Greater similarity to the papillae in Calamitean roots is, however, shown by the projections from the mycorrhizal filaments in *Calypogeia trichomanis* as recently described and figured by Nemec[1]. In this Liverwort the Fungus infects the rhizogenous cells, where it forms a pseudoparenchymatous tissue, and the hyphae send out very fine projections (haustoria) into the neighbouring cells, the walls of which, at first very thin and colourless so as to be indistinguishable in Canada Balsam preparations, become more distinct, thicker and yellowish in a later stage. Sometimes the projections are of the same length, sometimes some become longer, and branching may occur.

From what has been stated above, the similarity of the papillae in Calamitean roots to fungal hyphae often present in the internal tissues of the root, and their resemblance to fungal papillae, such as occur in recent plants, is, I think, very suggestive of their fungal nature. This supposition is further strengthened by the fact that they are not found in all Calamitean roots and are therefore not part of the organization of the root; moreover, they occur in roots of a fossil plant in no way allied to *Calamites*, but which is also subject to the attacks of Fungi. There seems, therefore, to be a good deal of circumstantial evidence in favour of regarding the epidermoidal papillae as of fungal nature.

The purpose which they fulfil in the life of the plant can only be conjectured. A consideration of similar occurrences in recent plants would suggest that they represent arrested branches of a Fungus which runs chiefly along the thick cell-wall of the host plant. The lighter substance with which some of them are covered suggests that their growth has been arrested by the deposition of some substance upon the invading hyphae; in some cases, certainly, there is the appearance as if the cell-wall substance of the host plant was heaped over the projection, just as Nemec[2] found to be the case with some of the 'haustoria' of the Fungus which penetrates the tissues of *Calypogeia*. The explanation that this is a defensive act on the part of the Liverwort, which is able to flourish either with or without mycorrhiza, might be used also to explain the appearance of arrested growth which characterizes the papillae of the Calamitean root.

I should like to express my best thanks for the help which Professor Weiss has given to me.

GRACE WIGGLESWORTH.

Owens College, Manchester.

ALGOLOGICAL NOTES. No. 5:—SOME POINTS IN THE STRUCTURE OF A YOUNG ŒDOGONIUM.—Of late years, quite a number of species of *Oedogonium* have become known[3], in which the young plants are attached by means of the entire hemispherical lowest cell, instead of the basal portion of this cell alone developing

[1] Nemec, Über die Mycorrhiza bei *Calypogeia trichomanis*. Beihefte zum Botanischen Centralblatt, vol. xvi, Part ii, 1904, pp. 256-62, Figs. 11, 14, 24.

[2] Nemec, l.c. p. 259, Fig. 24.

[3] See Hirn, Monographie der Oedogoniaceen. Act. Soc. Scient. Fennicae, T. XXVII, 1900, No. 1, p. 15.

into a colourless attaching-disc or a branched rhizoid. Three years ago, Schefferle[1] described the development of a young plant with this type of basal cell in *Oed. rufescens*, Wittr.; his account is as follows:—'In der Membran eines festgehefteten Keimlings wird in der Mitte der dem Substrat abgewendeten Fläche, am Scheitel der Wölbung, durch einen Kreisriss ein kreisrundes, 4 μ im Durchmesser haltendes Membranstück (eine 'Kappe') herausgeschnitten. Durch die so entstandene Öffnung wächst nun der Keimling, gleich einer keimenden Pilzspore, zu einem Schlauch aus, den Oedogoniumfaden bildend (Taf. XXXI, Fig. 4).... Die erste Theilung, welche die Sonderung der ersten cylindrischen Zelle des Fadens von der halbkugeligen Fusszelle zur Folge hat, geht demnach—wie es scheint—wie bei *Bulbochaete*, ohne Ringbildung vor sich' (loc. cit. p. 559).

In the species of *Oedogonium*[2], which forms the subject of the present note, and which I have had under observation for two years, the lowest (attaching-) cell can scarcely be designated hemispherical. Although occasionally slightly flattened on one side, the usual shape is decidedly spherical or oval (Fig. 61 *b*, *e*, *g*). The majority of these young plants were growing loosely attached to the sides of a glass vessel, frequently in large clusters (Fig. 61 *g*), and yet the side turned towards the substratum, was generally rounded off; this indicates the necessity of some means of attachment other than pure adhesion, and, as will be shown subsequently, such really occurs. The basal cells contained abundant chlorophyll and numerous starch-grains, like the succeeding cells of the filament, and, like these, showed two well-marked layers in their wall[3].

I have not been successful in observing the actual course of the first cell-division in these young plants, but an examination of two-celled stages affords no data which do not agree with those of Schefferle (loc. cit.); the cap, which is detached before the contents are protruded to form the filament, is frequently still to be met with at the apex of the young plants; in other cases it is absent, having undoubtedly been lost in the surrounding water. There seems to me, however, little difference between this type of division and that which Poulsen[4] has described for the first cell-division of the young plants of a species of *Oedogonium*, and which I[5] have subsequently found to occur regularly in *Oed. cardiacum* and in some cases in *Oed. stagnale*. This type of division is mainly due to the fact that the new cell-wall substance is not confined to an annular ring, but occupies a dome-shaped area in the upper portion of the original (basal) cell. This leads to the detachment of the entire apical portion of the cell-wall as a cap or lid. The curious shape of the basal cell in these species of

[1] Einige Beobachtungen über Oedogonien mit halbkugeliger Fusszelle. Ber. Deutsch. Bot. Ges., vol. xix, 1901, pp. 557–563, Tab. XXXI.

[2] I have unfortunately omitted to determine this species, although it produced oogonia during the past year; the measurements are as follows:—diameter of filaments = 10–15 μ; length of cells = 27–33 μ.

[3] Prof. G. S. West very kindly informs me that in *Oed. Howardii* Nov. Spec. MSS., there is a similar basal cell, to which the description 'hemispherical' scarcely applies. Hirn's (loc. cit.) Fig. VI A shows some indications of more than a merely hemispherical basal cell.

[4] Om sværmsporens spring hos en art af slægten *Oedogonium*. Botan. Tidsskrift, 3^{e} sér., vol. ii, 1879, p. 1.

[5] Structure and Development of the young plants in *Oedogonium* Ann. of Bot. vol. xvi, 1902, pp. 477–8.

course modifies this to some slight extent. There seems evidence that this type of division can, under certain circumstances, be continued for some time during the life of the young plant (cf. below).

In a large proportion of the young plants the lower surface of the basal cell was more or less completely enveloped by a hyaline substance (Fig. 61 *b*, *e*), which was sharply delimited towards the periphery. This substance is quite unaffected by Iodine and Chlor.-zinc-iodine, whereas Vesuvin stains it a dark reddish-brown colour, thus indicating its mucilaginous nature; at the same time the cell-walls take on an almost equally deep tint. This dense mucilaginous mass, which is thus found on the lower side of the basal cells, undoubtedly serves to attach these filaments, which are otherwise but badly suited for attachment. The occurrence of mucilage in this position is not without parallel in other species of *Oedogonium*, for the branched processes of the attaching-disc are in some cases mucilaginous at their tips, as are also the ends of the rhizoids[1]; in many species of *Oedogonium*, however, some ferric salt of iron appears to play a part in the attachment of the young plants, acting as a kind of cement[2]. I am not prepared to say in what way this mucilage is developed, i. e. whether it is formed by excretion or by the gelatinization of the cell-wall, but the former seems more probable.

In a very large percentage of the young plants examined, the apical cell presented a peculiarity, which I do not remember having seen recorded as yet; this phenomenon was generally wanting in the very young, few-celled filaments, although indications of it were occasionally also to be observed here. Instead of the apical cell having a rounded or pointed extremity, it was provided with a longer or shorter cap of cell-wall substance with square corners, so that the apex of the filament had a rectangular appearance (Fig. 61 *a*, *c*). This cap fits tightly over the terminal cell of the filament, which is generally slightly pointed and thus insinuates itself into a V-shaped incision in the cap. Examination of this cap under a high power shows that the cuticle (i. e. the outer layer of the cell-wall) extends right round it, and that its main mass is constituted by a not very highly refractive substance, enclosed between this cuticle and the inner layer of the cell-wall, which is quite conspicuous as a membrane limiting the apex of the cell contents of the terminal cell, i. e. the main mass of the cap consists of a rather darker substance enclosed between the cuticle and the bright inner layer of the cell-wall. Similar caps were occasionally also observed in the course of the filaments[3]; this was, however, rather rare, and they were never seen to attain the dimensions of the terminal caps (cf. Fig. 61 *d*). Their occurrence quite agrees with the explanation of their origin given below. Under a high magnification these caps are seen to have a very distinctly stratified structure, recalling the usual cap-structure of the cells of *Oedogonium*. This undoubtedly also explains their origin. The terminal cell has again and again formed cellulose-

[1] Wille, Über das Keimen der Schwärmsporen bei *Oedogonium*, in Pringsh. Jahrb., vol. xviii, 1887, p. 458; Pringsheim, Morphologie der Oedogonien, in Pringsh. Jahrb., vol. i, 1858, p. 55; Fritsch, Structure and Development of young plants in *Oedogonium*, in Ann. of Bot., vol. xvi, 1902, p. 471.

[2] Fritsch, loc. cit., p. 473.

[3] I have also noticed such intercalary caps in other species of *Oedogonium*, although no notes were made on the subject at the time.

thickenings, but no stretching of these has taken place, and they have combined together to form this cap of cell-wall substance. It seems to me, however, that this thickening has not been laid down in the normal manner, but rather according to the method, appertaining to the first cell-division, that is to say, each successive thickening has occupied the entire dome-shaped upper portion of the cell-wall (cf. Poulsen,

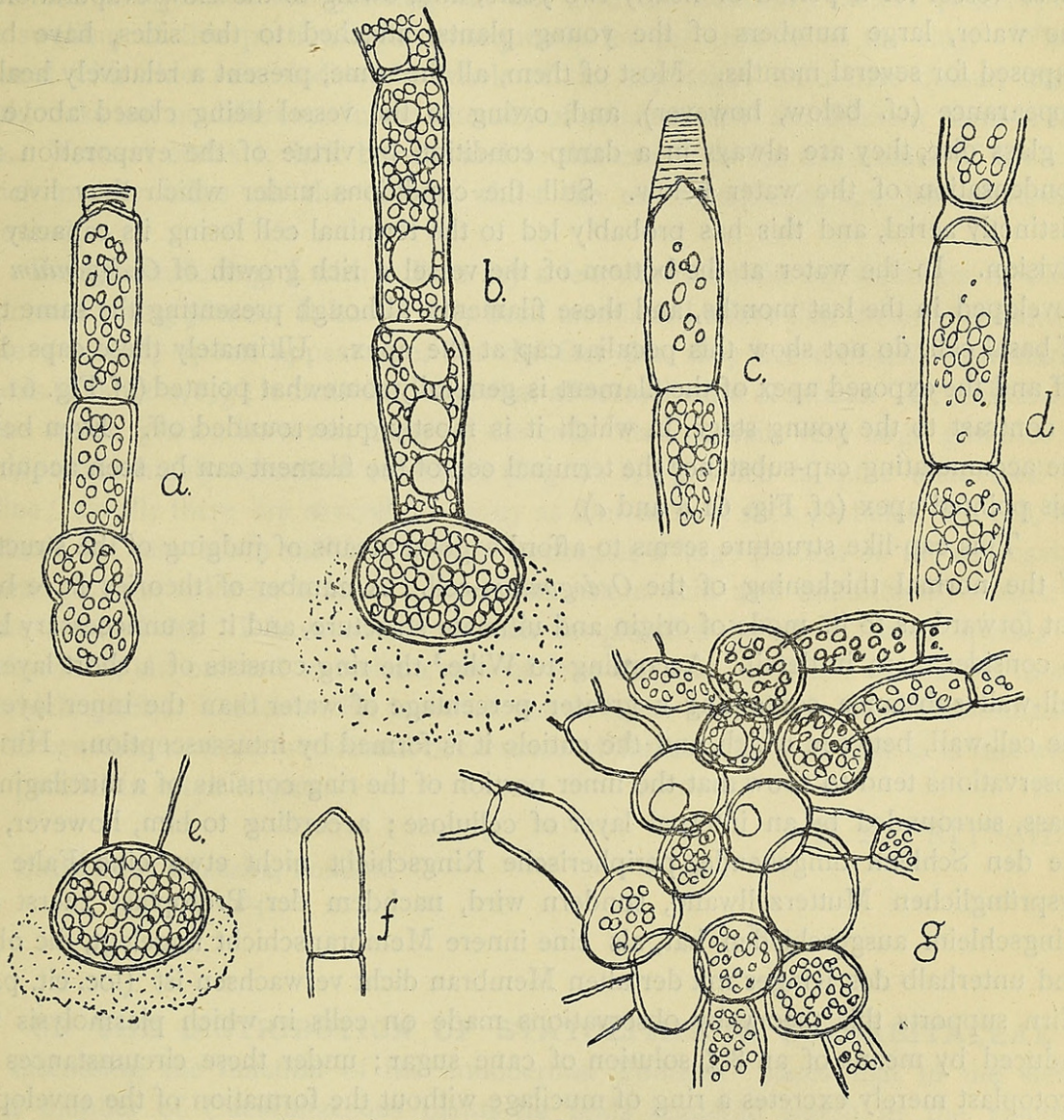

FIG. 61. *Explanation of the figures* (all magnified about 700 times) *Oedogonium* spec.: *a.* Three-celled young plant with somewhat abnormal basal cell, indicating a tendency to subdivide into two; a small terminal cap with well-marked stratification is present on the apical cell; *b.* Base of a many-celled plant with typical basal cell, surrounded by a thick mass of attaching-mucilage. The cells contain starch-grains and oil-globules; *c.* Apex of ditto, with well-developed stratified terminal cap; *d.* Portion of a filament, showing slight cap-formation on one of the intercalary cells; *e.* Basal cell with attaching-mucilage; *f.* Apex of many-celled filament, which has lost the terminal cap, and become somewhat pointed; *g.* Cluster of young plants, all with typical basal cells and devoid of mucilage; some of the basal cells contain oil-globules.

loc. cit.). It is difficult to conceive how the normal annular thickening should have given rise to this solid cap. In an earlier paper [1] I have described an abnormal case

[1] Cf. Fritsch, Structure and Development of young plants in *Oedogonium*. Ann. of Bot., vol. xvi, 1902, p. 480.

of successive ring formation in *Oed. cardiacum*, Wittr.; in this case, however, the annular thickening had developed in the normal manner, and a certain amount of stretching of the rings had taken place, so that they were quite distinct from one another (cf. loc. cit. Fig. 27 *a*).—The abnormal tip described in the present note is certainly due to unfavourable conditions. The material has been inside the same glass vessel for a period of nearly two years, and, owing to the slow evaporation of the water, large numbers of the young plants, attached to the sides, have been exposed for several months. Most of them, all the same, present a relatively healthy appearance (cf. below, however), and, owing to the vessel being closed above by a glass disc, they are always in a damp condition by virtue of the evaporation and condensation of the water below. Still the conditions under which they live are distinctly aerial, and this has probably led to the terminal cell losing its capacity for division. In the water at the bottom of the vessel a rich growth of *Oedogonium* has developed in the last months, and these filaments, although presenting the same type of basal cell, do not show this peculiar cap at the apex. Ultimately these caps drop off and the exposed apex of the filament is generally somewhat pointed (cf. Fig. 61 *f*), a contrast to the young stage, in which it is mostly quite rounded off. Even below the accumulating cap-substance the terminal cell of the filament can be seen acquiring this pointed apex (cf. Fig. 61 *a* and *c*).

This cap-like structure seems to afford a good means of judging of the structure of the normal thickening of the *Oedogonium*-cell. A number of theories have been put forward as to its mode of origin and ultimate structure, and it is unnecessary here to consider them in detail. According to Wille[1] the ring consists of a short layer of cell-wall substance, containing a greater percentage of water than the inner layer of the cell-wall, between which and the cuticle it is formed by intussusception. Hirn's[2] observations tend to show that the inner portion of the ring consists of a mucilaginous mass, surrounded by an internal layer of cellulose; according to him, however, 'ist die den Schleim umgebende, peripherische Ringschicht nicht etwa eine Falte der ursprünglichen Mutterzellwand, sondern wird, nachdem der Protoplast zuerst den Ringschleim ausgeschieden hat, als eine innere Membranschicht angelegt, die ober- und unterhalb des Ringes mit der alten Membran dicht verwachsen ist' (loc. cit. p. 7). Hirn supports this theory by observations made on cells in which plasmolysis was induced by means of an 8% solution of cane sugar; under these circumstances the protoplast merely excretes a ring of mucilage without the formation of the enveloping cellulose-layer. It is quite easy to make out the two portions of the ring, indicated by Wille and Hirn, without the use of staining reagents, in any actively dividing *Oedogonium*-cell; as to the mode of origin, I incline to the belief that Wille's theory is more correct. It is not easy to understand how the peculiar cap-structure, described in the present note, could have originated in any other way. The darker substance, which makes up the main mass of the cap, is evidently equivalent to Wille's water-containing layer and Hirn's mucilage-layer. The distinct stratification of this mass indicates its periodic deposition *between* the outer cuticle, which surrounds the whole and the well-marked inner layer of the cell-wall, which forms the internal

[1] Ueber die Zelltheilung bei *Oedogonium*. Pringsh. Jahrb., vol. xviii, 1887, p. 444. ('Der Ring ist also eine kurze wasserreichere Schicht in der Membran.')

[2] loc. cit., pp. 6 and 7.

limit of the cap. According to Hirn's theory we should expect the substance of the cap to consist of alternating layers of mucilage and cellulose, which is quite evidently not the case. The opinion of this latter observer that the central mucilaginous portion of the ring 'beim Zerreissen der Zellwand von Bedeutung sein dürfte,' seems very plausible; and possibly the somewhat aerial conditions under which the described *Oedogonium* was growing did not give the necessary factors (water?) for the swelling of this portion, and consequently for the rupture of the ring. When stained with chlor.-zinc-iodine the whole of the cap takes on a blue colour, but I could make out no difference in the intensity of colouration of the different parts of the cap. Vesuvin stains it dark brown, and in this case it is the main mass of the cap which mainly takes on the colour, whilst the cell-membranes are less obviously coloured.

Before concluding, I wish still to say a few words on the cell-contents of these abnormal young plants. It has already been mentioned above that the cells presented quite a healthy green appearance, but the fact that they are crowded with starch grains (Fig. 61 *a*, *b*, *g*) indicates a somewhat abnormal state of affairs. In addition to these starch grains, however, many of the cells often contain very large globules of a colourless highly refractive substance (Fig. 61 *b*, *g*), which is quite unaffected by iodine; usually there are several (as many as four or five) such globules in a cell, but at times one may attain such a size that it occupies a large portion of the cell-cavity. These globules take on a black colour with osmic acid and undoubtedly consist of some kind of fat. I have observed such fat-globules before in other species of *Oedogonium*, but omitted to make a note of it at the time, so that I am unable to say in which species. Undoubtedly, however, starch is the normal product of assimilation in *Oedogonium*, and the occasional occurrence of fat side by side with it is not without parallel in other Algae.

F. E. FRITSCH.

University College, London.
June 8, 1904.

ON THE DISTRIBUTION OF STATOLITHS IN CUCURBITACEAE.— In discussing the function of the endodermis Tondera[1] states that in the stems of a number of Cucurbitaceous plants he finds scattered starch in the younger internodes which are geotropic, and falling starch only in the older internodes which no longer respond to gravity. At the suggestion of Mr. Darwin I examined most of the species mentioned by Tondera. My results, owing possibly to difference in method, do not agree with his.

Cyclanthera pedata, *Momordica Charantia*, *Sicyos angulata*, *Thladiantha dubia*, and *Cucurbita Pepo* contain, according to Tondera, only scattered starch in their younger internodes. In all these plants I find falling starch in both older and younger parts, extending quite to the apex, or within 1 cm. of it. Again, Tondera finds no falling starch in the apical internodes of *Cucumis sativa* and *Lagenaria vulgaris*. I was

[1] Tondera. Beitrag zur Kenntniss des functionellen Werthes d. Stärkescheide. Bull. Int. de l'Acad. d. Sciences de Cracow, 1903.