in 1867, drew attention to the fact that Chytridial parasitic organisms had often been represented as part of the tissue proper of the host plants, *e.g.*, by SOLIER and DERBÉS,† in the case of *Aglaophyllum ocellatum*, while MAGNUS refers the "abnormally swollen up apical cells in *Ceramium spiniferum*, Kütz., figured by CRAMER, to a new species of Chytridium—*Olpidium tumefaciens*, Mag.,‡ which is figured by HARVEY§ as probably the antheridia of *Callithamnion dispar*, Harv.; he also believes that the "abortive spore mother cells," figured by NÄGELI|| in *Callithamnion cruciatum*, are referable to the parasitic *Chytridium plumulæ*, Cohn.

Professor E. P. WRIGHT¶ maintains that GRUNOW** has taken parasitic Chytridia for true spores in *Callithamnion*, and possibly in *Leda capensis* (Grun.), &c.

In *Ectocarpus granulosus*, Professor WRIGHT "has watched through all its stages, save that of germination, the Chytridial form which has been mistaken for an oosporangium," and while satisfying himself that the parasite is the "only fruit known" in *Ectocarpus crinitus*, he believes that in *E. sphærophorus* the oval cells, although they may not be foreign bodies, are "most suspiciously like some Chytridial growth."

* F. Cohn, "Beiträge zur Physiologie der Florideen," Max Schultze's *Archiv für Mikroskopische Anatomie*, Bd. iii. s. 41, 1867.

† Capt. Solier and Dr Derbés, *Memoire sur la Physiologie des Algues*, p. 67, pl. xxi. figs. 10-12.

‡ Magnus, in *Jahrbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel*, für die Jahre 1872-73, Berlin, 1875.

§ Harvey's *Phycologia Australica*, vol. vi. 1862.

|| Nägeli, *Die neuern Algensystem*, Zurich, 1847, p. 202, Tab. vi. fig. 1, s, s; 4, s, s.

¶ Prof. E. P. Wright "On a Species of Rhizophyidium parasitic on Species of Ectocarpus, &c." *Trans. Roy. Irish. Acad.*, vol. xxvi. August 1877.

** Grunow, *Reise S. M. F. Novara um die Erde. Botanik*, Th. i. Algen, Tab. vi.

The genus *Rhizophydium* was established by SCHENK for Chytridiaceous parasites, whose spores escape by one or more apertures. The globular and unicellular *Rhizophydium Dicksonii* has hitherto only been noted on *Ectocarpus granulosus* gathered at Howth, near Dublin, during the winters of 1876 and 1877. I, however, gathered specimens of *Ectocarpus siliculosus* which were affected with this parasite on December 4, 1884, about 10.30 A.M. The host plant was found growing epiphytically on a fragment of *Polysiphonia fibrillosa*, which was obtained about the level of $\frac{3}{4}$ -tide in the old Granton Quarry. A small part of the shale on which the *Polysiphonia* grew was removed at the same time, so that the epiphyte and its parasite were disturbed as little as possible. The temperature of the water at the time of removal was $41^{\circ}2$ Fahr. Some of the specimens of *Ectocarpus* thus obtained were placed in a small glass vessel containing sea water, and kept for some days in the microscopic room of the "Ark," the floating laboratory connected with this station. This material was repeatedly examined to determine when rupture of the cells would be likely to take place and this occurred about 1.30 P.M. on December 7, when specimens were at once mounted in weak acetic acid. The temperature of the water in the vessel in which rupture occurred was $51^{\circ}8$ Fahr.

The parasitic Rhizophydial cells were found to be widely disposed over the penultimate, but sometimes occurred on the ultimate ramuli of their host plant (Pl. CXLVII.). In the former they were not confined to any definite region, but were found scattered at irregular intervals along their entire length. They usually occurred singly, but at other times were found in pairs (Pl. CXLVIII. fig. 8), while in a few cases three contiguous host cells were attacked (Pl. CXLVIII. fig. 3).

The parasitic cells enter the cells of the host plant at a very early stage of their existence, and gradually develop at the expense of the highly organised protoplasmic contents of the latter. In Pl. CXLVIII. fig. 2, two adjoining host cells have been penetrated by the Rhizophydial cells, which have arrived at different stages of development; Pl. CXLVIII. fig. 2, *a*, represents the earliest stage which I have observed. The parasite presents the appearance of a nucleus, and is surrounded by a thin but definite cell wall. In figs. 1, 4, and 5 of the same Plate somewhat more advanced stages of development are represented, and while in figs. 1 and 5 the Rhizophydium has assumed an almost perfectly ellipsoidal form, in fig. 4 it exhibits a tendency to expand laterally, being even slightly involuted at one end, on account of the greater resistance to which it is exposed in this region. At this stage the presence of the parasite is, in ordinary circumstances, revealed by the slightly globular form assumed at a very early period by the host cell containing it. Sometimes, however, as in the case represented in fig. 2, *b*, the parasitic cell may grow to a moderate size without producing the ovoid bulging of its containing host cell, and without itself retaining the normal globular or ellipsoidal outline. This is probably attributable to the

fact that it has entered a cell which is not very rich in organic contents, in which it is enabled to develop without producing so great internal pressure as must necessarily be exerted when the latter is tensely filled with fluid cell sap and other protoplasmic substances, or derivatives from these.

A still more remarkable appearance is that represented in fig. 6. Here the host cell has become distinctly globular, and contains a well-defined parasitic Rhizophydium, around which a more or less hyaline area is found, in which the chlorophyll granules show manifest pathological changes. Instead of being absolutely round, this parasite has a well-defined and moderately deep indentation on one margin, around which its cell wall passes without interruption. It is not easy to give a satisfactory reason for the existence of this fold, although two possible explanations may be offered, namely, it may be due to the existence of a greater internal pressure existing in the host cell at this point, a slight divergence from the perfect equilibrium being sufficient to cause a sinuosity in the thin and pliant cell membrane, or if this parasite should ultimately be found to possess this indentation in its earlier stages, it may point to a specific distinction between it and the perfectly ovoid or globular type. As only a single instance of this peculiar phenomenon was observed, it is not unlikely that the former explanation is the more trustworthy.

At the moment of rupture the cells containing the mature Rhizophydia present in most cases a distinctly ovoid appearance. That the internal tension in these cells is at this time great is proved at once by their external form, by the fact that they bulge into adjoining cells of the host plant which are not so affected, and by the existence of creases which may not uncommonly be observed just after the rupture (fig. 12). It is also to be noted, that as soon as relief from this tension is obtained, the adjoining cells of the thallus of the host plant at once become convex on the side of the ruptured cell in virtue of their own elasticity, and so tend to cause a more violent rupture, and to facilitate the dissemination of the swarmspores of the parasite.

In cases where three adjoining cells contain parasites (fig. 3, *a*, *b*, *c*), the middle cell, which is unable to indent the walls of the adjoining tense cells, expands usually in a somewhat lateral direction, and always towards that side on which the resistance is least when this tendency is first manifested.

After rupture takes place the appearances presented by the affected cell areas are sometimes of a very fantastic kind. The cell wall of the parasite, as soon as the wall of the host cell opens, suddenly swells up, owing to the pressure exerted by the contents against its inner surface, in many cases to twice its former dimensions (figs. 7, 10, 11, &c.). At first the parasitic cell membrane is entire (fig. 10), but it soon opens to the exterior, sometimes by a single pore (fig. 9), which may be directed either towards the base of the filament, or towards its apex, or at right angles to its longitudinal axis, sometimes by two

pores, the one being directed towards the base of the filament, the other towards its apex (fig. 8, *a*), or both being placed approximately at right angles to its axis, either on opposite sides (fig. 8, *c*), or on the same side, at other times by three apertures arranged in various ways (figs. 11, *a*, and 12). It should here be noted that these apertures in the cell wall of the parasite often lie in different planes, and that it is not always possible to see all of them without a change of focus under the microscope.

Although two or three openings are of frequent occurrence in the cell membrane of the parasite, the cell wall of the host plant invariably opens only at one point, and in many cases it is possible to see clearly the margins of the ruptured wall (figs. 7, 9, 10, and 11). It may also be observed, that this ovoid wall is no longer able to recover its original form after rupture, inasmuch as the limit of its elasticity has in most cases been passed, so that a perfect rebound is not possible, while the long continued internal tension has contributed to it a certain fixity of form which its remaining elasticity is not able to reverse.

In some cases (fig. 9) one meets with a remarkable involution of the wall of the host cell after rupture has occurred. This fold, which usually occupies a position approximately diametrically opposite to the place of rupture, may have resulted either from the fact that the cellulose wall burst before the limit of its elasticity was passed, so that a sudden and sharp recoil became possible, or from the impact of some foreign body which, by striking against the involuted region, at once caused that fold, and affected a rupture of the wall at the diametrically opposite point. The occurrence of such a fold is, however, unusual.

After rupture the swollen cell membrane of the parasite, which invariably remains very thin and pliable, exhibits numerous creases, which become especially manifest when examined under a water immersion high power lens (fig. 7). These fine irregular folds point to the presence of a certain amount of rigidity in this membrane, which may be partly induced by direct contact with the water of the surrounding medium. That the immense surface which the intact but swollen host-cell membrane offers to the waves must tend powerfully to bring about the complete destruction of the host plant by inducing or effecting complete breakages of the thallus at these already weakened regions is at once obvious.

When the parasitic cells have just opened, relief from internal tension is at first experienced in the neighbourhood of the orifice or orifices, and it is often possible to observe that the young swarmspores, into which the protoplasm has divided, and which lie toward the opposite side of the cell, have, at this time, an angulated or polyhedral outline. This, however, is of a transitory character, and is due to the mutual pressure resulting from their continued growth (fig. 11, *a*).

A peculiar and interesting disposition of the swarmspores is to be observed

in fig. 10. Here the host cell wall has ruptured, and the membrane of the parasitic cell has swollen so much that a complete relief from internal pressure has occurred without rupturing the latter. The result is that the swarmspores are arranged in a retiform manner, forming meshes by adhering to each other along certain lines. That this is a transitory stage is at once manifest, but that it may be the final appearance, presented by the swarmspores generally just before the rupture of their bounding cell membrane takes place, is not unlikely. It indicates that, although the protoplasm contained in the parent Rhizophydium divides by a simultaneous process into numerous spores, a final separation is not effected at the same moment throughout the entire mass, but rather along certain lines whose direction is in all probability determined by the lines along which the force or forces that determine rupture act.

Various causes operate in bringing about the rupture of the cell wall of the host plant, as well as of the thinner and more elastic membrane of the endoparasite. These may be regarded as being (*a*) intrinsic and (*b*) extrinsic. Of intrinsic causes there may be noted (1) internal tension, and (2) weakness resulting from pathological changes. The former of these factors is no doubt that of the greater significance. It originates in the developmental changes that take place inside the endoparasite. The volume of the latter is being slowly increased, and while a certain amount of nutritive material must be removed from the host cell to produce this result, so that tension strain would thus so far be antagonised, the growth of the parasite that follows more than counterbalances the changes effected, while at the same time a certain amount of carbonic acid gas, resulting from protoplasmic oxidation, given out by the parasite, will tend still further to increase the pressure. As already noted, that pressure causes, first a bulging of the host cell into the surrounding medium chiefly, but also partly into adjoining cells of the thallus when these are not similarly affected, and finally it results in producing rupture at their weakest point. The ultimate expansion and rupture of the parasitic cell wall are due to a similar tension exerted by the ever-increasing swarmspores.

(2) The weakness resulting from pathological changes, operates, though in a less degree, in accelerating the bursting of the host cell wall. The full complement of nutritive material no longer reaches this wall from its normal channel, viz., its own cell protoplasm, so that the supply of new food molecules, to maintain the oxidation consequent on vital activity, is partially checked. This may result in pathological molecular transformations in the wall, producing areas of weakness, where rupture becomes possible by the operation of internal pressure and the other extrinsic causes. In confirmation of this view, it is to be remarked that the host cell is not usually found to rupture at or towards an angle of the cell,* but, in most cases, opposite the middle of the cell lumen.

* If rupture occurs here, it is attributable to the action of extrinsic and purely accidental causes.

This is explicable on the supposition that the parts of the cell wall adjoining other cells continue to receive relays of food molecules from the latter, when they are no longer able to procure them from the protoplasmic material which occupies the lumen of the cell which they themselves bound, so that devitalising changes are retarded most, just in the immediate vicinity of these adjoining cells, but less and less as we advance from that point, and least of all opposite the middle of the cell lumen where rupture is effected.

Among the extrinsic causes that induce rupture, there may be noted (1) the pressure exerted by the contents of adjoining cells which are not similarly affected with the parasite. The operation of this cause becomes plain when it is remembered that the bulging of the affected cell causes the cell walls, bounding adjoining cells, to become concave on the side next itself. This sets up an elastic pressure in the contents of these adjoining cells, which in turn acts on cells next them, and so on. When rupture of the ovoid host cell takes place, the hitherto concave walls of the neighbouring cells become convex, and so bulge into the ruptured cell, thereby causing a wider dissemination of its contents than would otherwise be the case.

(2) The impact of ripples or foreign bodies against the swollen host cells, the former of which especially occurs when the tide just reaches the level at which the plant grows, have obviously a similar tendency.

Negative heliotropism of the swarmspores of Rhizophyidium.—After a large number of the swarmspores of *Rhizophyidium* had escaped into the watch-glass in which the host plants lay, the glass was surrounded, to the level of its brim, with black paper, so that no light could penetrate into it from beneath. The surface was then covered as closely as possible to the level of the water with a similar piece of black paper. Before being covered on the surface, the water in the glass was stirred gently with a needle, so that the swarmspores were equally diffused through it. The cover when adjusted was allowed to remain for several hours, and it was so arranged as to conceal the surface of fully three-fourths of the glass. On re-examination of the water by removing two samples of it simultaneously with two very small dipping tubes, and placing them under microscopes, it was found that while the water which had been exposed to the daylight contained a few swarmspores, the greater number of the spores, which were still in active motion, had congregated on the dark edge of the glass. Their general tendency must, accordingly, be regarded as negatively heliotropic.

In connection with this subject, it may at this point be noted, that in the same gathering of *Ectocarpus siliculosus*, many specimens were obtained which bore the ordinary multilocular fruit figured by HARVEY.* The biciliate swarmspores that escaped were observed for some hours under the microscope. The

* Harvey, *Phyc. Brit.*

light was so adjusted, by means of the mirror, that about two-thirds of the field was dark, while the remaining third was illuminated with diffuse daylight, and it was observed that the true reproductive swarmspores of this species had similar negative heliotropic tendencies, as they congregated on the dark part of the field.* In a genus closely allied to *Ectocarpus*, viz., *Sphacelaria plumigera*, I am informed by Mr TRAILL that Mr E. M. HOLMES, F.L.S., has recorded similar heliophobic movements of the swarmspores. It may be added, by way of contrast, that, according to BORZI,† the zoogonidia of *Ulva* are positively heliotropic, while the conjugated zoospores have opposite or heliophobic tendencies.

The significance of such movements, in relation to the light, may be of importance as affording an early indication of the habit of the plants. Thus many marine algæ avoid exposed sunny places, and delight in dark rocky crannies, where the rocks, from their softer nature, have become eroded by wave action, aided by the denudatory effects of the impact of hail, snow, rain, &c. That such seaweeds tend to accelerate marine erosion cannot be doubted, when it is remembered that their rhizoids, in many cases, become entangled among minute particles of shale or other soft rock, and that the plants possess a certain buoyant power which tends to lift the fragments, to which these rhizoids are fixed, from their place. This buoyant power, moreover, is often largely increased by the passage of waves which play against the thallus, and so increase its pull upon the rock to which it is fixed.

Although swarmspores, that are thus heliophobic, tend in the first instance to settle down upon shaded water-worn spots, it does not follow that round mammillated or exposed rocks are never covered by algæ, whose spores exhibit such a tendency. It is to be borne in mind, on the contrary, that a heliophobic spore may often find enough of shade among the rhizoids of other pre-existing weeds, while its rhizoids will in turn form a suitable nidus for another similarly disposed spore, so that finally a round exposed protuberance may be entirely covered with algæ whose spores are negatively heliotropic.

In connection with what has been stated above, with regard to the escape of the multilocular swarmspores of *Ectocarpus siliculosus*, it is of interest to record that the period during which spores may escape in that species can no longer be limited to the summer season, as has hitherto been done in the basin of the Firth of Forth, but must be extended to December. It is, however, to be borne in mind, that the unusual mildness of the season, combined with the sheltered locality in which the specimens were found, may have largely contributed to this result. It is also worthy of remark, that a rise of temperature has a direct influence in hastening the escape of the swarmspores, inasmuch as specimens

* In this case direct rays of light were carefully excluded from the stage of the microscope.

† Borzi, *Studi algologici*, 117 pp. (9 pl.). Messina, 1883.

from the same gathering, which were kept in a somewhat colder part of the "Ark," did not discharge them so soon as others which were placed in the microscopic room, which was kept at a higher temperature.

It is, moreover, interesting to observe, that although the septa across the multilocular sporangia of *Ectocarpus siliculosus* usually persist, yet it sometimes happens that these septa disappear before maturation of the spores, in which case the sporangium becomes ultimately unilocular.

This observation corroborates the statements made by PRINGSHEIM* with regard to *Ectocarpus siliculosus* and *E. granulosus*, whose general conclusion is stated as follows:—"Diese Beobachtungen führen zu dem Schlusse, dass die Differenz der beiden Sporangienformen der Phæosporien, die sich in der fehlenden oder vorhandenen Fächerung ausspricht, keine absolute ist, sondern nur einen verschiedenen Grad der Ausbildung und Persistenz oder Resorption des transitorischen Mutterzellgewebes der Schwärmsporen ausdrückt. Bei den Oosporangien geht dasselbe der Regel nach schon gleichzeitig mit der Reife der Zoosporen zu Grunde und persistirt nun in einzelnen Fällen; bei den Trichosporangien bleibt mindestens der ältere Theil des Mutterzellgewebes gewöhnlich stehen, während die jüngeren Generationen—ob immer?—zu Grunde gehen; aber in einzelnen Fällen wird auch hier das ganz Mutterzellgewebe resorbirt und dann erscheinen die Trichosporangia wie uniloculäre Organe."

Although conjugation between the escaped swarmspores of the multilocular sporangia was carefully looked for, no instance of it was detected. GOEBEL,† however, has already pointed out that such swarmspores conjugate during summer, when two neighbouring sporangia burst simultaneously. Probably the inertness induced by the lower temperature of the watery medium in December was enough in itself to check any such reproductive process.

Although in most cases specimens of *Ectocarpus siliculosus* which were affected with parasites did not bear true normal reproductive organs of any kind, I have, in one case, seen young multilocular sporangia and parasitic Rhizophydia on the same plant, but in no instance have I found these sporangia to be mature.

In conclusion, it would appear that the effect of the presence of Rhizophyidium in *Ectocarpus* cells is to produce results analogous to those found in animal tissues that have become invaded by Bacterial germs of disease. That there is primarily the same stimulation, which, however, does not advance so far as to induce rapid cell divisions, as happens in the case of Bacteria, is manifested by the fact that the parasite containing cells are usually of a somewhat larger

* Pringsheim, *loc. cit.*, p. 169, 170.

† Goebel, *Bot. Zeit.*, 22nd March 1878.

absolute size than the other cells of the thallus. This stimulation is no doubt caused by the waste products evolved by the parasite as well as by the very presence of the latter inside the host cell. Moreover, in both cases, there is the same final result, namely, complete devitalisation of the organic substance, and the ultimate death of the host.

All the figs. on Plate CXLVIII. have been drawn by the aid of Abbe's camera: fig. 7, under Leitz's microscope Oc. 1, Ob. No. 10 Hartnack (water immersion); the other figures under Zeiss's microscope Oc. 3, Ob. CC.

EXPLANATION OF PLATES CXLVII., CXLVIII.

Plate CXLVII. represents a specimen of *Ectocarpus siliculosus* richly covered with the parasitic *Rhizophydium Dicksonii*. The latter occurs in various stages of development on the ultimate and penultimate ramuli of the host which bears none of the ordinary fructification.

On Plate CXLVIII. various conditions of the parasite may be observed.

Fig. 1 shows a host cell enlarged, rounded, and containing a Rhizophydium of considerable size, and bounded by a faint though distinct cell wall.

Fig. 2, *a*, represents the earliest stage of the parasite that has been observed, while the adjoining cell (fig. 2, *b*), contains a large reniform Rhizophydium, which, however, has not caused the usual bulging of the host cell wall.

Fig. 3 shows a condition in which three adjoining host cells have been attacked.

Fig. 4. Here the host cell is slightly swollen, and the parasite, instead of being perfectly round, has expanded somewhat in a lateral direction, and shows slight involutions on two opposite sides.

Fig. 5 represents a perfectly elliptical Rhizophydium lying in a somewhat swollen host cell.

Fig. 6 shows a parasite which possesses a remarkable indentation on one of its margins. The host cell is very much enlarged and rounded.

Fig. 7 is a very much enlarged representation of a parasite which has just ruptured. The broken margins of the host cell wall are well seen, as also the creases of the cell wall of the parasite.

Figs 8*a*, 8*b*, and 8*c* show the positions of the points of rupture of the cell wall of the parasite, with reference to the direction of the axis of the filaments of the host plant.

Fig. 9 shows a remarkable involution of the cell wall of the host plant, rupture having taken place at the diametrically opposite point.

Fig. 10 shows a peculiar reticulation of the spores of the parasite, which occurs just before rupture of its cell wall.

Fig. 11, *a*, represents the angulated condition in which the spores exist at and before the period of rupture. This is the result of mutual pressure caused by the continued growth. In fig. 11, *b*, a very much enlarged cell is seen, which is also obviously affected by the presence of a parasite.

In fig. 12 the angulation of the parasitic spores, the creasing of the cell wall, and the positions of rupture of the parasite, may be studied.