NOTES.

THE PAPILLAE IN THE EPIDERMOIDAL LAYER OF THE CALAMITEAN ROOT.—Miss Stopes in her note in *Annals of Botany*, September, 1903, p. 793, on 'the Epidermoidal layer of Calamite roots' refers to the 'fibrous fragments' which project from the thickened outer membrane of the cells into their cavities, stating that it is not possible to ascertain their minute structure and that she is not aware of any similar appearance in recent plants that would throw light on their nature. I should like to put forward the suggestion that they represent the short arrested branches of a fungal mycelium, a suggestion which I base upon their similarity with fungal hyphae observed in other parts of the roots and upon the occurrence of similar papillae in recent plants, the fungal nature of which is beyond doubt.

Fungi are very commonly present in the roots of *Calamites*, in some cases only in the outer layers, in others penetrating to the central tissues; often hyphae can be seen closely surrounding the roots.

The outer walls of the epidermoidal cells of Calamitean roots are generally much thickened and often possess a stratified appearance, darker and lighter layers alternating. The deep clefts between the cells, which are noticeable in many of the roots (see Fig. 58), probably afforded favourable places for the Fungus to enter, and the lighter layers, in which splitting seems to have sometimes taken place, possibly offered less resistance to fungal attacks. Some specimens show apparent sporangia attached to hyphae in the clefts between two neighbouring epidermal cells. Doubtless in many cases the Fungus observed was of saprophytic nature, but the excellent preservation of the delicate tissues of some of the rootlets containing Fungi suggests that they were also subject to attacks of Fungi while in the living condition. Whether the Fungus was of parasitic or symbiotic nature is impossible to say. According to Stahl¹ and Janse, mycorrhizae do not occur in the Equisetaceae of the present day,

FIG. 58.

¹ Stahl, Der Sinn der Mycorrhizenbildung. Pringsheim's Jahrbücher, 1900, p. 570.

but this does not necessarily exclude their formation from the members of the enormously developed Equisetales of early Geological times.

Slide R. 88 B. in the Manchester Museum (Fig. 58) shows a young Calamitean rootlet which has no papillae projecting into the cavities of the epidermal cells, but closely surrounding the rootlet, especially in the clefts, are small round bodies, apparently the cut ends of fungal hyphae. There seems to be some indication of the presence of hyphae in the walls themselves in one or two places, but this cannot be definitely asserted. As this is a very young rootlet, an early stage in the attack of the fungus may be represented here.

Many of the older Calamitean roots show numerous projections from the thickened walls into the cavities of the epidermal cells and less frequently into cells belonging to internal layers.

Fig. 59 represents an epidermal cell of one of these Calamitean roots (Q 285 Cash Coll. in the Manchester Museum) containing a number of dark-coloured projections from the thickened outer wall.

FIG. 59.

These processes project further into the cavity of the cell than is usually the case; two of them are branched and two show swellings; they vary in length and diameter. Two of the branches show a double outline, as if some substance had been deposited upon them, as was found to be the case with some of the fungal papillae in *Galeola javanica* described by Groom, and in *Calypogeia trichomanis* as described by Nemec.

Fig. 60 represents a portion of a diarch rootlet of a fern which Dr. Scott has kindly identified as belonging to *Rachiopteris corrugata*, Will., one of the Botryopterideae (R 608 Hick Coll. in the Manchester Museum), in which the outer walls of some of the peripheral cells have become somewhat thickened and many of the cells have internal, dark, tapering processes from the walls, like those commonly found in the epidermoidal layer of Calamitean roots. Here, as in many Calamitean roots, these processes are not absolutely confined to the outer wall or even to the outer layer of cells, and the presence of a branching Fungus in the tissues of the rootlet makes it difficult to distinguish between these processes from the walls and fungal hyphae. The papillae vary in length and diameter, often expanding towards the base and sometimes appearing as mere knobs on the wall. Occasionally they branch, but on the whole they are much shorter than those shown in Fig. 59, so one would not expect much branching. Some of them show very distinctly a double outline—a dark core running through the centre of a light-coloured process.

The hyphae in the internal tissues of the rootlet vary in diameter, some of the branches being very fine, others much stouter; occasionally they appear to taper to a point, but this may be due to their taking a different direction of growth at these points, or to constrictions—such constrictions appear in various places in the mycelium.

Swellings occur in the hyphae present in this rootlet, although they are not so common as they are in several of the roots of *Calamites* examined.

Occasionally, the fungal hyphae are as dark-coloured as in the projections in the epidermoidal cells, or they may be marked with bands of a darker colour; the latter feature is also sometimes observable in the processes projecting from the thick epidermal wall.

Thus a comparison between the projections of the epidermoidal layer and the fungal hyphae in the internal tissues tends to the conclusion that the former may be of fungal nature.

FIG. 60.

Parallel cases amongst present-day plants are also to be found. P. Groom¹, in his 'Contributions to the Knowledge of Monocotyledonous Saprophytes,' describes peculiar papillae which protrude into the cavity of certain thick-walled cells immediately beneath the external layer of the root, and in thick-walled epidermal cells and sclerenchymatous cells of aerial parts of *Galeola javanica*. These papillae look like processes of the cell-wall but apparently are the modified walls of arrested mycorrhizal hyphae.

¹ P. Groom, Contributions to the Knowledge of Monocotyledonous Saprophytes. Linnean Soc. Journ. Bot., vol. xxi, pp. 157-8.

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 Nemec¹. 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 Nemec² 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.

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ALGOLOGICAL NOTES. No. 5:—SOME POINTS IN THE STRUCTURE OF A YOUNG OEDOGONIUM.—Of late years, quite a number of species of *Oedogonium* have become known³, 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.

Wigglesworth, Grace. 1904. "The papillae in the epidermoidal layer of the Calami tean root." *Annals of botany* 18, 645–648.

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