XIV. *On the Organization of the Fossil Plants of the Coal-Measures.*—Part X. *Including an Examination of the supposed Radiolarians of the Carboniferous Rocks.*

By W. C. Williamson, *F.R.S., Professor of Botany in the Owens College, Manchester.*

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[Plates 14–21.]

In 1865 my friend Mr. Edward Wunsch, of Glasgow, made the discovery of some thin carboniferous shales imbedded in volcanic ash at Laggan Bay, in Arran. These beds have already been described by their discoverer,* and their fossil contents referred to by Mr. Binney, Mr. Carruthers, and Sir Charles Lyell. From within a very limited area the bases of more than 13 large erect stems of carboniferous trees have been extracted by Mr. Wunsch, the most important of which he has kindly placed in my hands. In the summer of 1877 we conjointly superintended some quarrymen, who tore up large portions of these strata with the result, I believe, of obtaining a fair knowledge of the nature of these beds and their contents.

The trees certainly stood where they originally grew; most of them consisted of a thin cylinder of the outer bark, which was deeply *fissured* longitudinally but exhibited no true Sigillarian flutings or traces of leaf-scars. The interior was in most cases filled with volcanic ash, but in a few instances by vegetable débris introduced from without; and in one specimen, imbedded in the vegetable mass, are several decorticated Diploxyloid vascular axes of very old stems. These have been referred to as young growths that sprang up within the bark-cylinder;† but such is not the case. Each one is not only decorticated, but is large enough to be the vascular axis of the large tree within which the entire group occurs, and where they are mixed up with fragments of the similar vascular axes of *Stigmaria* and other plants.

The primary question which we endeavoured to determine was the botanical character of these stems, as indicated by the remains of their bark and by the nature of the numerous fragments of twigs, branches, and fruits found in the overlying beds. No one of the trees afforded any evidence of being Sigillarian. The outer surface of each stem exhibited a rough and irregular longitudinal fluting, but this was very different from that characterising a Sigillarian bark; the ridges and furrows were

* 'Geol. Magazine,' 1865, p. 474; 'Trans. Geol. Soc., Glasgow,' vol. ii., p. 98, 1865.

† Lyell's 'Student's Elements of Geology,' second edition, p. 547, 1874.

merely results of the expanding growth of the inner portions of the stem fissuring the outer bark, as is the case with exogenous stems.

I may here express my conviction that many of the trees that have been loosely designated Sigillarian have no claim to be regarded as such. Dr. DAWSON and other palæontologists have recorded the fact that the characteristic leaf-scars and other superficial features of the younger stems and branches disappear towards the base of the older trunks; and this has evidently been the case with the Arran specimens.

Our prolonged researches failed to supply the smallest portion of a true *Sigillaria*. I obtained one fragment of a cast of the outer surface of a bark exhibiting what at the first glance had a Sigillarian appearance. It exhibits strongly-marked ridges, but these proved to be but casts of the unsymmetrical longitudinal fissures just referred to. That such is the case is shown by the positions of the oblong leaf-scars—which are wholly independent of those of the ridges—which could not have been the case in a *Sigillaria*. These leaf-scars are of the Lepidodendroid type.

The most numerous fragments which we met with were long, slender Lepidodendroid twigs, densely clothed with very short, scaly leaves, such twigs being usually about half an inch in diameter; fragments of larger branches were not uncommon, some of these being from two to three inches in diameter, and which were also true *Lepidodendra*, retaining the closely-united, rhomboidal bases of their leaves in union with the outer bark, each rhomboid having a diameter of a quarter of an inch. Mr. BINNEY has figured and described some fruits found by Mr. WUNSCH, all of which are true *Lepidostrobi* furnished with macrospores and microspores; and I am indebted to Dr. YOUNG and to Mr. JOHN YOUNG, of the Glasgow University, for their permission to make a section of a similar *Lepidostrobus* from Laggan Bay, but which unfortunately contained no spores. We have thus a mass of evidence of a positive kind indicating that these stems were true *Lepidodendra* and not *Sigillariæ*—a conclusion which the negative testimony afforded by the entire absence of true Sigillarian fragments from these beds equally sustains. Most of these specimens apparently belonged to one species; only the one fragment of a cast of the bark already referred to appears to have been distinct from the rest.

Fig. 1 is a transverse section of one of the small twigs that abound in the deposit in such numbers as to leave no room for doubting that they are the ultimate branches of the large stems. These twigs are long and slender, generally about half an inch in extreme diameter, including the closely-compressed scale-like leaves. In the centre of the section is the principal vascular bundle, *a*, of which a more enlarged representation is given in fig. 2; it is composed entirely of barred vessels, without any visible intermixture of cellular tissue. The vessels are pretty uniform in size, the largest being about ·005 in diameter*; but at the periphery of the bundle we find a limited number of much smaller vessels. It is from these latter that are derived the numerous foliar vascular bundles (fig. 2, *b*) that cluster round the main axis. The inner portions of

* These measurements are recorded, as in my previous memoirs, in the decimal parts of an inch.

the bark have been destroyed in every one of these twigs that I have examined, but the leaves (fig. 1, *c*) are all in their normal positions, varying in shape according to the portion of the leaf intersected by the section; they present the usual structure of Lepidodendroid leaves, consisting of cellular parenchyma and with the single vascular bundle (fig. 1, *c'*) running through it. The distorted outlines of the sections of these leaves have most probably been due to desiccation; they are chiefly found imbedded in the volcanic ash, which probably fell in a heated condition, producing the shrivelled condition in which most of these leaves are found.

On comparing this section with the similar one of the Burntisland *Lepidodendron*, represented in Plate 41, figs. 2 and 3, of my third memoir, the difference between the two specimens will be seen at a glance. In the Burntisland plant the bundle has a diameter of about ·015. In the Arran specimen it is about ·033. In the former, there is already a small irregular central medullary space from which vessels are absent—nothing of the kind exists in the latter plant. In it the bundle is more compact, the vessels more equal in size, and the structure altogether more symmetrical and robust than in the Fifeshire plant. Fig. 3 represents a section of a branch of larger dimensions; such branches vary from one-and-a-half to three or more inches in diameter. Next to the twigs these are the most common fragments found in the deposit. The bases of the leaves still adhere to the bark, but when these are removed, as they are in a part where the specimen from which the section, fig. 3, had been a little water-worn, they present the aspect of such Lepidodendroids as *L. nothum* of UNGER, *Halonia gracilis*, &c. The central vascular bundle has now expanded into a vascular cylinder, fig. 3, *a*, enclosing a cellular medulla, *d*. The structure of this cylinder is further illustrated in fig. 4, which is enlarged 15 diameters. The cells of the medulla are much disorganized,* but at the junction of this tissue with the inner surface of the vascular cylinder I observe that a few of them are strongly barred—as I have shown to be also the case with many of the medullary cells of *Lepidodendron Selaginoides*.† The diameter of the pith is about ·1, the mean diameter of the vascular cylinder enclosing it being about ·2. Each transverse section of this vascular cylinder has a crenulated outline exactly corresponding with that seen in so many of the Diploxyloid stems described as *Sigillariæ*. The mean size of the vessels composing the cylinder is about ·01. The projecting points of the periphery, fig. 4, *a'*, consist of very small vessels, elongated radially in the sections; these are the orienting numerous foliar vascular bundles, *c*, which evidently detach themselves from the cylinder at first obliquely and then ascend more vertically when passing through the inner bark. Their transverse sections in the latter position, as seen at *c*, are circular. All these vessels are barred.

Returning to the section, fig. 3, we now find, beautifully preserved, much of the middle bark, *e*. It is a delicate parenchyma, the cells of which are very uniform in

* Vertical sections show that these medullary cells are arranged in perpendicular columns as is the case with so many of these Carboniferous Lepidodendroids. See memoir, Part II., Plate 25, fig. 14.

† Memoir, Part II., Tab. 24, fig. 3.

arrangement and size, the latter ranging between ·005 and ·0025. Numerous vascular bundles are seen passing outwards to the leaves, as at *b*. The more external portions of the bark have nearly all disappeared. The little that remains, *f*, binding together the leaves, *c*, *c′*, shows that it possessed the bast-layer, composed of vertically elongated prosenchymatous cells, with an outer investment of parenchyma—the usual structure of this portion of Lepidodendroid and Sigillarian stems. The leaves in this section exhibit nothing worth remarking except that the three *c*, *c*, *c*, have been intersected through their larger transverse diameters, whilst the two alternating ones, *c′*, *c′*, have been crossed close to the point where their bases spring from the bark. Their closely united rhomboidal bases have a diameter of about $\frac{3}{16}$ths of an inch.

The next progressive step brings us to the specimen represented by fig. 5, which is a section of either a small stem or a very large branch found by Mr. Wunsch. It is represented three-fourths its natural size. We now find the central medulla, *d*, about an inch in diameter, but its cellular tissues have disappeared through decay or mineralisation. At *a* we have the vascular medullary cylinder corresponding exactly, in all but size, with that seen in the specimen, fig. 3. But we now find externally to this cylinder a very thin layer, *i*, of barred vessels arranged in radiating lines. This zone is, of course, the "Cylindre ligneux" of Brongniart, and my exogenous zone, the existence of which, according to the French author, *de facto*, transfers the plant possessing it from the Lepidodendroid to the Sigillarian group—or, in other words, from the Cryptogamic to the Gymnospermous divisions of the vegetable world. At *e* we again have the delicate middle parenchyma seen at fig. 3, *e*, but often disturbed by a stalagmitic arrangement of the carbonate of lime, as at *e′*. This inner tissue is less perfectly preserved than in the specimen, fig. 3, but sufficiently so to establish the perfect identity of the two structures. We pass by a somewhat rapid transition from the delicate parenchyma of this middle bark to the much coarser parenchyma of what, in my previous memoir,* I have spoken of as the middle bark, fig. 5, *g*; and which yet more externally, fig. 5, *h*, passes gradually into the radiating lines of prosenchymatous cells of what may be designated the bast-layer. In these two outer portions the foliar bundles are numerous and distinct. Now if any unbiassed student compares the arrangement of these tissues, as shown in this fig. 5, with those seen in many of my previous figures of *Lepidodendra* and *Haloniæ* (*e.g.*, Plate 24, fig. 1, and Plate 26, fig. 13, of memoir, Part II.), and then further compares these with Brongniart's own figures of his typical Lepidodendron, as represented in Plate 20, figs. 2, 3, and 4, of vol. 2 of his 'Vegetaux Fossiles,' it will be seen at a glance how complete is the identity of these detailed organizations, and what violence is done in separating them widely asunder merely because nature met additional nutrient wants by an addition to the nutrient machinery. In fig. 5 of this memoir we see the beginnings of this process, which in the larger stems underwent a much further extension. Fig. 6 represents a transverse section of one of the vascular axes already referred

* See memoir, Part II., Plate 24, fig. 1, *h*.

to, three-fourths the natural size. At *d* we have the medulla; the inner, non-exogenous ring is seen at *a*; and at *i* we have the, now very much thickened, vascular exogenous zone. It is unnecessary to enter into a detailed description of these structures, since they correspond in the closest manner with similar ones described in my previous memoirs—especially with those of the Burntisland plants. I would only remark that we notice in their inner or medullary vascular cylinder the same remarkable proof of the increase which has taken place in the number of the medullary vessels, *a*, as the stem increased in size, as I have already referred to in previous memoirs. I can only conclude that these additions to this vascular zone must have been made by a conversion into vessels of the cells of the central or medullary parenchyma by a centripetal process of development. If this has been the case, this centripetal growth of the medullary vascular ring affords another feature of resemblance to the vascular bundles of the living Lycopods, of which I believe it to be the true homologue. Fig. 6A represents a portion of a photograph of a section similar, but further enlarged, to fig. 6, for which I am indebted to Mr. WUNSCH. It shows the exact relations of size and number of vessels which the medullary and exogenous zones bear to each other. All the vessels in these stems exhibit with great distinctness the innumerable vertical parallel lines of lignine (fig. 4*, *b*), connecting the transverse bars (fig. 4*, *a*) which I described and figured in my memoir, "On the Structure and Affinities of some Exogenous Stems from the Coal Measures," ('Monthly Micros. Journal,' Aug. 1, 1869, p. 71, plate 20, fig. 10). Before examining the condition in which the bark of the large Arran stems is found, we may advantageously recall some observations made by Dr. DAWSON, of Montreal. In his 'Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada,' that observer remarks: "In older stems (of Lepidodendron) three modes of growth are observed. In some species the expansion of the bark obliterates the leaf-bases and causes the leaf-scars to appear separated by wide spaces of more or less wrinkled bark, which at length becomes longitudinally furrowed and simulates the ribbed character of *Sigillaria*."* This description accurately represents the condition of the exteriors of the larger Arran stems. All that remains of their bark is a cylinder, usually about two inches thick, which consists almost entirely of the prosenchymatous or bast-layer—the cells of which are always seen, in transverse sections, arranged in radiating lines, and which is interposed in younger stems between the coarse outer-bark parenchyma, fig. 5, *g*,—and the somewhat similar outermost or sub-epidermal parenchyma. As I have already pointed out, the surface parenchyma has entirely disappeared from these Arran stems. Since the true leaf-bases and their subjacent leaf-scars belong solely to the outer surface of this parenchyma, it follows that when it was thrown off through the pressure of internal growth, combined with atmospheric agencies, all definite traces of the outlines of these leaf-scars would disappear. Such a change brings the bast-layer to the surface where it forms a protective or "healing" tissue corresponding teleologically to the corky layer of ordinary exogens.

* *Loc. cit.*, p. 41.

This has been the case with our Arran plants, in most of which this bast-layer has increased with the general growth of the stem to a thickness of fully two inches. As in the stems referred to by Dr. DAWSON, deep longitudinal furrows exist at its outer surface,—but these furrows are, as I have already shown, perfectly distinct from those of the true *Sigillariæ*. They are but the fissures occasioned by the increase in the diameter of the stem, due to the growth of its more internal tissues. One fact is rendered further obvious from these specimens, viz., that this bast tissue increases in thickness along with the increase in the diameter of the other tissues forming the stem, but my specimens throw no additional light upon the physiological question discussed in my previous memoir (Part IX., p. 355), viz.: Whether the additions to the thickness of this bast layer are due to a plane of genetic activity on its external or its internal surface. Tangential sections of this bast layer exhibit no peculiarities in the arrangement of its prosenchymatous cells.

I have already stated that I have obtained one cast or impression of what appears to have been the outer surface of the bark of one of these large stems. In it the leaf-scars are fairly preserved. They are elongated vertically, as shown in fig. 7, which represents the form of one of these scars three-fourths the natural size. There is a rounded central depression, *a*, *in the cast*, marking a corresponding elevation in the original bark, above and below which the cicatrix is prolonged upwards and downwards into a somewhat acuminate form; a slightly elevated sharp ridge, *b*, in the cast, marking a corresponding vertical groove in the original cicatrix. These cicatrices are arranged in the usual oblique rows seen in *Lepidodendron*, the centre of each scar being about five-eighths of an inch apart from its next diagonally-disposed neighbour. The rhomboidal and closely contiguous leaf-bases seen in the smaller branches are here separated widely apart from each other, besides being enlarged longitudinally. This fragment, however, may belong to a species distinct from the more abundant Arran examples.

As already stated, the only fruits that have hitherto been found in the Arran beds are true *Lepidostrobi*. Of these Mr. BINNEY has figured three* which he regards as distinct species, and all of which obviously contained, when living, both macrospores and microspores. In two of the specimens both kinds of spores are preserved, and in the third, which is only the basal part of the cone, the macrospores which it displays imply that microspores occupied its apex. The specimen already referred to, for which I am indebted to Professor YOUNG and Mr. JOHN YOUNG, of Glasgow, is a true *Lepidostrobus*, but all its sporangia are empty. Of such fruits as *Trigonocarpum* and other forms, such as large and matured Gymnospermous trees might be expected to produce, not a trace has been discovered. We are thus led to the conclusion that these Arran trees are essentially Lepidodendroid. The large collection of specimens accumulated by Mr. WUNSCH during a series of years was examined with the utmost care, to see if

* 'Observations on the Structure of some Fossil Plants found in the Carboniferous Strata,' Part II., plate xi. (Palæontographical Society.)

the smallest Sigillarian fragment could be discovered in it, but in vain. I found *Lepidodendra* in abundance of various sizes, and *Stigmariæ* in sufficient numbers; but no one specimen existed indicating the possibility that these trees might have been *Sigillariæ*.

Ulodendron.

In my second memoir (Phil. Trans., 1872) I described the only specimen of *Ulodendron* hitherto met with in which the organization was preserved. I have received a second specimen from Mr. D'Arcy W. Thompson, of Edinburgh, which, though less perfect, is confirmatory of the truly Lepidodendroid character of these stems, and their conformity to the type of *Lepidodendron Harcourtii*. In that memoir, in speaking of the bilateral series of scars which characterise the genus, I observed: "It seems probable that these scars sustained objects which were chiefly developed from the epidermal layer, and whose bases rested upon the outer bark; they certainly were not roots or branches, and I incline to the belief that they were organs of fructification" (*loc. cit.*, p. 210). My young friend Mr. Thompson has recently collected a fine series of these *Ulodendra* from the Edinburgh coalfield, some of which conclusively settle this question. I am indebted to him for a fine specimen, in which the branch bifurcates in the usual Lepidodendroid manner. The large characteristic scars are seen, as usual, on both the inner and outer surfaces of these branches. The inner series is curious, since one of them is located at the exact point of bifurcation of the branch—a position from which no ærial root could possibly be given off. The scars average about 0·9 in diameter. Mr. Thompson has also obtained two branches, each of which exhibits the usual rows of scars, *but in each specimen one scar supports an actual cone in situ.* The actual area of attachment of each cone to its branch is a very circumscribed one, being wholly different from that of a secondary to a primary branch. On the other hand, the diameter of the entire base of the cone is very considerable—corresponding, in fact, with that of the peripheral margin of each characteristic Ulodendroid scar. It is now easy to understand these scars. We constantly find the greater part of their surfaces covered with the modified bases of leaves. The cone obviously originated as a small lateral bud, but its development into a branch was arrested, leading to the formation of a strobilus. As this expanded, though the actual attachment of its central axis to its parent branch was a very circumscribed one, the entire base of the cone became broad, and as a result of its active growth it pressed down the leaves of the branch over an area corresponding to the diameter of that base. The very large scars seen on many specimens bear no relation to the size of the cone, but have obviously increased in size through the continued growth of the stem after the deciduous strobili had fallen.

Spores.

In my last memoir (Phil. Trans., Part I., 1878, Plate 23, figs. 59–64) I figured a series of remarkable macrospores, which occur abundantly in some portions of the

Halifax beds, associated with a still greater profusion of microspores, which latter I concluded belonged to the same species of strobilus as the macrospores. Since that memoir was written we have found the strobilus in a section made for me by Mr. EARNSHAW, of Oldham. We had looked for a strobilus of considerable size, like those common in the carboniferous strata, whereas it is remarkable for its small dimensions; but that it has been fully grown is shown by the perfect development of its macrospores. The specimen is much crushed, as is seen in fig. 8, which represents it enlarged nearly 12 diameters. At *a* we find the usual central vasculo-cellular axis. At *b*, *b* are clusters of macrospores, several of them being enclosed in their sporangial envelopes. The upper part of the strobilus, *c*, has been cut off obliquely, owing to some accidental curvature in its form; but the entire absence of macrospores from the portion of it which remains shows the distinctiveness of its character from the lower macrospore-bearing part. At *d* we have two sporangia full of microspores, possibly disturbed by the pressure from their original positions.* The surrounding matrix is full of microspores. The entire length of this section is ·33. The strobilus was doubtless a little longer when perfect at its upper extremity; but when every allowance is made for the missing portion it remains a diminutive organism, reminding us more of the dwarfed fruits of many living *Selaginellæ* than of the larger *Lepidostrobi* which are so abundant in the upper Coal-measures.

In Plate 23, figs. 64 and 64*, of my last memoir I figured some anomalous pedunclular organs connected with the macrospores of this strobilus, which were wholly inexplicable to me when that memoir was written. Further research has cleared up the mystery. Fig. 9 represents a cluster of four macrospores, which demonstrate that these pedunculate appendages are but collapsed portions of the spore-wall, due probably to the destruction of their contained protoplasm, and consequent arrested growth. This is especially obvious in the two macrospores, *a* and *b*. Fig. 10 represents a tangential section of a detached bract of a different *Lepidostrobus*, with its sporangium on its upper surface filled with microspores. The slightly-distorted bract is seen at *a*, composed of strongly-defined cells at its upper portion, *a'*, and of a more delicate parenchyma inferiorly. In this strongly-marked differentiation of the upper and lower tissues of the bract the strobilus differs from the Burntisland one.† The structure of the sporangium-wall, *b*, is identical with that of the similar one surrounding the macrospores.‡ The mode of attachment of this cellular investment to the

* At the same time it must not be forgotten that whilst in the greater number of the *Lycopodiaceæ* the macrospores occupy the lower extremity of the strobilus, and the microspores its apical portion, there are several, such as *Selaginella Martensii*, in which the macro- and micro-sporangia are intermingled without any regularity in their arrangement. I have found this to be partially the case with the *Lepidostrobus* from Burntisland. In the macrospores of *S. Martensii* the exosporium is furnished with long radiating spines, which, as BURMEISTER has shown, become brittle and are often broken off. I have frequently found the similar appendages of the Halifax macrospores broken into detached fragments.

† Memoir, Part III., Plate 44, fig. 25.

‡ Memoir, Part IX., Plate 23, fig. 64.

bract shows it to be, as is also the case in the Burntisland species, an extension of the epidermal layer of the bract. But in this new species I find what I have not previously observed in these sporangia: an apparently distinct inner membrane, *c*, investing the mass of microspores. The inferior keel, *d*, of the bract is also much shorter than the elongated one of the Burntisland plant. The entire maximum diameter of the sporangium, including its bract, is only ·05, corresponding in this respect with the proportions of the crushed strobilus, fig. 8.

The relations between the structure of these primeval spores and sporangia and that of recent ones are not devoid of interest. In my last memoir I showed that each macrospore consisted of a very thick dark-coloured outer layer, and a very thin inner one. I think I cannot err in regarding the former as the representative of the exosporium and the latter as the endosporium of the spores of living Lycopods. The macrospore of the recent *Selaginella Martensii* possesses a similar thick dark-brown exosporium. I have already identified the cells contained within the endosporium of the fossil species with the endospermic cells of the recent ones. I have searched, but thus far in vain, for any representative of the prothallus which many living macrospore develop in addition to the endospore. The structure of the sporangium also requires to be observed. In most living Lycopods the sporangium-wall possesses, in its early state, three distinct cellular layers—an outermost epidermal one, which is merely the uplifted epiderm of the parent plant, and two subjacent layers of chlorophyll-bearing cells. As I have already explained, the wall of the fossil sporangium, fig. 10, consists of *two* layers. The outer one, *b*, is obviously identical with the epidermal layer of living forms. This is made clear equally by its structure and by the way in which it terminates inferiorly on the surface of the bract, *a*. The inner membrane, *c*, *appears* to be structureless; but when we remember that in recent sporangia the three layers eventually become reduced to two as the spores ripen, through changes that affect the two inner or chlorophyll-bearing layers solely, I shall probably not be far wrong in regarding the layer, fig. 10, *c*, as the representative of these layers.

In Plate 22, figs. 38–57, of memoir IX. I gave representations of a new strobilus with spores of one kind and of a peculiar character; but in the only specimens of that strobilus which I then possessed the structure of the central vascular axis of this fruit was very imperfectly represented by a crushed mass of vessels. I have more recently received from Mr. SPENCER, of Halifax, transverse sections of a second specimen of this strobilus, in which the central structures of the axis are well preserved. The *outer* bark (fig. 11, *d*) in these sections corresponds with that of fig. 53, *b*, of the previous memoir, except that the cells of its inner portion (fig. 11, *d'*) are more delicate, in comparison with the outermost ones, than in the older specimen; the bracts (fig. 11, *e*), also composed of numerous much-elongated cells, are longer and do not exhibit any proof of their having been so much expanded at their free extremities in a *lateral* direction as fig. 56 of the previous memoir showed them to have been *vertically*. In

the interior of several of these bracts I observe a slender vascular bundle composed of two or three minute barred vessels.

Fig. 12 represents the cellulo-vascular axis of fig. 11; in its centre, *a*, is the cylindrical medulla, composed of parenchymatous cells. It has a maximum diameter of about ·01. Surrounding this is a vascular zone, *b*, composed of barred vessels, not arranged in radiating lines, and remarkable for the approximate uniformity of their size. This cylinder, which has a mean diameter of about ·034, exhibits several indentations, *c*, in its outer margin as if characterised by a tendency to break up into separate wedges. I am unable to say whether this is a normal feature or whether it is a result of partial dessication, but the same feature presents itself in both my sections. The individual vessels range from ·0016 to ·001 in diameter, the peripheral ones being the smallest. Surrounding this vascular axis is a sheath, *d*, of very delicate parenchymatous cells, radial prolongations of which, *d'*, *d'*, composed of similar but more elongated cells, proceed outwards. Though I have detected no vascular bundles on these cellular prolongations, I have no doubt that they accompanied such bundles in their passage outwards to reach the sporangiferous bracts. It will be observed that the specimens nowhere exhibit traces of the orientation of these bract-bundles, neither do we see any traces of transverse sections of them grouped around the vascular axis such as constitute so striking a feature of the corresponding sections of true *Lepidostrobi*. Otherwise the general features of these sections correspond with those previously figured in possessing a generally Lycopodiaceous aspect. A very large unoccupied space separates the inner bark (fig. 11, *c*) and the more robust outer cortical zone *d*, which space was doubtless originally occupied by a delicate middle parenchymatous layer. The disappearance of this layer, leaving a thin inner zone like fig. 11, *d*, surrounding the vascular axis, is a common feature of the Lepidodendroid axes both in stems and fruits. At the same time the structure of this newly-discovered vascular axis agrees with the features previously described in giving to this strobilus a very distinctive individuality. This strobilus may be named *Lepidostrobus insignis*.

Fig. 12A represents a transverse section of an object from the Halifax deposit, for which I am indebted to Mr. SPENCER; its mean diameter is about ·033. It is evidently a section of the upper extremity of either a fruit or a young shoot with pentamerous phyllomes alternating in contiguous verticils. The only plants with which we are at present acquainted having verticilate phyllomes are *Calamites Sphenophyllum*, *Annularia*, *Asterophyllites*, and their immediate allies; but I have seen nothing amongst them that corresponds with this organism. The nearest approach to it is perhaps the little fruit figured in my last memoir (Plate 25, fig. 103), but even in this case the resemblance is but remote. In the fruit *Calamostachys Binneyana* the phyllomes are also arranged in alternating verticils; but in them we find an hexamerous arrangement, *six* fertile bracts alternating with twelve sterile ones.

Since the publication of my fifth memoir I have obtained some additional illustrations of the structure of *Calamostachys Binneyana*.

Fig. 13 is a fine longitudinal section of this strobilus from Halifax, for which I am indebted to Mr. BINNS. The vascular axis is seen at *a*, composed of barred vessels at its inner portion, but at each of the three prominent angles of this bundle there is a cluster of smaller spiral vessels. These clusters mark the points from which, as I shall show directly, the vascular bundles are given off to the bracts. The cortical portion, *b*, the sterile bracts, *c*, and the fertile ones, *d*, have already been described; but the section well illustrates the oblong cells which constitute the uppermost layer of each sterile bract as distinguished from the coarser parenchyma of its inferior portion. The sporangia, some few of which contain spores, appear at *e*; but that which is of the most importance to my present purpose is the existence of some symmetrically-disposed apertures, *d'*, *d''*, in the bark, through which apertures the vascular bundles of the bracts have originally passed—those marked *d'* going to the fertile bracts and consequently being six in number in each verticil, whilst those indicated by *d''* have been double that number, and destined for the corresponding number of sterile bracts. Fig. 14 is a beautiful transverse section through the sterile bractigerous disk, enlarged 17 diameters. At *a* is the vascular axis; at *b* the *outer* cortical parenchyma, the inner layer being almost entirely wanting; at *c*, *c'* we have the tissues forming the bractigerous disk, chiefly composed of coarse cellular parenchyma, but at *c* we find the cells elongated radially,* going to the free vertical bracts already described by Mr. BINNEY, Mr. CARRUTHERS, and myself. Running along the centre of these lines of prosenchymatous cells I find in each of two or three of the bracts the bundle of small spiral vessels pursuing its way across the disk to reach the free marginal bract. At *f*, *f* we have transverse sections of the vertical portions of the bracts belonging to the next inferior verticil, whilst the extreme tips of those of the next lower verticil but one appear at *g*, *g*.

Fig. 15 is a transverse section of the *Calamostachys* made through the plane of the fertile sporangiophores. It is the only specimen I have yet seen in which the cortical structures are preserved in their entirety. The central vascular axis, *a*, is closely surrounded by a dense cellular layer, *b*; this passes into a more open and delicate cellular tissue, *b'*, in which there are large lacunæ—but which latter are probably due to partial desiccation, since they are irregularly distributed. Bounding this externally is the outermost cortical layer preserved in all specimens of this fruit, and of which the sporangiophores, *d*, are mainly prolongations. At *d'* we have part of the peripheral peltate expansion of the sporangiophore, *d*.

But the points of this section which are specially important relate to the central vascular axis with its dense cellular investment; the form of its transverse section is here unmistakably that of a triangle with each of the angles truncated at its extremity. We further see at each of *two* of these truncated angles two small vacant spaces, which, like the similar spaces, *d'*, *d''*, in the outer bark of fig. 13, doubtless

* These lines of elongated prosenchymatous cells only occupy the upper surface of the disk until they reach the upper extremities of the free bracts, *f*, *g*, which portions are chiefly composed of such cells.

transmitted vascular bundles to the sporangiophores. In the present instance the apertures are in the innermost layer of the bark, and indicate the points at which vascular bundles emerged from the central vascular axis. The third angle very distinctly exhibits *one* such lacuna, and it is easy to discover in the specimen itself the position of the second one. We have here a triquetrous axis, each truncated angle of which gave off two vascular bundles. There being but six sporangiophores, one bundle obviously went direct to each sporangiophore; but in the sterile verticils there were 12 bracts, and the specimen fig. 13 affords the evidence that in these verticils a corresponding number of 12 vascular bundles must have emerged from the outer bark, the result of dichotomous division of the six primary ones.

In my memoir, Part V., p. 65, I endeavoured to demonstrate, so far as the less perfect specimens then in my cabinet enabled me to do so, the triquetrous character of the axis of this fruit and its consequent affinity with the similar axes of *Sphenophyllum* and *Asterophyllites*. The specimens now described fully confirm the conclusions then arrived at—viz.: that *Calamostachys Binneyana* had not the slightest relationship with the *Calamites*, but that it had strong affinities with *Asterophyllites* and *Sphenophyllum*. A comparison of the positions of the symmetrically-disposed pairs of apertures in each angle of my fig. 14 with that of the vascular bundles of the transverse section of *Sphenophyllum* figured by M. RENAULT* will demonstrate how close is the resemblance between the two; and I have no doubt that a similar section made through a perfect example of one of the sterile verticils would exhibit exactly identical results with the cortical portion of the same figure—*i.e.*, it would show the division of the six bundles into 12, exactly corresponding with the number of the lines of elongated cells seen in my fig. 14. Unfortunately, the fine section represented in the latter figure has lost the cortical layer through which the inner portions of these bundles had to pass; but they are distinctly seen, as I have already pointed out, in some of the 12 radial lines of elongated cells, *c*, belonging to the disk represented in that figure.

In fig. 38 of my memoir, Part V., I represented a section of the central vascular axis of *Calamostachys Binneyana*, in which there appeared to be an exogenous growth investing the primary vascular bundle. In describing this axis I pointed out (*loc. cit.*, p. 61) that whilst its centre consisted of barred vessels grouped in the usual way, its periphery was composed of similar vessels but arranged in radiating laminæ, the inner extremities of which exhibited a decided tendency to curve inwards towards three points in the periphery of the primary vascular bundle. At the time when this specimen was described it was the only one which I had seen exhibiting this peculiar structure, and its peripheral margin being imperfect I was unable to determine what its normal outline had been. I have more recently received from Mr. SPENCER another, and fortunately more perfect, specimen of the same form of strobilus, the axis of which —surrounded by a portion of its outer cortical parenchyma—is represented in fig. 16.

* "Nouvelles recherches sur la structure de *Sphenophyllum*, et sur leurs affinités Botaniques," 'Annale des Sciences Naturelles,' 6e série, Bot., tom. 4, plate 7, fig. 3, *i*.

The central portion of the vascular axis, *a*, is composed, as previously described, of the ordinary group of barred vessels. The exogenously developed layer is produced into three prominent lobes, *b*, *b*, *b*. The component radiating laminæ of each lobe are more or less curved, their concavities being directed towards the centre of each lobe. The result of this arrangement is to exhibit in a new manner the tendency towards a triquetrous arrangement which I have already shown to be a characteristic feature of some of these strobili whenever we obtain them in anything approaching to a perfect condition.

In the sporangia of this specimen, which is from the Halifax bed, we find beautiful examples of numerous mother-cells, each of which exhibits three, but doubtless contains four daughter-cells. These latter appear to me to be the true spores since they correspond, so far as size is concerned, with most of those seen in my numerous other sections of this fruit. A second specimen from Halifax, for which I am indebted to Mr. BINNS, exhibits this condition of the spores yet more perfectly. Fig. 17 represents one of the mother-cells of this example, enlarged 400 diameters. Its three contained daughter-cells are perfect in their outlines; those in Mr. SPENCER'S section are more shrivelled and ruptured. In none have we a trace of elaters. In the slide containing Mr. BINNS' specimen is an obliquely transverse section of another strobilus of which the axis has had the same structure as that represented in fig. 16. It displays four of its sporangia, all of which are filled with parenchyma, in which no spores or daughter-cells are yet visible. The sporangium walls, fig. 18, *a*, are strongly defined, and the parenchyma, *b*, entirely fills the cavity of each sporangium, differing in this respect from most of the other examples which I have seen. This absence of daughter-cells from each of the parenchymatous cells obviously suggests that we here have the strobilus in a very young state; yet we find that, in its axis, the peripheral radiating vascular laminæ seen in fig. 16, *b*, are already present. This fact seems to show that we have at least two species of these fruits, distinguished from each other by these differences in the structure of the central axis, but identical in every other respect; both being equally characterised by a tendency on the part of the vascular axis to assume more or less distinctly the triquetrous form.

Ferns.

The Halifax beds have furnished two new forms of fern-stems or petioles. Of the first of these, of which a transverse section is represented in fig. 23A, I have received sections both from Mr. SPENCER, of Halifax, and from Mr. EARNSHAW, of Oldham. In its essential features this agrees with many of the other *Rachiopterides* which I have already described. Its chief characteristic resides in the form of its very large oval vascular bundle which consists of a dense mass of thick-walled barred vessels. Its maximum diameter is about ·11. I propose to distinguish it by the provisional name of *Rachiopteris robusta*.

For specimens of a second and more remarkable *Rachiopteride* I am indebted to both Mr. BINNS and Mr. SPENCER. They are from the Halifax beds. Fig. 19 represents a transverse section of Mr. BINNS' specimen enlarged 15 diameters, and fig. 20 represents the central portion of fig. 19, enlarged 46 diameters. The outer cortex, *a*, is identical in all respects with the corresponding tissue in the other Rachiopterides that I have described, consisting of a thick-walled cellular prosenchyma, the peripheral cells of which are much smaller than those of its inner portion. Within this is a more delicate thin-walled parenchyma, *b*, the transition from which to the investing prosenchyma is somewhat abrupt. This inner tissue is frequently wanting in these *Rachiopteride* sections, it having apparently disappeared through decay, prior to the mineralisation of these stems. The yet more internal structures are best illustrated by the enlarged fig. 20, in which *b* again represents the parenchyma of the middle cortex. Within this we find a narrow zone, of inner cortex *c*, the cells of which exhibit a decided tendency to arrange themselves in regular radiating lines. This tissue passes into a still more internal series of cells, *d*, which fill up the interspaces and round off the outlines of the vascular bundle. Between the two series of cells, *c* and *d*, a dark, ill-defined, but nevertheless distinct line of demarcation, *h*, surrounds the entire central vasculo-cellular axis. The vessels, *e*, *f*, are arranged in this plant as in the genus *Zygopteris* of authors. The central ones, *e*, are extremely large, some of them having a diameter of ·01. These are virtually arranged in two rows, which separate at each end of the bundle, where the vessels rapidly diminish in size, and recombine to form the two vascular loops, *f*, *f*, enclosing a small mass of parenchyma, *g*, *g*, located at each extremity of the double row of large vessels. Many of the vessels of these peripheral loops, *f*, are not more than ·0012 in diameter, but, like the larger ones, they are thick-walled. The tissues *d* and *g* probably represent liber structures.

All the larger vessels of this bundle are densely crowded with tylose-cells, constituting the second example which I have met with of this tissue existing in carboniferous plants. I described a previous one in the case of the fern-like *Rachiopteris corrugata* in my memoir, Part VIII.*

Fig. 21 represents the central part of a transverse section of a similar stem to fig. 19, but made so obliquely as to be almost a longitudinal one. From it we learn that all the cells *c* and *d* enclosed within the middle cortical layer *b*, *b*, excepting *g*, are long, narrow, and have square ends. We also see that the large vessels, *e*, and the small ones, *f*, are alike barred, the former being filled with tylose as in the transverse section.

Fig. 22 represents the transverse section of another stem, for which I am indebted to Mr. BINNS. It corresponds with fig. 20 in almost every essential respect, but the large vessels, *e*, exhibit no traces of tylose. The cells of the innermost portions, *c*, of the cortical layer exhibit less tendency to arrange themselves in radiating lines than they do in fig. 20, and the dark line, *h*, separating that layer from the

* Phil. Trans., Vol. 167, Part I., p. 214, Plate 6, figs. 15 and 16.

endophlœum, *d*, is still more strongly marked than in the former specimen. I cannot doubt for a moment the specific identity of figs. 20 and 22. The presence of the tylose, therefore, would seem to be an accidental phenomenon, and not a specific feature of the former specimen. As for the dark line, *h*, I think I cannot be wrong in regarding it as identical with a similar boundary-line or bundle-sheath seen in many recent ferns, and which occurs in a form closely resembling that of fig. 20 in the petioles of *Woodwardia orientalis*. So far as its central vascular bundle is concerned, this plant somewhat resembles the *Zygopteris elliptica* of M. RENAULT ;* but it differs in the relative proportions of its transverse terminal arcs, which are very much longer and less robust in *E. elliptica* than in my species. The various cellular layers, *b*, *c*, *d*, and *g*, of the latter not being preserved in M. RENAULT'S specimen, makes a more detailed comparison of the two plants impossible. I propose to distinguish my plant by the name of *Rachiopteris insignis*.

Fig. 23 represents a lateral bundle passing outwards through the cellular layer, *b*, of fig. 21. In its centre we obviously have the central bar, *e*, of fig. 20 ; but it is impossible to say which of the surrounding structures are vascular and which cellular, or to determine whether this is the bundle of a secondary petiole, or of a root, but it is most probably the former.

Conceptacles.

In my last memoir I described some remarkable reproductive structures under the generic names of *Sporocarpon* and *Oidospora*. Having obtained additional examples of these objects, I am now able to throw further light upon them, and also to add to their number. I described one of these under the name of *Sporocarpon elegans* (*loc. cit.*, p. 348, Plate 23, figs. 67, 68, 69, 69A), and a second I designated *S. compactum* (*loc. cit.*, p. 349, Plate 24, fig. 76A). Specimens recently discovered suggest the possibility that these apparently distinct species may be but different stages in the development of the same organism ; the latter being the younger, and the former the more matured states. It is also possible that the minute objects which I designated *Oidosporæ*, may be *very* young forms of the same, though at present I have not sufficient evidence to prove that such is the case.

Fig. 24 is a transverse section through the centre of a very perfect specimen of the *Sporocarpon elegans*. Its radially disposed, hour-glass-shaped cells, *a*, are arranged in the most symmetrical manner. Some of the cells are prolonged into long, radiating, unicellular hairs, *b*, *b*, whilst in others, *c*, *c*, these hairs have been broken off near the periphery of the organism. This example has further satisfied me that in the specimens ordinarily met with, most of these hour-glass cells are open at their peripheral extremities, and that all of them were once more or less prolonged into hollow hairs, the free portions of which have in most instances been broken off. I have already referred to the brittleness of many of these cellulose hairs, as illustrated by those clothing the

* 'Annales des Sciences Naturelles,' 5e série, Bot., tom. 12, plate 7, fig. 10.

exterior of the macrospores of *Selaginella Martensii*. In my previous memoir (*loc. cit.*, p. 347) I was unable to discover any evidence that smaller cells occupied the spaces, *d*, intermediate between the hour-glass cells, hence I was disposed to believe that the constricted portions of those latter were surrounded by a crypt-like cavity, whose ramifications were co-extensive with the entire sphere. But on bringing one of the new oil-immersion lenses made by KLEISS, of Jena, to bear upon an oblique section I discovered that this was an error.

Fig. 28 represents a portion of the section in question enlarged 320 diameters. At *a* we have the inner extremities of the cells forming the continuous boundary of the central cavity of the organism. At *b* are the constricted portions of the same cells rising up like a series of hollow pillars from their closely-united flattened bases. At *c* these cells again expand, and form by their conjunction a second or outer continuous tissue, whilst their constricted portions, *b'*, now appear descending from them like so many funnels; at *d*, *d*, we have some of these cells prolonged into hollow tapering hairs. But what is most significant in this section is the series of extremely delicate lines, *e*, which proceed from one constricted cell to its next neighbour, and which in several instances, as at *e'*, are seen to be double. The discovery of these lines, which unquestionably represent the two walls of extremely thin-walled, contiguous cells, demonstrates that the lozenge-shaped interspaces (*d*, of fig. 24) are really occupied by a delicate parenchyma.*

Fig. 25 is a section through a slightly crushed specimen exhibiting a transverse section of the sporocarpal wall at *a*, and a tangential one of the outer surface of the same wall at *c*. In the interior of the organism is a structureless membrane containing a small number of relatively large cells. I had already figured a similar membrane, but devoid of cells, contained in Plate 23, fig. 67, of my previous memoir, and also another in fig. 69A of the same Plate. In the latter case the membrane is filled with numerous small parenchymatous cells, varying from ·001 to ·0015 in diameter. In the specimen now described these cells are nearly double that size, the largest being ·0025 in diameter.

Figs. 26 and 27 represent two specimens intersected more tangentially. The former of these is especially important, because whilst it displays the peripheral ends of the

* Since writing the above description I have discovered the specimen represented in fig. 57. It is a tangential section of the wall of the above fruit which displays the outer surface of the organism, where the cells, *a*, are arranged with great regularity and approximate uniformity of size. At *b*, *b*, we have the inner bases of four hairs, which are merely outward prolongations of some of the cells, *a*. Opposite *c* the section has penetrated a little more deeply into the structure, bringing into view a lower, optical section of the tissues forming the centre of the fruit-wall. At *d*, *d*, we have optical sections of the constricted portions of the hour-glass cells, and at *e*, *e*, we have the radiating walls of five or six cells which surround these central constricted portions. These are here seen so distinctly as to place the existence of a central layer of smaller cells, occupying the lozenge-shaped space *d* of fig. 24, beyond all doubt. In fig. 57 it is the outer conjoined extremities of the hour-glass cells that are in focus. The radiating walls of the central cells, *d*, are seen *through* and *below* the funnel-shaped contracting walls of the surface areolations under a low magnifier.

cells arranged with the regularity of ordinary parenchyma, it further shows the prolonged hairs to be much more numerous than in any of the specimens previously described—indeed, in several portions of the section they are developed from every cell.

Fig. 29 represents an almost superficial tangential section of the *Sporocarpon cellulosum* of my previous memoir. The numerous component cells constituting its wall are of nearly uniform size, and arranged with parenchymatous regularity. The dark zone marks the boundary of the central cavity into which we look through the small central orifice, where the section has sliced off the most prominent part of the sphere. On the opposite side of the slide the section has passed nearly through the centre of this cavity, the maximum diameter of which corresponds with the outer boundary of the dark zone. On employing a one-eighth oil-immersion lens, we discover that the free or peripheral extremities of most of the cells are slightly prolonged into small, dark-coloured mammillæ, as represented in fig. 30.

Fig. 31 is a transverse section of an important specimen, since it seems to indicate a connexion between figs. 29 and 24. It reveals the cells of the boundary wall in every stage of transition from the form seen in fig. 29, to those elongated into the radiating hairs of fig. 24. Thus at *a* the terminal mammilla of fig. 30 is becoming slightly elongated, at *b* it is yet more drawn out, and at *c* it has nearly assumed the full dimensions of the hairs of figs. 24, 25, and 26.

Like fig. 25, the interior of fig. 31 is filled with large cells, averaging about ·0025 in diameter.

This fine series of illustrations suggests the possibility that these objects are cellular spheres, the cells of which were in the first instance short, and compactly grouped; but that as their growth advanced the peripheral extremities of many of them became prolonged into hollow and extremely brittle hairs, and that as this growth progressed further, a small number of large cells appear in the inner cavity, and are gradually developed into a large number of small ones, like those which occupy the interior of fig. 69A of my ninth memoir. On applying the oil-immersion one-eighth objective to the latter specimen, I discovered that many of its contained cells displayed the features represented in figs. 32, 33, and 34. The protaplasms of 32 and 34 have subdivided to form four daughter-cells, whilst fig. 33 contains two such cells. Whether these are the ultimate spores, or whether they are destined to be the mother-cells of yet further developments, it is impossible to say; but seeing that in the only specimen in which these spore-like objects have been found the sphere-wall has attained the fullest development with which we are acquainted, whilst its subdivided cells are no longer free but are reduced to the state of a somewhat compact parenchyma, I think we have strong reasons for inferring that they are destined to be the true spores of the organism.

Of the specimens just described I am indebted to Mr. BINNS for the slides containing figs. 24 and 29, to Mr. EARNSHAW for 25, 27, and 30, and to Mr. SPENCER for 26.

Two of the slides from Halifax, for which I am indebted to Mr. SPENCER, contain

clusters of conceptacles of a perfectly distinct type. Each conceptacle has a diameter of about ·016 to ·012. As seen in figs. 35 and 36, their form is that of rounded spheres, having a very thick outer investing layer, *a*, and a delicate, structureless inner one, *b*. In fig. 35 this inner membrane is intersected through its centre, but in fig. 36 the section has passed through it tangentially, illustrating its spherical form. In the latter instance it contains a number of very minute granular bodies that look like spores. When examined under low powers, even with the quarter-inch objective, the outer layer, *a*, appears to be composed of a mass of small, irregular parenchymatous cells, but the oil-immersion (one-eighth) revealed the structure shown in fig. 37. It consists of a dense mass of branching and interlacing tubes of varying diameters, the interstices of which appear to be filled up with a structureless substance. At numerous points, as at *a*, *a*, in the figure, the section has cut through these branches transversely. In other places, as at *b*, *b*, we have the meshes of the tubular network. In a few specimens I find two inner circular cavities of this form enclosed within a common peripheral tubular investing layer *a*; but there is usually but one, and their ordinarily detached condition and comparatively uniform contour suggests that they have been closely grouped but independent organisms, and not the broken up portions of a common mass. Figs. 35 and 36 are enlarged 162, and fig. 37 750 diameters. I propose for them the name of *Sporocarpon pachyderma*.

What these objects are is not easy to determine. It is impossible to overlook the resemblance between the branching tubules of the outer investment, *a*, and fungoid hyphæ; but I know of no fungoid reproductive structures that in any way resemble them in their entirety.

Fig. 38 represents the only example I have seen of what appears to be a transverse section of another conceptacle which exhibits very distinct features. It is contained in a slide of the Halifax material, for which I am indebted to Mr. SPENCER. Its maximum diameter, including the radial prolongations, is about ·016. Its peripheral layer consists of a thick investment of parenchyma, *a*, which is prolonged into six unequal obtuse rays. Within this tissue is a central spherical cavity, *b*, within which again is a very thin structureless membrane, the tangentially intersected margin of which is seen at *c*. That the interior cavity is a spherical one is beyond doubt. Whether the six parenchymatous radii were the only ones which this object possessed, or whether similar ones existed perpendicular to the plane of the section, I am unable to say. I propose the name of *Sporocarpon asteroides* for this object.

Fig. 39 is a transverse section of an organism from Halifax, for which also I am indebted to Mr. SPENCER. Being the only specimen I have seen of this type I am unable to determine whether, in its perfect condition, it was a spherical or a cylindrical body. Its central cavity has a mean diameter of about ·055. This is surrounded by a ring of dark, carbonaceous, compressed fragments, *a*, which I have no doubt represent compressed parenchyma, apparently the innermost portions of the layer, *b*. This is a layer bounded externally by an undulating outline and consists of a very regular form

of parenchyma, the cells of which appear as if slightly thickened at their angles. Under a low power these dark angular points are the only portions of the cells that are visible. The outermost of these cells have a mean diameter of ·0022, but they become smaller as they approach the inner boundary of the tissue where many of them have less than half that size. The outermost layer of this organism is very peculiar. I have already observed that the periphery of the middle layer is an undulating one. Each of its peripheral projections sustains a cluster of very large thin-walled cells, *d*, *d*, most of which are prolonged radially. Each interval between these projecting cell-clusters is occupied by a single row of very strongly-marked, thick-walled cells, *c*, which appear to be modifications of the inner parenchyma, but whose entire cell-walls are thickened to form a protective layer at the depressed points of the surface of the organism. I find no trace whatever of any epidermal or other layer external to the large cells, *d*, and the obviously protective character of those marked *c* makes it clear that this is not an organism torn from its surroundings, but that we have substantially its true peripheral outline. There are some features of resemblance between the layer, *b*, and the cells, *a*, of fig. 38, hence it is not impossible that they may ultimately prove to belong to the same, or at least to allied plants. I propose to designate fig. 39 by the provisional name of *Sporocarpon ornatum*. One common feature characterises the whole of the objects which I have included in the provisional genus *Sporocarpon*, viz.: they exhibit no trace of having possessed any peduncular appendage wherewith to be attached to their parent plants.

Wide diversity of opinion has long existed between Mr. CARRUTHERS and myself respecting the next specimens to be described. At the meeting of the British Association for the Advancement of Science held at Bristol, Mr. CARRUTHERS described some small objects from the lower Coal-measures of Lancashire, to which he gave the name of *Traquaria*, and which he believed to be carboniferous *Radiolarians*. An abstract of his communication appeared in the Report of the Association for 1872.* Having examined specimens of these objects in my own cabinet in 1874, I ventured to doubt their Radiolarian character, and suggested† that they bore more resemblance to some Cryptogamic spores than to the marine siliceous *Protozoa* with which Mr. CARRUTHERS associated them. The study of a fine series of these objects so far confirmed my convictions that I presented a communication to the British Association at its Dublin meeting held last summer, in which I assigned what appeared to me sufficient reasons for regarding them as reproductive organisms belonging to some unidentified Cryptogamic plants. I next forwarded the more important of my specimens to our highest authority on the subject of the Radiolarians, viz.: Professor HÆCKEL, of Jena, who, in addition to his own careful study of them, kindly invited his colleague, Professor STRASBURGER, to examine them along with him. Both these distinguished biologists have arrived at the same conclusion as myself respecting them, viz.: that they are

* Trans. of Sections, p. 126.

† Phil. Trans., 1874, Memoir, Part V., p. 56.

vegetable and not animal structures. The *Traquaria* is a spherical organism with a thin structureless investing layer or capsule-wall prolonged into numerous radiating tubular appendages, which for convenience may be designated spines. The mean diameter of the central sphere in eight specimens is ·01333, the maximum being ·02, and the minimum ·01. The interior of the sphere is occupied, in several examples, by cells, enclosed within one or more inner membranes, and the entire organism, including its spines, *appears* as if it had been invested by some plastic substance.* Since these several parts of the organism exist in various forms in different examples, the most convenient mode of describing them will be to examine the more characteristic individual specimens in detail.

Fig. 40 represents the smallest specimen I have met with. Though crushed, it is valuable, since it shows that, at this stage of its development, both the capsule-wall, *a*, and the spines, *b*, were free from brittleness, having been flexed by the pressure to which they have been subjected, but without breaking. The plastic (?) investment is seen at *e*, as a faintly granular element devoid of any very definite outline. At *b'*, a portion of the outer capsule-wall has got displaced, revealing sections of three spines, and the entire extent of this tissue exhibits numerous circles and parts of circles shortly to be explained. Fig. 41 represents a fine example of which the central sphere, *a*, has been intersected a little on one side of its maximum diameter, the latter being shown at the circumference, *a'*, of the dark ring. The outer capsule-wall is thus seen obliquely and exhibits numerous small rings. The spines, *b*, are here more rigid than in fig. 40. They have yielded to pressure, but at *b'*, *b'*, *b'* they have done so less readily than in fig. 40—hence they have been thrown, at the yielding points, into more angular forms than seen in the curved ones of that figure. Each spine is broadest at its base, and is muricated externally throughout its entire length, but these muricated projections become more sharp and prominent as we pass from the basal to the free extremity of each spine. The murications are arranged in irregular verticils and ultimately develop into branching tubes, but in the example under consideration they have not reached this stage of growth, displaying as yet little more than sharp projecting points. One or two of the spines, *b''*, exhibit a disposition to branch at their free extremities; the more faintly shaded ones represent some seen out of focus. The plastic investment is seen at *e*, not only surrounding the central sphere but extending to the extremities of the spines.

In fig. 42 the densely clustered spines are imperfectly preserved. The outer capsule-wall, *a*, now appears as an extremely thin tissue. At *f* we find it separating from a second thin, structureless layer of membrane, whilst at *f'* we have another spherical membrane enclosing a mass of detached cells, *g*, the diameters of which range from ·0008 to ·00125. Most of these cells display their outer cell-walls, with the contracted primordial utricle (?) free in the interior of each cell. Fig. 45 represents a transverse section of an example in which the spines, *b*, have become more rigid, and, in addition,

* The "spongy substance" of Mr. CARRUTHERS.

their murications, *b*, have now become tubular. Fig. 47, which represents one of the spines of fig. 46, exhibits this condition more distinctly. The murications on the surface, *a*, have had their extremities broken off, consequently we can look through the circular apertures thus left, into the interior of the hollow spine. We further see, at *a'*, that these murications are now developing into tubular secondary extensions of the primary cavity of the spine: a feature to which further attention will be drawn. Within the capsule-wall, fig. 45, *a*, we again find the inner membrane, *f*, distended by large cells, *g*. These latter now touch one another, though their mutual pressure has not been sufficient to interfere with their spherical form. These cells now average ·0025 in diameter. The plastic investment reappears as before at *e*.

Fig. 46 is a section of a crushed specimen in which both the capsule-wall, *a*, and the spines, *b*, now become brittle, are broken up into innumerable sharply-defined fragments, *b'*. These brittle spines all display the tubular form of murication represented in fig. 47. But the most curious feature of this section is furnished by its inner layers of membrane. We have a structureless one at *f*, splitting into two layers at *f'*, the innermost of the two laminæ uniting with a yet more internal one, *f''*. This latter is covered with numerous closely-grouped circles. A more enlarged representation of a portion of this innermost membrane is given at fig. 48. The rings are now seen to be circular prominences, *f*, the summit, *f'*, of each of which is a little depressed and circumscribed by a sharply-defined circular groove, *f''*.

Figs. 43, 44, and 49 throw light upon each other. Fig. 43 represents the surface of a portion of the capsule-wall, as seen under a comparatively low power, exhibiting the bases of numerous spines. When the microscope is so focussed that we obtain an optical section at a plane corresponding to the *external* surface of the fragment, we merely see the transverse sections of the hollow cylindrical spines, as at *b*, *b*, but on increasing the magnifying power and bringing a more internal surface of the fragment into focus we obtain the effects seen in fig. 44, which represents the upper left-hand portion of fig. 43, enlarged 650 diameters. We now see that at their bases, *a'*, *a'*, the cavities of several spines *appear to* open into one another. But this arrangement is explained by the segment of a transverse section of a *Traquaria*, fig. 49. We here observe that not only are the lower extremities of the spines enlarged, as already described, but that they frequently spread out (fig. 49, *a''*, *a'''*) like the roots of a tree, covering areas many times wider than the maximum diameter of the spine. Fig 49 only exhibits such of these outspread roots as run in the plane of the section; but at *a*, *a*, *a*, we have transverse sections of other similar roots which spread out at right angles to that plane, and which interlace and often appear to anastomose with other similar ones. It is this ramification of the bases of the tubular spines that occasions the numerous irregular circular and semi-circular areolations visible in the capsule-wall in such sections as figs. 40, *a*, and 41, *a*, *a'*. A considerable portion of the inner surface of fig. 43 is covered with a very irregular and ill-defined reticulation.* In fig. 49 the free ends of the spines subdivide into large branches.

* Explained in some supplementary observations on p. 533.

On applying KLEISS' oil-immersion lens to the specimen illustrated by fig. 44, new phenomena were brought to light. I had already obtained some faint glimpses of two or three delicate threads springing from some of the pointed murications of the spines in such specimens as fig. 41, and which threads appeared to lose themselves in the investing plastic substance. In the specimen now under consideration we find that such threads are but the commencements of a very complicated system which permeates the plastic substance in every direction. I was long inclined to believe that these branching threads anastomosed to form a regular network. I noticed that whenever two of them met there was a small but very decided apparent thickening of the tissue, visible even when the threads themselves were almost invisible; but later observations each have led me to conclude that such is not the case, but that they merely start from each pointed mucro as at fig. 44, *a*, *a*, *a*, and spread through the plastic substance by a succession of dichotomous divisions. It is scarcely necessary to say that the structures, *a*, *a*, *a*, of fig. 44, represent the free portions of spines that have been intersected as they pass through the plastic element a little above the outer surface of the capsule-wall, but similar threads are given off *from the upper surfaces* of the branching tubes, *a'*, *a'*.

I have already pointed out that in the more matured spines, as in fig. 47, *a'*, we find the mucronate projections of specimens like fig. 44 also converted into branching tubes. This condition is well represented by fig. 50, where three of the spines are seen intersected transversely, whilst a fragment of a fourth appears in its longitudinal aspect. All four spines demonstrate that the mucronate projections, with their divergent threads of fig. 44, are here replaced by freely branching tubes which radiate in every direction. I have examined the section from which this figure is taken to see if I could discover any anastomoses between the separate sets of branching tubules; but I have failed to do so. In all the cases where such anastomoses appeared to exist, it became manifest that separate branches merely overlaid one another.

I think there can be no doubt that the branching threads of fig. 44 are identical with the branching tubules, *b*, *b*, of fig. 50. If so we must assume that the former is their undeveloped condition, whilst in the latter they have not only attained, but have even passed their maturity. Fig 50 represents them in the most perfect form in which I have yet found them; but it is obvious that the branches, *b*, *b*, of that figure are but the truncated bases of what were at one period much more extended ramifications. Wherever we see into these truncated branches, we find open mouths of thin-walled cylinders, as at *b'*, *b'*.

It appears to me most probable that the external capsule-wall indicated in all the specimens figured by the letter *a*, is a cellulose exosporal membrane, which has been prolonged into numerous radiating branching tubes, the secondary branches of which very closely resemble those figured by VAN TIEGHEM and LE MONNIER in their 'Recherches sur les Mucorinées;'* but having their ramifications more multiplied and

* 'Annales des Sciences Naturelles,' 5e série, Bot., tom. 17, plate 20, figs. 12 and 13.

extended than is the case in the conjugating cells of the *Phycomyces nitens* described by the French biologists.

That these dark-coloured, hollow, thin-walled branching tubes are as different as possible from the transparent and colourless siliceous spines of the *Radiolarians* is too obvious to require further remark. Soft and flexible in their young state, they became brittle only when more matured, a condition to which I have referred in an earlier part of this memoir as not uncommon amongst the macrospores of such recent Lycopods, as *Selaginella Martensii*. The cells seen in figs. 42 and 45 are wholly undistinguishable from similar endospermic cells seen in the Lycopodiaceous macrospores figured in Plate 23 of my last memoir, Part IX. Hence I adhere to my previously expressed conviction that the *Traquairæ* are really vegetable organisms, and that there are strong grounds for supposing them to be Cryptogamic macrospores. Professor STRASBURGER suggests that their nearest allies will possibly be found in those of Azolla and other Rhizocarpous genera.

In my last memoir I gave small figures (*loc. cit.*, Plate 23, figs. 72, 73, and 74) of three small bodies, respecting which I observed: "It is impossible to overlook the striking resemblance of these little objects to the fossil Xanthidia of the chalk flints, and to the zygospores of some of the Desmideæ." When these words were penned I was not certain that these objects might not prove to be young states of some of the numerous spores with which the Halifax rock abounds. Since then I have obtained numerous additional examples of these objects in sections for which I am indebted to Messrs. SPENCER and EARNSHAW, and find their characteristic features to be so constant that I cannot doubt their being matured organisms, whatever may be their botanical nature. That they were all more or less spherical, with radial appendages distributed over their entire periphery, is certain.

Fig. 51 represents one of these objects in their most common aspect. The diameter of the central disk is about ·0014. The radiating arms are of somewhat variable length. These arms always branch more or less peripherally as represented by the further enlarged fig. 52. It is not always easy to trace their exact ramifications owing to imperfections in their mineralisation, but in those which are well preserved there are usually two or three primary divisions, the extremities of which are further subdivided.

Fig. 53 represents another of these objects, the extreme diameter of the disk of which, exclusive of the radiating arms, is ·0018. The arms in this example are rather shorter than in the last one. The section has here passed tangentially through the uppermost portion of the disk—hence we see at *a* the bases of arms springing at regular intervals from what remains of its convex surface. Fig. 56 is a less highly magnified figure of a much larger specimen, the disk of which has a diameter of ·006. It is chiefly interesting from the fact that it unmistakably exhibits an inner structureless membrane, *b*, devoid of all radial extensions. I have found faint evidences of the existence of such a membrane in several of my specimens, leaving no room for doubting

that it is an integral part of the organism. Fig. 55 is also one of the larger specimens, its disk having also a diameter of ·006. Each of its radial arms terminates in an unbranched, semi-clavate extremity, but I doubt if this is normal. It appears rather to be a result of imperfect preservation. The real importance of this specimen is seen in the large and very distinct cells, *c*, located within the cavity of the disk. Other examples have afforded similar, though less strongly-marked indications that such cells belong to the organism, and were doubtless developed, as in other spores, within the interior of the membrane, *b*, of fig. 56.

I have met with several examples of the apparently distinct form represented by fig. 54, and as all the sections exhibit the same aspect, having a pentagonal or hexagonal disk, with a diameter of about ·0018, and five or six long, slender arms, the length of each arm being about equal to the entire diameter of the central sphere, this object is probably distinct from the other species described. I would therefore designate figs. 51, 53, 55, and 56 *Zygosporites brevipes*, and fig. 54, *Z. longipes*.

I have given to these objects the name of *Zygosporites*, without meaning that they are actually zygospores, though there is much reason for adopting such a conclusion. M. Charles Brongniart, of Paris, informs me that he has found similar objects amongst the discoveries of M. Grand-'Eury, at St. Étienne, and that he refers them to living types of Desmideæ. I am not prepared to advance thus far. Had true Desmideæ existed in the carboniferous strata, I see no reason why their extremely characteristic bilateral cells should not have been preserved as readily as other cellular tissues which my cabinet contains. Having many scores of examples of these *Zygosporites*, the plants to which they belonged must have been common in the locality in which they grew; but I have not discovered the slightest trace of a Desmid in these deposits.

Figs. 58 and 59 represent sections of an organism of which I have met with several examples in two slides from Halifax, for which I am indebted to Messrs. Spencer and Binns. Fig. 58 is a transverse section through the centre of one of these objects, enlarged 1260 diameters. Its actual length is ·0042. Fig. 59 is a more tangential section of another specimen about ·0041 in length. In both specimens the wall of the organism exhibits numerous points at which it is projected outwardly into small, hollow prominences, and which appear to have subdivided extremities like the radial arms of the *Zygosporites*. Indeed, these objects only appear to me to differ from *Zygosporites* in their oblong form, and in the smaller size and greater numbers of their peripheral appendages. Such being the case they may be named *Zygosporites* (?) *oblongus*.

In my memoir, Part VIII., I described and figured (Plate 9, fig. 44 and 46, *g*, *g*) sections of branches of *Dadoxylons*, in which pairs of vascular bundles passed outwards through the woody zone. These specimens left me under the impression that these paired bundles proceeded to leaves, and not to branches. Fig. 60 represents part of a transverse section of a branch obtained by Mr. Spencer from the marine Ganister

bed near Halifax, from which bed, as is also the case at Oldham, I have obtained my principal specimens of these Gymnospermous stems. They have obviously been drifted fragments. The pith, *a*, consists as usual of large-celled parenchyma. The prosenchymatous woody tissues, *c*, *c*, *c*, are arranged in their normal manner. The pith is prolonged outwards at *b* and *b*; its coarse, parenchymatous cells rapidly developing into radially elongated prosenchymatous ones, as the two medullary outgrowths proceed outwards. In the early part of their course these outgrowths do not appear to be accompanied by any of the woody fibres, *c*, through which they pass; but more externally, as at *c'*, there are clear indications that many of these fibres are deflected outwards in the same direction as the pith-cells. This specimen leaves no doubt in my mind that these pairs of fibro-cellular bundles are sometimes destined to supply branches, which must have sprung from the stem in pairs. Since no such dual arrangement of either leaves or branches is seen in M. GRAND-'EURY's fine examples of *Cordaites*, which plants that author regards as identical with the *Dadoxylons*, this want of harmony between his specimens and mine strengthens my conviction already expressed elsewhere,* that our English *Dadoxylons* cannot, as yet, be identified with the French examples of *Cordaites*.

That pairs of vascular bundles given off from *small* twigs may have proceeded to leaves, as suggested in my eighth memoir (*loc. cit.*, p. 231), is possible, and does not militate against my explanation of the morphology of the specimen just described, since the primary orientation of its branches must have been from the axils of corresponding leaves.

In the memoir, Part VIII., I described the organization of the seed to which I gave the name of *Lagenostoma ovoides*. In the specimens of that seed which were obtained from the Oldham deposits, the outermost layer of the testa was converted into an almost structureless carbonised substance (*loc. cit.*, Plate 10, figs. 60, 62, and 71A). In figs. 65 and 66 of that memoir there is also observable a thin layer of tissue external to the layer, *e*, or what I have designated "the canopy," or folded tent-like prosenchymatous membrane which encloses the lagenostome, or pollen-chamber, whilst in fig. 69, *a'*, *a'*, I showed that the testa split into two layers, the inner one of which is I believe identical with those seen in figs. 65 and 66.

Mr. SPENCER has sent me a slightly oblique longitudinal section of one of these seeds from the Halifax bed, which throws additional light upon its structure. Fig. 61 represents this specimen enlarged 18 diameters, in which *a* is the outer layer of the testa, *b*, *b'* portions of the canopy, *c'* the wall of the lagenostome, and *g* the embryosac.

Fig. 62 represents a portion of the outer layer of the testa, 61, *a*, enlarged 200 diameters. It consists wholly of sclerenchymatous cells, of which the central cavities are nearly obliterated owing to the thickness of the ligneous deposits lining their cell-walls. A regular superficial layer of nearly cubical cells, *a''*, constitutes the external

* 'Nature,' June 21, 1877, p. 138.

surface of the testa, whilst the rest of its substance is made up of others, *a*, less regular in size and form. Within this portion of the seed the layer, fig. 61, *a'*, is seen on both sides of the seed, intervening between the sclerenchyma just described, and the prosenchymatous folds of the canopy, and which layer obviously corresponds with the similar one shown in figs. 65 and 66 of my memoir, Part VIII., and probably also with the layer *a'* of fig. 69 of the same memoir. Fig. 63 represents a portion of this tissue as seen in fig. 61. It consists of extremely delicate prosenchymatous, barred or spiral cells, such as are seen in so many living seeds. When writing my previous description of *Lagenostoma ovoides*, I was not aware of the extreme distinctness of this layer as a differentiated portion of the testa. I presume it may be regarded as the endotesta, though the exact identification of these subdivisions of the testa in recent and fossil Gymnospermic seeds is necessarily difficult and somewhat uncertain.

Fig. 64 is a vertical section through the shorter axis of *Cardiocarpon anomalum*. The memoir, Part VIII., fig. 119, showed the aspects of this seed when cut through in the plane of its maximum diameter. The present figure exhibits the appearance of the same seed when intersected in the plane vertical to that of the above figure. We find the exotesta at *a*—the delicate prosenchymatous endotesta at *b*; the prolonged micropylar canal at *d*; the Chalaza, with the prolonged funiculus at *i*, *i'*, and what in the previous memoir I have designated the perispermic membrane at *g*.

At a very early stage of my researches my attention was arrested by the circumstance that the fragments of wood and bark found in the calcareous modules, both of the Oldham and Halifax districts, were frequently drilled through by numerous circular canals. It soon became obvious to me that these passages had been produced by Zylophagous animals. Similar borings have been described by Dr. DAWSON in his Triassic *Dadoxylons* from Prince Edward Island,* and still later by M. CHARLES BRONGNIART from some of the French carboniferous strata.†

Fig. 65 represents a specimen of some prosenchymatous bark, which has been perforated by animals of diameters varying from about ·0066 to ·0011. The creatures have not merely pushed the prosenchymatous cells aside, but have eaten their way through them. I was long perplexed by the occurrence of many specimens like that represented in fig. 66. I found numerous groups of small, round, or oval spore-like bodies, like those seen at *a*, *b*. They usually occurred in clusters, those composing each cluster being generally of very uniform size. Under high powers they exhibited a somewhat granulated structure. At length the truth dawned upon me that these were the copros of vegetable feeders—probably the same as those that had drilled the round holes in fig. 66. I noticed that these objects were invariably lodged in cavities from which the tissues had been extracted. Thus in both, 66 *a* and *b*, the cellular parenchymas, *a'* and *b'*, have been eaten away, and the copros, *a* and *b*,

* 'Report on the Geological Structure and Mineral Resources of Prince Edward Island,' by J. W. DAWSON, LL.D., assisted by B. T. HARRINGTON, B.A., 1871, plate 3, fig. 27.

† 'Annales de la Société Entomologique de France.' Séance du 12 Avril, 1876.

have been deposited in the cavity left as the result of the manducatory efforts of the animals. Their variation in size is obviously also a result of corresponding variations in the Zylophagi, whilst their uniform granular structure is explained by their origin. These copros are exactly like those of the phytophagous larvæ of recent insects; but beyond this probable association of them with insect forms, I discover no grounds for arriving at a more definite identification.

In 1874, Count CASTRACANE announced to the Academia del Nuovi Lincei, at Rome, that after subjecting pulverised coal to a process of combustion and afterwards to the action of certain chemical reagents, he not only found the siliceous frustules of Diatoms in the residual ash, but that many of these Diatoms were of well-known living species. The coals thus operated upon were derived from near Liverpool, from Newcastle, and from the French coal-field of St. Étienne. This discovery, if real, possessed an obvious importance. Hence its verification or the reverse became very desirable. My colleague, Professor ROSCOE, kindly allowed Mr. SMITH, one of his able assistants, to subject numerous specimens of coal to Count CASTRACANE'S process. The coals thus experimented upon were the following Yorkshire and Lancashire ones :—

Bradford Better bed.
Worsley Binns.
„ Roof of Cannel.
„ Cannel.
„ „ Base of bed.
„ Fourfoot. Top of seam.
„ Black.
„ Dow.
„ „ Bottom of seam.
„ „ Top of seam.
„ Brassey.
„ „ Roof of coal.
„ Trencherbone. Top layer.
„ „ Middle coal.
„ White.
„ „ Roof of coal.
„ Yard.
Middleton (Yorkshire) Main.
„ „ Settle Black.
„ „ Adwal. Top of Cannel.
„ „ Main. Top of coal.
Australian coal. Three samples.

The result of these investigations was to obtain a series of preparations of coal-ash

of very diversified character, but in no one example did I discover the smallest fragment of a Diatom.

Mr. F. KITTON, of Norwich, informs me that he examined samples of Welsh, Durham, and Newcastle coals, as well as others from "Inland" collieries, and from Scotland. Like myself, he could find no trace of Diatoms. The Rev. E. O'MEARA,* of Hazlehatch, near Dublin, states that he examined specimens from the Whitehaven coal-field. He says in a letter: "The result was that in all cases not the slightest trace of Diatomaceous forms was found; and if any had been present I have no doubt they could not have escaped my observation." The same correspondent also informs me that the Rev. GEORGE DAVIDSON, of Logie Coldstone, Aberdeen, a gentleman highly competent to conduct such investigations, also examined a series of coals with the same negative results. Under these circumstances I can only conclude that Count CASTRACANE has been mistaken as to the source of his Diatoms.

Calcisphæra.

It only remains for me to examine a group of objects which may have no claim to be noticed in this series of memoirs, since it is quite possible that they may ultimately prove to be animal and not vegetable forms; but having already inquired into one supposed *Radiolarian* with the result of relegating it to the vegetable kingdom, it may not be undesirable to examine some other carboniferous organisms, for which a *Radiolarian* rank is also claimed.

Attention has already been directed to these objects by Professor JUDD. In the discussion that succeeded the reading of a memoir on siliceous sponges by Mr. SOLLAS, before the Geological Society of London, Professor JUDD is reported† to have "referred to the discovery of *Radiolarians* in carboniferous rocks near Chester, and stated that, on dissolving portions of the rock that show the *Radiolarian* structure, the latter entirely disappears, but at the same time the rock itself furnishes small crystals of quartz. This seemed to be confirmatory of Mr. SOLLAS's statements"—*i.e.*, that siliceous organisms imbedded in calcareous rocks might have their siliceous elements replaced by carbonate of lime.

I am indebted to Mr. SIDDALL, of Chester, for specimens of the limestone in question, which comes from Rhydymwyn, near Mold, in Flintshire. It is a very fine-grained limestone of a light brown colour, containing vast numbers of the minute objects referred to by Professor JUDD.

It is impossible to obtain these organisms free from their investing matrix, hence they can only be examined either in thin sections of the limestone as transparent objects, or on polished flat surfaces as opaque ones. The differences which they exhibit, according to the method of viewing them, throw some light upon their morphology.

* Now unhappily lost to science, May 6th, 1880.

† 'Quarterly Journal of the Geological Society of London,' May, 1877, p. 835.

The most indisputable feature which they present is that they are all hollow spheres, most of which are furnished with varying forms of peripheral appendages. The true sphere-wall is always *darker* than either the investing matrix or the contents of the spherical cavities when examined by transmitted, and *lighter* when seen by reflected, light. In these respects the conditions are identical with those presented by the shells of *Foraminifera* seen in the same matrix. The differences seen in various parts of each object are of material value in enabling us to distinguish between primitive organic elements and secondary infiltrated ones. The former appear to be always opaque, and to exhibit structural organic features. The latter are always translucent and crystalline. Differences are further observable according to whether a very thin section is taken out of the centre of a sphere, or whether a sphere is merely cut into two equal or unequal halves.

The discrimination of species, when we only know the objects through sections of them, is always difficult and sometimes impossible. At the same time it is often desirable that we should have provisional names whereby to recognise certain typical forms. Hence I venture to follow the plan adopted in the case of the *Foraminifera*, in which latter the purport of the names, generic as well as specific, is understood to have no reference to real genetic distinctions. I propose for the objects under consideration the generic name of *Calcisphæra*, as not involving any premature hypothesis respecting their nature.

Fig. 70 represents the inner portion of a hemisphere of *C. lævis*, viewed as an opaque object. I select this for our first consideration, because it exhibits these organisms in their simplest form. Its maximum diameter is about ·006, whilst the thickness of the sphere-wall is about ·00058. I can detect no trace of structure in the sphere-wall, neither has it any peripheral appendages. It is simply a smooth sphere—with a thick sphere-wall and an equally smooth internal spherical cavity—the latter portion being occupied by a crystalline calcic carbonate, which has obviously reached the cavity as a solution that filtered through the permeable sphere-wall.

Fig. 79, *Calcisphæra cancellata*.—This is rather a rare form. The drawing represents a thin equatorial section viewed by transmitted light. The central sphere cavity is filled with infiltrated crystalline calcic carbonate. The sphere-wall is now not only double, but the inner and outer layers enclose between them numerous small cubical compartments separated by radiating partitions. The compartments are filled, like the central sphere-cavity, with infiltrated translucent calcic carbonate. This object is of the same size as fig. 70.

Fig. 67, *Calcisphæra fimbriata*, is also of the same maximum size as fig. 70, though, like that object, we find it of very variable dimensions, the smallest specimen being not more than an eighth part of the diameter of the larger ones. The central sphere-cavity as seen by transmitted light is filled with crystalline infiltrated calcic carbonate. This is surrounded by a dark sphere-wall, which is obviously not homogeneous, but has rather the appearance of being composed of radiating fibres. I suspect that this

is a modification of the condition seen in fig. 79, only the radiating partitions are much more numerous, and consequently the compartments are very much smaller. But externally to this sphere-wall we now have a second investing layer, which is semi-translucent by transmitted light, and in which the existence of numerous opaque radiating lines is sufficiently obvious. I presume that this is a second sphere-wall, constructed like the inner one, but that, in it, the primary calcareous radiating partitions have been extremely thin, whilst the larger, long, narrow cavities which they enclose having been hollow, are again filled by calcic carbonate, hence the greater translucency of this outer sphere-layer as compared with the inner one.

Fig. 69, *Calcisphæra hexagonata*.—This form is not very uncommon, though more so than the variety last described. The central cavity is again filled with crystalline calcic carbonate, and the dark, double-inner sphere-wall is now more clearly defined than in fig. 67. The space between the two layers of which this sphere-wall consists, is again occupied by radiating opaque partitions separated by translucent lines. Its distinctive feature is seen in the outline of the outermost investing layer. So far as structure is concerned it differs in no respect from the same layer in fig. 67—save that it is somewhat thicker—but it has a perfectly hexagonal peripheral outline, the sides of the hexagon being almost geometrically equal in size; occasionally they exhibit a slight degree of convexity. The specimen figured is rather larger than fig. 67, having a diameter of about ·0066.

Fig. 68, *Calcisphæra Sol.*—This form exhibits a general resemblance to fig. 67, only both its opaque, inner sphere-wall, and its outer translucent layer are thinner in proportion to the entire diameter of the organism than in that species. Its distinctive feature, however, is found in the outermost sphere-wall, which is prolonged into numerous elongated pointed radii, arranged with a considerable degree of regularity both as regards size and position. These radii are somewhat translucent, like the investing layer of which they appear to be extensions. I think it would not be difficult, by persevering search, to find specimens linking this form to that of fig. 67.

Figs. 71 to 77 appear to represent a series of modifications of fig. 70, inasmuch as in them the sphere-wall appears to be single and homogeneous, but much thinner than in that example, and the surface is drawn out into a series of tubercules and spines of very variable number, length, and acuteness. In many, the section of the sphere is rounded, as in fig. 71. In others it is pentagonal as in figs. 72 and 73, whilst in 76 it becomes trigonal. But I find so many connecting links between these varieties that I propose to unite all this series under the name of *Calcisphæra spinosa*. So far as I can discover, the entire series differs from figs. 67, 68, and 69, in the simpler structure of the sphere-wall.

Fig. 78 is a representation of an example in which, as also in fig. 75, the section has only cut off a small tangential slice from one side of the sphere, the remainder of the hemisphere being seen through the somewhat translucent matrix in which it is embedded. It is larger than the other specimens figured, the diameter of its sphere-

cavity being ·01. Its superficial protuberances are not drawn out into acute spines, but are short, obtuse tubercles, which are irregularly distributed over the surface of the hemisphere. Fig. 75 exhibits a combination of these short tubercles with elongated spines in the same individual, hence this specimen may be regarded as a largely modified example of the group which I have designated *C. spinosa*.

The only additional example of the Welsh series to which I would call attention is that represented by fig. 80, but as seen under a one-sixth objective. It is enlarged 190 diameters. It may belong to the type of *S. spinosa*, but that is not certain. Its importance is found in the minute but obvious foramination of its sphere-wall, a condition that readily explains the surface structure of such examples as fig. 67.

Such are the objects which Professor JUDD believes to be Carboniferous *Radiolarians*—a conclusion which neither I nor my experienced friend HENRY BRADY, F.R.S., are able to accept. In support of this determination I would call attention to some specimens, myriads of which constitute almost the mass of a "Corniferous limestone" from the Devonian beds of Kelly's Island, U.S.A., for specimens of which I am indebted to Mr. BRADY, and which we both believe to be closely related to the Welsh organisms. These objects have also been spherical bodies, having a diameter of from ·05 to ·04. Like the Welsh specimens, they are more opaque than the mean of the surrounding matrix, when viewed by transmitted light, and more brightly white when examined by reflected light. The limestone consists almost entirely of perfect examples and fragments of these objects, the intervals between these being chiefly occupied by a translucent crystalline carbonate of lime. Each organism has been a hollow sphere. The sphere-wall has been much thicker in proportion to its entire diameter than is the case among the Welsh specimens. Externally, the transverse section of each sphere presents an undulating outline, due to the intersection of prominences and ridges that characterise its surface. Sometimes these projections surround the entire section; but more frequently, as is the case with fig. 81, they are absent from limited portions of the periphery. Occasionally these ridges may be seen pursuing an oblique direction like the bands crossing the nucules of a *Chara*. The central cavity is always occupied by crystalline infiltrated carbonate of lime. Though the sphere-wall often exhibits a granular texture, I discover a radiating structure in a sufficient number of the specimens to convince me that, in this respect, they have closely resembled some of the Welsh objects. Since I cannot learn that this American form has received a name, it may be designated *Calcisphæra robusta*. Whilst I am thoroughly satisfied that these objects are *not Radiolarians*, it is not easy to say what they are. Like the *Traquariæ*, they are altogether different from all known *Radiolarians*. The *C. robusta* constitutes the chief part of the material of the Corniferous limestone, which appears to have been as much indebted to them for its calcareous matter as the chalk is to the *Foraminifera*. Hence in this case any idea of a substitution of calcareous matter for silica is out of the question. They are, and obviously have always been, calcareous organisms, and the Welsh examples present many

features leading to the same conclusion. The structure of the latter forms is different from that of any existing *Radiolarians*. Instead of possessing the fenestrated skeleton which would allow the calcareous ooze, constituting the matrix, to penetrate freely into the interior of each sphere-cavity, all such intruded material has been absolutely excluded from those cavities. The interior of each is occupied, not by amorphous matter like the investing matrix, but by crystalline calcic carbonate, a solution of which had obviously filtered through the porous sphere-wall, and crystallized within the interior of a closed cavity. In this respect the conditions of the objects correspond exactly with those of the carboniferous *Foraminifera*, which I find associated with them; I am convinced that no known *Radiolarian* would exhibit similar conditions. Then their form is more like that of the *Foraminiferous Orbulina* than any *Radiolarian*. Occasionally chance sections like figs. 73 and 76 remind us of a Dictyoca; but other specimens, such as figs. 74 and 77, show that these apparently regular symmetrical forms and arrangements of the spines are not characteristic of the organisms. Even in fig. 76 the second unsymmetrical spine to the right hand of the figure is fatal to the idea of the object being a Dictyoca. It is obvious that these organisms were closed spheres with a sphere-wall so nearly solid as to exclude all inorganic matter save such crystalloids as were in a state of solution, and which, consequently, were capable of reaching the sphere-cavity by infiltration.

But a further difficulty stands in the way of our regarding these objects as *Radiolarians*. Unable generally to accept Mr. SOLLAS's hypothesis of the replacement of silica by calcareous matter, I am still less able to do so in the case of the objects under consideration. I have already said that such a hypothesis is wholly inapplicable to the *C. robusta* (fig. 81), and it appears to me equally so to the other forms. Mr. H. BRADY has arrived at the same conclusion. But anxious to obtain the opinion of some of our leading chemists on this point, I showed my specimens to Professors ROSCOE and SCHORLEMMER, and they both express their inability to understand how such a substitution could take place. I presume that on the subject of organic chemistry no higher authority than Professor SCHORLEMMER could be appealed to. After examining my specimens, he writes to me as follows: "I don't know what *morphological* evidence you may possess rendering it probable that the minute calcareous objects in limestone that you showed me were originally siliceous animals or organisms; but I should require such evidence to be overwhelmingly strong before I should accept such a conclusion. I know of no agency by which siliceous structures could be converted into calcareous ones, by mineralogical substitution, under the condition in which these organisms exist, embedded in a calcareous matrix. The fact that the silica was of animal origin does not appear to me to render the possibility of such a substitution more probable."* I have already shown that such morphological evidence as Professor SCHORLEMMER demands is non-existant—hence I am impelled towards the conclusion that these *Calcisphæræ* were calcareous, and not siliceous organisms, and consequently were not

* *In litera.* Jan. 22, 1879.

Radiolarians. Unfortunately, such a negative conclusion is more readily arrived at than a positive one, telling what these objects really were. They are wholly unlike any living organisms that we are acquainted with. Their spherical form suggests the possibility that they may have been the tests of some extinct form of *Protozoa.* The porous tissue seen in fig. 80 gives some support to the idea of their having been Foraminiferous—and the radiating structure seen in so many of the transverse sections is quite compatible with the same idea. On the other hand it is not impossible that they may have had some affinity with the recent Rhabdoliths and Coccoliths, though this does not seem very probable. The only other possibility that suggests itself is that they may be reproductive capsules of some marine form of vegetation, but no facts yet discovered afford any definite support to this hypothesis. Mr. BRADY informs me that in one instance he found indications of spore-like objects in the spherical cavity, but the whole of the thousands which I have examined were entirely devoid of such elements. This fact is suggestive of their having been filled with some material incapable of fossilisation—*e.g.*, of sarcodic protoplasm, pointing to a Protozoan nature.

I have once more to acknowledge the assistance I have received from Mr. SPENCER and Mr. BINNS, of Halifax, from Mr. EARNSHAW, of Oldham, and especially from Mr. WUNSCH, of Glasgow, to whom we owe the discovery of the magnificent carboniferous forest of Laggan Bay, and whose invaluable aid demands my warmest thanks. Mr. SIDDALL, of Chester, has laid me under obligation for the Welsh limestones, and I am indebted to Mr. HENRY BRADY for calling my attention to the corniferous limestone of Kelly's Island.

INDEX TO THE PLATES.

PLATE 14.

LYCOPODIACEOUS PLANTS.

Arran Lepidodendron.

Fig. 1. Transverse section of one of the youngest twigs. *a.* Central vascular bundle. *c.* Leaves. *c′.* Foliar vascular bundle. Enlarged 16 diameters.

Fig. 2. Central vascular bundle of fig. 1. *a′.* Small vessels at the periphery of the axis, from which the foliar vascular bundles (*b*) arise. Enlarged 37 diameters.

Fig. 3. Transverse section of a larger branch. *a.* Central vascular bundle expanded into a medullary cylinder. *b.* Foliar vascular bundles. *c.* Leaves. *d.* Cellular medulla. *e.* Delicate parenchyma of middle bark. *f.* Remnant of the bast-layer of the outer bark. Enlarged 3 diameters.

Fig. 4*. Portion of a vessel of the vascular cylinder. *a.* Transverse Lignine bars. *b.* Longitudinal threads of Lignine.

Fig. 4. Central vascular axis of fig. 3 enlarged 14 diameters. *a*. Vascular medullary cylinder. *a'*. Vessels going off radially to form the free foliar bundles, *c*. *d*. Cellular medulla.

Fig. 5. Transverse section of a still larger branch. *a*. Vascular medullary cylinder. *d*. Cellular medulla. *e*. Middle bark corresponding to *e* of fig. 3. *g*. Inner portion of prosenchymatous bark. *h*. Bast-layer of outer bark. *i*. Exogenous layer of vascular axis. Three-fourths the natural size.

Fig. 6. Transverse section of the vasculo-medullary axis of a stem of large size. *a*. Vascular medullary cylinder. *d*. Medulla. *i*. Enlarged exogenous vascular cylinder. Natural size.

Fig. 6A. Segment of a section like fig. 6 enlarged 3 diameters.

Fig. 7. One of the rhomboidal scars of a cast of the outer bark-surface of a large stem. Three-fourths the natural size.

PLATE 15.

Halifax Lycopodiaceæ.

Fig. 8. Small crushed *Lepidostrobus* from Halifax enlarged nearly 12 diameters. *a*. Vasculo-cellular axis. *b*. Clusters of macrospores. *c*. Upper part of the strobilus. *d*. Clusters of microspores in their sporangia.

Fig. 9. Sporangial cluster of four macrospores, showing that the "peduncular appendages" are but collapsed portions of the spores. Enlarged 34 diameters.

Fig. 10. Tangential section of a sporangiferous bract from Halifax, with its sporangium filled with microspores. *a*. Bract. *b*. Outer sporangium-wall. *c*. Inner membrane of the sporangium. Enlarged 45 diameters.

Fig. 11. Transverse section of the central axis of the strobilus figured in Plate 22, fig. 53, of memoir, Part IX. *a*. Medulla. *b*. Vascular cylinder. *c*. Innermost cortical parenchyma. *d*. Outer cortical parenchyma. *e*. Bracts. *f*. Sporangia. Enlarged 12 diameters.

Fig. 12. Central axis of fig. 11, enlarged 45 diameters. *a*. Medulla. *b*. Vascular cylinder. *c*. Radial breaks in the continuity of the cylinder. *d*. Innermost cortical layer. *d'*. Radial prolongations of *d*, apparently accompanying vascular bundles proceeding outwards to the bracts.

Fig. 12A. Transverse section of a pentamerous fruit (?) from Halifax.

Calamostachys Binneyana.

Fig. 13. Longitudinal section of a specimen of *Calamostachys Binneyana* from Halifax. *a*. Vascular axis. *b*. Cortical layer of the axis. *c*. Sterile bracts. *d*. Fertile bracts or sporangiophores. *d'*, *d''*. Empty passages

in the bark through which vessels passed to the bracts and sporangiophores. *e.* Sporangia. Enlarged 14 diameters.

Fig. 14. Transverse section through a sterile bractigerous disk of a *Calamostachys Binneyana*. *a.* Vascular axis. *b.* Cortical layer of the axis. *c.* Elongated cells passing horizontally outwards to the sterile bracts. *c'.* Parenchyma of the bractigerous disk. *e.* Sporangia. *f.* Transverse sections of the apices of the bracts of the next inferior sterile verticil. *g.* Tips of the next inferior sterile bracts. Enlarged 16 diameters.

Fig. 15. Transverse section of *Calamostachys Binneyana* made in the plane of a verticil of the fertile bracts, and with the entire cortical layer preserved. *a.* Central vascular axis. *b.* Innermost cells of the cortex. *b'.* Middle and outermost parenchyma of the same. *d.* Bases of sporangiophores. *d''.* Peltate extremity of a sporangiophore. *e.* Sporangia containing spores. Enlarged 22 diameters.

PLATE 16.

Fig. 16. Transverse section of the vascular axis of a strobilus of *Calamostachys Binneyana* (?). *a.* Vascular axis. *b, b.* Radially disposed additions to the central vascular bundle, disposed in three radiating groups. *c.* Middle cortical layer. Enlarged 46 diameters.

PLATE 15.

Fig. 17. A mother-cell with three daughter-cells (spores ?) from a sporangium of *Calamostachys Binneyana*. Enlarged 405 diameters.

PLATE 16.

Fig. 18. A sporangium of *Calamostachys Binneyana* filled with parenchyma. Enlarged 162 diameters.

Ferns.

Fig. 19. Transverse section of a stem or petiole of *Rachiopteris insignis*. *a.* Outer cortex. *b.* Middle cortex. *c.* Inner layer of cortical cells. Enlarged 15 diameters.

Fig. 20. The central portion of fig. 19, enlarged 62 diameters. *b.* Middle cortex. *c.* Inner cortex. *d.* Cellular bundle-sheath with a line of dark-coloured cells, *h.* *e, f.* Large and small peripheral vessels, the former filled with tylose cells. *g.* Cells enclosed within a loop of the vascular bundle. Enlarged 46 diameters.

Fig. 21. An oblique, semi-longitudinal section of the central part of fig. 20. (Reference letters as in that figure.)

Fig. 22. Similar section to fig. 20, but from a specimen containing no tylose. (Reference letters as in that figure.)

PLATE 17.

Fig. 23. A divergent vascular bundle passing off laterally through the middle cortical layer of a part of the section, fig. 21. Enlarged 62 diameters.

PLATE 16.

Fig. 23A. A transverse section of a petiole of *Rachiopteris robusta*. Enlarged 30 diameters.

PLATE 17.

Cryptogamic Reproductive Organs.

Fig. 24. Transverse section through a matured capsule of *Sporocarpon elegans* in its matured state. Enlarged 93 diameters. *a*. Hour-glass bases of unicellular hairs. *b*. Peripheral extensions of *a*. *c*. Bases of hairs intermediate between the states *a* and *c*. *d*. Spaces between the hour-glass cells, *a*, and occupied by an intermediate layer of cells.

Fig. 25. Tangential section of a crushed example like fig. 24, the cells being intersected radially at *a*, and transversely at *c* where their outer extremities are exposed. The interior is occupied by a cluster of large cells. Enlarged 93 diameters.

Fig. 26. A yet more tangential section of a *Sporocarpon elegans* displaying the symmetrically disposed, outer ends of the cells at its peripheral surface, and passing obliquely into the internal cavity of the organism at the interior of the section. Enlarged 93 diameters.

Fig. 27. Similar section to fig. 26, but yet more peripheral. Enlarged 93 diameters.

Fig. 28. Oblique section through a part of the cellular-wall of *Sporocarpon elegans*. *a*. Its inner surface formed of the expanded centripetal extremities of the hour-glass cells. *b*. The inner portions of the constricted parts of the same cells. *c*. The outer expanded portions of these cells. *d*. The free portions of the cells prolonged into hairs. *e*, *e'*. Delicate cell-walls of cells forming the central layer, and connecting the hour-glass constricted cells. Enlarged 320 diameters.

Fig. 29. A superficial tangential section of the object designated *Sporocarpon compactum* in the memoir, Part IX. Enlarged 93 diameters.

PLATE 18.

Fig. 30. Peripheral extremity of one of the outermost cells of fig. 29. Enlarged 170 diameters.

PLATE 17.

Fig. 31. Transverse section of a specimen apparently uniting *Sporocarpon elegans* with *S. compactum*, and filled with large cells. Enlarged 170 diameters.

PLATE 18.

Figs. 32, 33, and 34. Mother-cells, containing daughter-cells, from the interior of the specimen of *Sporocarpon* represented in fig. 69A of the memoir, Part IX. Enlarged 322 diameters.

PLATE 17.

Fig. 35. Transverse section of *Sporocarpon pachyderma*. *a*. Outer wall of branching and interlacing cells. *b*. Inner membrane. Enlarged 162 diameters.

Fig. 36. Transverse section of a second specimen of *S. pachyderma* with the inner membrane, *b*, enclosing small spore-like granules. Enlarged 162 diameters.

PLATE 18.

Fig. 37. A portion of a tangential section of the outer wall *a*, of a specimen like fig. 36. Enlarged 750 diameters. *a*. Transverse sections of tubular portions of the branching cells. *b*. Intercellular meshes enclosed within anastomosing branches of the cells.

PLATE 17.

Fig. 38. Transverse section of *Sporocarpon asteroides*. Enlarged 163 diameters.

PLATE 18.

Fig. 39. Transverse section of *Sporocarpon ornatum*. *a*. Inner layer of the conceptacle wall. *b*. Thick middle layer. *c*. Strongly marked cells occupying indented portions of the organism. *d*. Very large, loosely aggregated cells, occupying its prominent ridges. Enlarged 16 diameters.

Traquaria (CARRUTHERS).

PLATE 19.

Fig. 40. A young example, with the unbranched spines in a flexible state. Enlarged 160 diameters. *a*. Wall of the capsule. *b*. Hollow muricated spines. *e*. An ill-defined investing tissue.

PLATE 18.

Fig. 41. A slightly tangential transverse section of a *Traquaria*. *a*. Wall of the capsule. *b*. Tubular spines. *e*. Investing tissue. Enlarged 150 diameters.

Fig. 42. Transverse section of a young example, displaying a double inner membrane, *f*, *f'*, the latter occupied by numerous cells. Enlarged 150 diameters.

PLATE 19.

Fig. 43. Small portion of the capsule-wall of *Traquaria* seen near its inner surface. *a*. Sections of free portions of five tubular spines. *b*. Bases of tubular spines, close to the capsule-wall. Enlarged 200 diameters.

Fig. 44. Part of fig. 43. Enlarged 660 diameters. *a*. Small mucronate projections of the exterior of the tubular spines, giving off branching and interlacing tubular (?) threads, which spread through the investing substance, fig. 41, *e*. *a'*. Coalescing portions of several tubular branches.

PLATE 18.

Fig. 45. Transverse section of a specimen of *Traquaria* with more rigid tubular spines. *a*. Capsule-wall. *b*. Spines with openings at the points corresponding with the murications of figs. 40 and 41. *e*. Investing substance. *f*. An inner membrane containing numerous large cells, *g*. Enlarged 113 diameters.

Fig. 46. Transverse section of a crushed specimen. *a*. Shattered capsule-wall. *b*. Muricated spines. *b'*. Crushed and broken spines imbedded in the investing substance. *f*. An inner membrane splitting into two at *f'*. *f''*. A yet more internal membrane, with numerous flattened circular prominences. Enlarged 113 diameters.

Fig. 47. The tubular spine, *b*, of fig. 46. Enlarged 240 diameters. *a*. Bases of broken off tubular branching processes like those seen at *a'*, *a'*.

PLATE 19.

Fig. 48. Portion of the internal membrane, *f''*, of fig. 46. Enlarged 660 diameters. *f'*. Flat-topped areolæ, each surrounded by a circular depression, *f''*, and forming the summits of corresponding prominences, *f*.

Fig. 49. Part of a transverse section of a *Traquaria*, showing tubular spines branched at their summits, *b*, and expanded at their bases, *a*, *a'*, *a''*, *a'''*, into numerous branching tubules, in contact with the capsule-wall. *e*. Investing substance. Enlarged 322 diameters.

Fig. 50. Fragments of four tubular spines, exhibiting the murications of the preceding figures developed into branching tubes *b*, *b'*. Enlarged 340 diameters.

Zygosporites.

Fig. 51. *Zygosporites brevipes.* Enlarged 637 diameters.
Fig. 52. Single ray of *Zygosporites brevipes.* Enlarged 2258 diameters.
Fig. 53. *Zygosporites brevipes.* Enlarged 850 diameters.
Fig. 54. *Zygosporites longipes.* Enlarged 450 diameters.
Fig. 55. *Zygosporites brevipes,* containing cells in its interior.
Fig. 56. *Zygosporites brevipes,* exhibiting an inner membrane.

PLATE 20.

Fig. 57. A tangential section of *Sporocarpon elegans.* *a.* Cells seen at the surface of the sphere. *b.* Peripheral prolongation of the cells into hairs. *d.* Constricted portions of the hour-glass cells. *e.* Similar constricted portions, as seen under a lens of high penetrating power, and showing the radiating walls of the middle layer of cells (fig. 28, *e*), filling up the intervals between the constricted portions of the hour-glass cells.
Fig. 58. Transverse section of *Zygosporites* (*?*) *oblongus.* Enlarged 1260 diameters.
Fig. 59. Tangential section of the same.

Miscellaneous objects.

Fig. 60. Part of a transverse section of a branch of a *Dadoxylon,* exhibiting a pair of cellular prolongations of the pith, apparently destined to form the medullæ of two branches. Enlarged 10 diameters.

PLATE 19.

Fig. 61. Slightly oblique longitudinal section of a *Lagenostoma ovoides.* *a.* Testa. *a′.* Inner layer of testa. *b.* Canopy. *c.* Lagenostome. *g.* Embryosac. Enlarged 18 diameters.
Fig. 62. Portion of the testa, *a,* of fig. 61, composed of sclerenchymatous cells. Enlarged 200 diameters.
Fig. 63. Portion of the inner layer (fig. 61, *a′*), of the testa, composed of spiral prosenchymatous cells. Enlarged 249 diameters.

PLATE 20.

Fig 64. Longitudinal section through the shorter diameter of *Cardiocarpon anomalum.* *a.* Exotesta. *b.* Endotesta. *d.* Prolonged micropile. *i.* Chalaza. *i′.* Funiculus (?)
Fig. 65. Fragment of bark perforated by zylophagous animals of various sizes.
Fig. 66. Copros (*a, b′*) of zylophagous animals, left in their borings.

Calcisphæræ. The supposed Radiolarians of the Welsh Carboniferous Limestones.

Fig. 67. *Calcisphæra fimbriata*, seen as a transparent object by transmitted light.
Fig. 68. *Calcisphæra Sol*, seen as a transparent object by transmitted light.
Fig. 69. *Calcisphæra hexagonata*, seen as a transparent object by transmitted light.
Fig. 70. *Calcisphæra lævis*, seen as a transparent object by reflected light.
Figs. 71–78. Various modifications of *C. spinosa*, seen as opaque objects by reflected light.
Fig. 79. *Calcisphæra cancellata*, seen as an opaque object by reflected light.
Fig. 80. *Calcisphæra spinosa* (*?*) seen as an opaque object by reflected light.
Fig. 81. *Calcisphæra robusta*, from the corniferous limestone of Kelly's Island, U.S.A.

All the above objects are enlarged 112 diameters, except fig. 80, which is enlarged 180, and fig. 81 is magnified 33 diameters.

Supplementary Observations.

(Added August 12, 1879.)

I have obtained some important additional information respecting some of the organisms described in the preceding memoir since its communication to the Society, especially in reference to the supposed *Radiolarians*, hitherto known as *Traquariæ*.

I am indebted to Mr. Cash, of Halifax, for some valuable specimens from his cabinet, originally prepared by Mr. Binns. The most important are a series of sections of a crushed *Lepidostrobus* in all of which *Traquariæ* occur, under such conditions as leave no doubt that they are the macrospores of a Lycopodiaceous plant. The structure of a transverse section of the axis of this fruit is represented in fig. 82, enlarged 16 diameters. Its vascular centre, *a*, is a nearly solid cylinder of vessels, in the middle of which are what appear to be a very small number of cells representing the medulla. The entire cylinder has a diameter of ·05. The vessels are uniform in size, except at the extreme periphery where they are very small, as is usual with the Lepidodendroid cones. Surrounding this vascular axis we have numerous small *cellular* cylinders, *b*, each one of which contained a foliar vascular bundle supplying the bracts or sporangiophores of the cone; the vessels composing these bundles have disappeared. The similar disappearance of the inner and middle cortical layers of the axis of the cone has left these foliar cylinders isolated. Both this isolation of the individual cylinders, the mode in which they are clustered round the vascular axis, and the disappearance of the vessels of each foliar bundle are features identical with what we see in nearly all

our sections of *Lepidostrobi*. The detached masses of prosenchyma, *c*, *c*, are portions of the outermost cortical layer of the axis of the strobilus, which are being prolonged radially into the usual Lepidostroboid sporangiferous bracts. Extensions of these bracts radiate, in a more or less fragmentary form, to the circumference of the specimen, which even in its imperfect state indicates a cone having a diameter of fully an inch. Interspersed amongst these bracts or sporangiophores are the usual sporangia, the wall of each of which displays the structure so common amongst these carboniferous Cryptogams, viz.:—a single series of cells elongated vertically to the surface of the sporangium, and having their two extremities flattened, so that the two surfaces of the sporangium wall exhibit the ordinary aspect of tubular thick-walled parenchyma (fig. 83), whilst vertical sections present the aspect seen in fig. 84 or that of cylindrical parenchyma.

One of these sporangia is shown in fig. 85, *a*, enlarged 16 diameters, and contains three of the Traquarian macrospores. At *a'* are fragments of two other contiguous sporangia. Throughout the greater part of its extent the sporangium wall, *a*, exhibits the appearance of fig. 84, but here and there its flexures have caused it to be intersected obliquely, as at *a''*, where it resembles fig. 83. Two of the macrospores are intersected nearly through their centres, the third one more tangentially, hence its apparent smaller size. The specimen from which this and other similar sections were prepared not only places the vegetable nature of these *Traquariæ* beyond the possibility of doubt, as well as demonstrates the fact that they are Lycopodiaceous in character, but from the excellent preservation of the macrospores, throws further light upon their structure.

That the specimens with tuberculated but unbranched spines (represented by figs. 40, 41, and 42, of the earlier portion of this memoir) are immature, whilst those represented by figs. 45 and 46 are more matured examples, is now clear. I think there is no doubt but that in the young state there was a distinct outer exosporium and an inner endosporium. At an early period the exosporium became differentiated into two layers. Of these, the inner one (represented by *f* in fig. 42) retained its structureless, spherical form, being undistinguishable from the endosporium, fig. 42 *f'*, in all points save in its more external position. The outer layer of this exosporium, fig. 42, *a*, on the other hand, underwent a development into a system of ramifying tubes, the complexness of which exceeds what I had observed to be sufficiently remarkable when the earlier part of this memoir was written. There is now no doubt that the minute projections, *a*, from the radiating spines of fig. 44 with the delicate branching threads which spring from those projections, are the early conditions of the branching tubes seen in fig. 50. The almost invisible threads expand into a series of tubular dichotomous branches.

Fig. 86 represents a portion of a tangential section of one of the macrospores from Mr. Cash's strobilus. At *a* we find what I assume to be the inner structureless layer of the differentiated exosporium, now very distinctly separated from its outer tubulated one; *b*, *d* represent the transversely intersected bases of 11 of the branching tubes, *a*, *b*, of the figs. 40–49 of the memoir. We now see that in addition to

the *shorter* radiating branches given off from the entire length of the tube, there is a special *basal* series, fig. 86, *c*, much longer and less freely supplied with secondary ramifications than is the case with the upper ones. These basal branches appear to be similar to the upper ones in their general features and origin, those radiating from each central tube forming a system independent of the corresponding ones given off by its neighbours. They interlace most freely, enclosing the endosporium in a perfect network of superficial ramifications, but I have not been able to detect a single example in which they anastomose with those of the surrounding similar systems of tubes.

We obtain further light on this subject from fig. 87, which represents a portion of a macrospore from the same strobilus, but which has been intersected vertically. The drawing exhibits the bases of three of the tubular spines, *b*, *b'*, and *b'''*, the two former being the principal ones in focus. The spines have been cut through longitudinally and tangentially, so that we look into their interior, which is very large in comparison with the thickness of the enclosing tube-wall. The spine, *b'''*, lies deeper in the section, which has only sliced off a little of its base. At *c* we have one of the large basal branches of *b*. We now see that it gives off short, thick, lateral branches, *d*, in every direction, downwards as well as upwards. These branches subdivide by repeated dichotomisations, each of the secondary and subsequent branches being very short. Hence each of these secondary branch-systems constitutes a dense tuft of hollow tubes, whose repeated and peculiar ramifications remind us of the characteristic branching of a tuft of the well-known sea-weed, *Chondrus crispus*, only in the case before us the ultimate subdivisions are so fine that we fail to trace their individual outlines where they interlace with those of the neighbouring tufts. This condition probably explains the nature of the network shown in fig. 43, and referred to on page 513 of the memoir. The lateral branches, *e*, given off from each spine become rapidly shorter as we ascend, but in all those above the basal series, *c*, we find the ternary clusters of branches to be more numerous and more closely crowded together than in these basal ones; in other respects they present no differences. There is in them the same succession of curvilinear dichotomisations as before. The consequence is that the primary spines and their secondary branches are closely invested by a dense interlacing network of these ramifications. In the earlier part of the memoir I suggested the probability that these tubes had been invested by a plastic substance, in which the ultimate ramifications of the tubes distributed themselves. I am now satisfied that whatever may have been the case with the immature macrospores the matured ones were not so invested. What gave that appearance was merely the imperfectly preservation of the minute extremities of these ramifying tubules. We have at *c''*, in fig. 5, the intersected portions of other branches corresponding to *c*, but emanating from other spines.

Whilst these portions of the organism are now interpreted without difficulty, other features of the structure become less easy of explanation. Proceeding upon the

supposition that each of these *Traquariæ* was a spore, and as such, primarily a single cell, it was easy to regard the branching tubes as outward extensions of the spherical exosporium, originally the outer cell-wall of the organism. The development of the remarkable ramifications of the sporocarp of the Fungoid *Phycomyces nitens*, described by Professor BORNET,* appeared to furnish an illustration of the mode in which these radiating and branching extensions had been formed, but in the latter example the central stem of each branch-system opens at its base by a wide communication with the central cell cavity of which its tubules are but extensions. When describing fig. 43 (p. 513) I pointed out that the specimen there delineated appeared to favour a similar explanation, but those now described seem to tell a different story. It will be seen that the bases of each of the three principal stems, *b*, *b'*, and *b'''*, are *closed* and not *open*. I have examined every available specimen of *Traquaria* in reference to this point with the utmost care, but they all seem to lead to the same conclusion, viz.: that in their matured state each of these branching spines is closed at its base and thus assumes the form of a separate, unicellular, branching trichome; that they are really trichomes is, however, too improbable to be accepted as true. Hence the only conclusion at which I can arrive at present is that they were primarily mere extensions of the exosporium, but that when this exospore became differentiated into two layers and the outer one developed its remarkable system of branching tubes, the latter organs became separated from one another and each had its basal aperture closed in by the contraction of that part of its exosporial wall; the inner layer of the differentiated exosporium meanwhile retaining its primary simplicity as a thin spherical cell-wall.

Another feature of interest in these objects is the condition of the cells contained in the interior of several of the macrospores. The modification of the endosporal cells seen in some of the recent *Selaginellæ*, especially the large cells which PFEFFER not only compares with the endospermic cells of *Angiosperms*, but even designates by the same name, invest the study of these ancient forms with importance. I have now met with nine examples of these Traquarian macrospores containing cells. Some of these are already represented in figs. 42 and 45.

I find several modifications in the cellular contents of these spores, which are probably significant. In one to which I will refer as A (fig. 45), the endospermic cavity is filled with comparatively large, thin-walled cells, which compress each other so closely as almost to constitute a loosish parenchyma, their individual diameters being about ·0036; none of these cells display any definite organised contents. In specimen B, for which I am indebted to Mr. SPENCER, of Halifax, the endosperm consists of similar cells, though of smaller size, having a diameter of from ·0011 to ·0015. Most of these are like those of specimen A, though less closely packed, and about six of them contain each a single small, round, dark-coloured cell, having a diameter of about ·00036. A third specimen, C, which I obtained from Mr. BINNS, of Halifax, is filled with similar thin-walled transparent cells (diameter ·0014, ·0015), but now *every* cell contains one

* 'Annales des Sciences Naturelles,' 5e série, tom. 17, pl. 20, figs. 7–13.

of the smaller, dark-coloured cells, the diameters of these latter varying from about ·0011 to ·0009. In specimen D in the same slide as B, I find many of the thin-walled cells (diameter ·0013 to ·0015). Some of these are empty, and have lost some of the turgid, rotund form that usually characterises them. Others are more rounded, and each one contains, in its interior, one of the smaller, dark-coloured cells (diameter ·0009 to ·0007). Intermingled with these larger cells are many *free* examples of the smaller ones, which I expect have been liberated from the interiors of the empty larger ones. Specimen E only contains a few of the large, thin-walled cells (diameter ·0015, ·0014). Some of these are empty, two of them contain each a cell, with a diameter of about ·0009, and in one other was a single example of the smaller cells (·00015). Along with these is a very large number of the smaller cells in a free state. This specimen is in the cabinet of Mr. CASH. Specimen F is that of which portions are represented in fig. 87, and some of the endosporal cells of which are represented in fig. 88, enlarged 320 diameters. At *a* is a portion of the enclosing endosporal membrane. At *b* are some of the large thin-walled cells (diameter ·0013, ·0014). Each of these contains an inner cell, having a diameter of from ·0009 to ·0008, whilst each of these inner cells again contains, usually adhering to one side of it, a somewhat irregular dark mass of rather variable size. Of these larger cells my section of the spore contains about a score. But along with them we have 300 or 400 of the smaller, dark-coloured cells, *c*, of somewhat smaller size than those already described, their diameter ranging from ·00058 to ·0004. These are aggregated into a loose irregular central group, detached from the endosporal membrane, and condensed at its innermost portion into an opaque, somewhat defined mass. The true nature of the apparent central membrane *f''* of fig. 46, is now clear enough. It consists of an aggregated layer of these small cells, of which the mean diameter is about ·00055. Why they should have assumed so much the aspect of a continuous membrane as they have done is not so clear.

From the above description I think we may conclude that the large turgid cells, *b*, belong to the earlier stage in the development of this macrospore, and that the smaller and far more numerous ones, *c*, belong to a later stage. The degree of advancement in the development of these endosporal structures does not appear to correspond exactly with that of the respective exosporal tissues; still there is sufficient of an approximation to such a correspondence to sustain my general conclusion that the specimens A, B, C, and D are all immature spores, whilst E, F, and the crushed specimen fig. 46, are highly matured ones. At the same time, A is undoubtedly a more advanced growth, so far as the exosporium is concerned, than B, C, and D; but much less so than any of the remaining three, in which the small dark-coloured cells are so abundant. The question now arises, What are these dark objects? That they are cells is certain. In many of them the true cell-wall is sufficiently obvious, though in most it fits so closely upon its cell contents, as to be almost invisible. I have now no doubt that in fig. 46 the outer cell-walls are in contact, and that the transparent ring surrounding each central circular body represents the space between that cell-wall and its contents.

In the sections of the strobilus many of the sporangia contain a quantity of disorganised fragments, which appear to me to be the remains of microspores. Of course this Traquarian macrospore now merges its specific individuality in the strobilus of which it forms so characteristic a feature. But as it is desirable that the well-known name should be retained in connexion with it, I propose for the entire cone the name of *Lepidostrobus Traquaria.*

In the previous part of the memoir (p. 510, fig. 38) I described, under the name of *Sporocarpon asteroides*, a structure which appeared to me to be a spherical reproductive organ, and not a mere section of some cylindrical body. Mr. SPENCER, of Halifax, has obtained several additional examples of this organism, which demonstrate the correctness of my previous conclusion. They vary much in the size, shape, and number of their radial appendages, but in the peculiar features of their regular parenchymatous tissue, and in the perfectly spherical form of their central cavity, they agree with the example already figured. The one now represented (fig. 89) displays a second membrane (*a*) within the clearly-defined spherical cavity; this membrane encloses an opaque, spherical mass (*b*). Similar conditions are seen in several of the other *Sporocarpons* which I have already described.

I am indebted to Mr. GEORGE WILD, of the Bardsley Collieries, Ashton-under-Lyne, for the fine specimen of a new Zygopteroid form of fern-stem or petiole, of which a transverse section is given in fig. 90, enlarged nearly 6 diameters. Mr. WILD found the specimen in a shale heap, containing the usual marine Ganister fossils (*Goniatites, Aviculopectens*, &c.), and which had come from the roof of the "Bullion" coal near Burnley. The maximum diameter of the slightly ovoid section is three quarters of an inch, but we certainly have not the entire bark, which has lost some of its external portions, though how much I cannot ascertain. Its present outermost layer of large cells corresponds pretty closely with that seen in *Rachiopteris bibractiensis*, immediately below the prosenchymatous layer which constitutes its peripheral portion; as a corresponding prosenchyma forms the periphery of the allied *R. Lacattii*, and, though in a less degree, of the *R. elegans*, described in this memoir, it is most probable that a similar layer invested the coarse outer parenchyma of the plant under consideration.

The vascular axis, *a*, approaches nearer, in its general contour, to that of *R. bibractiensis*, than to that of *R. Lacattii*, especially in the trim neatness of its vessels, and in the perfect parallelism of the two sides of the central bar, *a*, which in *R. Lacattii* are oppositely convex. But the two transverse bars, *a'*, *a'*, differ from the similar ones in *R. bibractiensis*, in the absence of the very distinct peripheral bands of vessels somewhat imperfectly shown at *a''*, in fig. 49 of my sixth memoir. In the plant now described, the outer margin of each of the transverse bars, *a'*, *a'*, is occupied, as in *R. Lacattii*, by a series of vessels much smaller than those constituting the rest of the axis, and from which the foliar (?) bundles have arisen. Surrounding this vascular axis is a thin layer of parenchymatous cells, *b*, which I expect has originally formed

the symmetrical boundary or endoderm, enclosing a sheath of endophlœum that has invested the axis, but which has disappeared. At *c*, *c*, we have a pair of vascular bundles passing upwards and outwards, also enclosed in a supposed phlöem boundary, and at *d*, *d*, is a second similar pair which have entered the coarse parenchyma of the outer bark, but which are immediately surrounded by a parenchymatous zone, *e*, of a much more delicate texture. At *f*, on the opposite side of the section, we have a single bundle passing outwards, which from its symmetrical form and central position seems to correspond with the united bundles of each of the two opposite pairs. Here again the bundle, *f*, is surrounded by thin-walled parenchyma.

The greater portion of the tissues of the middle and inner bark have disappeared. Here and there we obtain faint glimpses of them, indicating that they consisted, as is usually the case in these ferns, of delicate, thin-walled parenchyma.

On turning to vertical sections of this plant, we find that they agree with similar ones of the other species of the Zygopteroid group of fern petioles. Fig. 91 exhibits a vertical section through the central part, *a*, of the vascular axis, enlarged 56 diameters. Its vessels, *a*, are now seen to be of the most perfect scalariform type that I have hitherto met with amongst these carboniferous ferns. Immediately external to this vascular axis is a thin investment of three or four layers of very long and narrow, thin-walled, square-ended cells, *b*, *b*, the extreme delicacy of which makes them almost invisible save under high magnifying powers. Vertical sections through the transverse bars, *a'*, of the vascular axis, show that whilst the greater number of its vessels are of the same type as those of the single central bar, *d*, the outermost ones, some of which become detached to form the foliar (?) bundles, *c*, *d*, and *f*, approach more closely to spiral vessels. The foliar bundles themselves consist wholly of vessels of the spiral type, enclosed in a distinct investment of delicate, oblong, square-ended cells. The outer bark, *h*, is seen to consist in the vertical section, of vertically disposed rows of cubical parenchymatous cells of large size and coarse texture.

The orientation of the supposed foliar bundles in symmetrical pairs is a curious feature in several of these Zygopteroid forms. I have already described its occurrence in *Rachiopteris duplex* and *R. Lacattii*. The peculiar form which the transverse section of the vascular bundle of the specimen now described exhibits, so closely resembles that of two severally inverted Greek capital letters, that the stem may be provisionally recognised as *Rachiopteris di-upsilon*.

Index to Figures.

PLATE 21.

Fig. 82. Transverse section of the central axis of a *Lepidostrobus* from Halifax. Enlarged 16 diameters. *a*. Central vascular cylinder. *b*. Cellular investments of the vascular bundles going to the bracts. *c*, *c*. Portions

of the prosenchymatous tissues of the bracts or sporangiophores of the cone.

Fig. 83. Superficial aspect of the cells of the sporangium-wall.

Fig. 84. Vertical section of a portion of a sporangium-wall.

Fig. 85. A sporange, *a*, *a''*, containing three *Traquariæ*, two of which are intersected equatorially, and the smaller one tangentially. Enlarged 16 diameters. *a'*. Fragments of two other sporangia.

Fig. 86. Portion of a tangential section of one of the Traquarian macrospores of the strobilus. Enlarged 225 diameters. *a*. Inner structureless layer of the exosporium. *b*, *d*. Transversely intersected bases of 11 of the radiating tubular spines. *c*. Long radiating tubes given off from the base of each spine.

Fig. 87. Portion of a transverse section of the outer or tubular layer of the exosporium of a macrospore. Enlarged 640 diameters. *b*, *b'*, *b'''*. The basal portions of three radiating tubular spines, with their lateral branches. *c*. Large basal tubular branch of the spine, *b*, corresponding to *c*, *c*, of fig. 86. *c'*. A similar tube of the spine, *b'*, *b''*. *d*. Secondary tufts composed of dichotomously branching tubes. *e*, *e*. Secondary tubular branches of the upper portions of the primary spines.

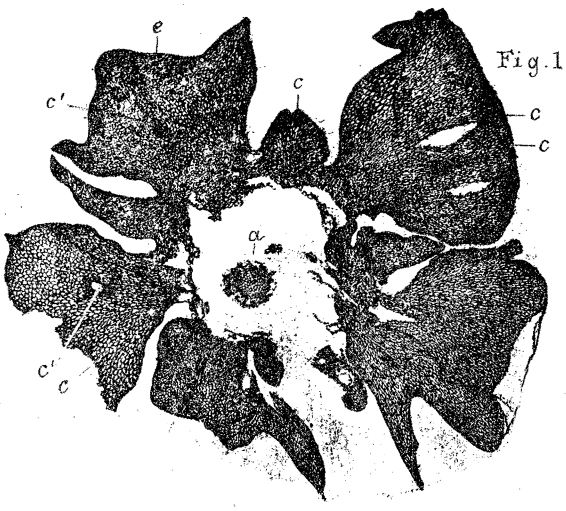
Fig. 88. Portion of the contents of the endosporium of fig. 87. Enlarged 320 diameters. *a*. Portion of the endosporial membrane. *b*. Large thin-walled cells. *c*. Smaller dark-coloured cells.

Fig. 89. Transverse section of a specimen of *Sporocarpon asteroides*. Enlarged 18 diameters. *a*. Inner free membranous capsule. *b*. Condensed central substance.

Fig. 90. Transverse section of a petiole of *Rachiopteris di-upsilon*. Enlarged nearly 6 diameters. *a*, *a'*. Vascular axis. *b*. Thin layer of small parenchymatous cells. *c*, *c*. A pair of vascular foliar (?) bundles. *d*, *d*. A second, yet more external pair of similar bundles. *f*. An undivided symmetrical bundle, apparently similar to *c* and *d*. *h*. Coarse, large-celled parenchyma in vertical columns.

Fig. 91. Vertical section across the middle of the central vascular bundle, *a*, of fig. 90. Enlarged 55 diameters. *a*. Scalariform vessels. *b*, *b*. Thin investment of narrow, oblong cells.

Fig. 1.



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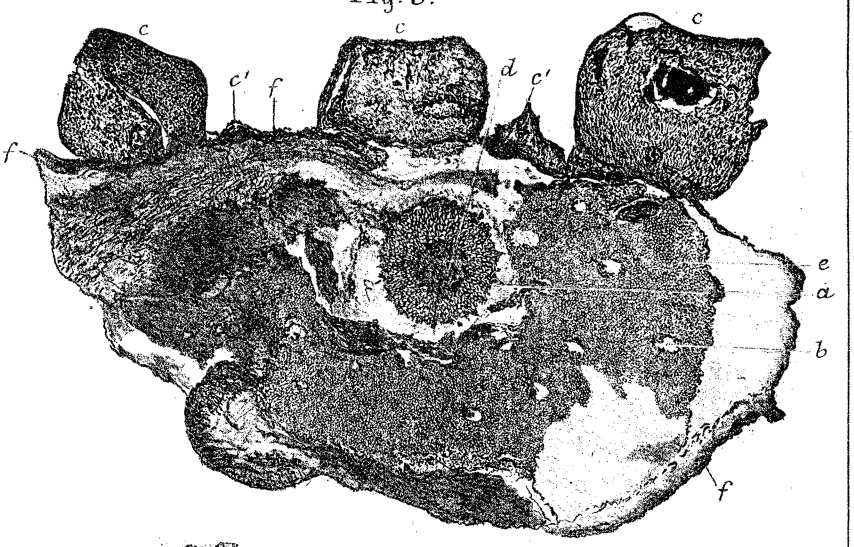
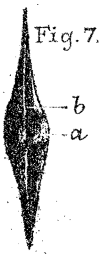


Fig. 7.



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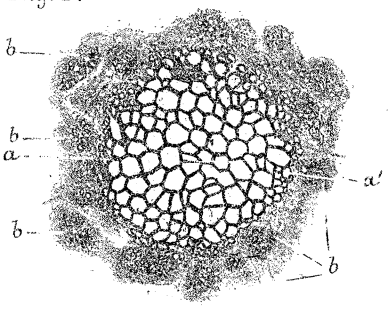

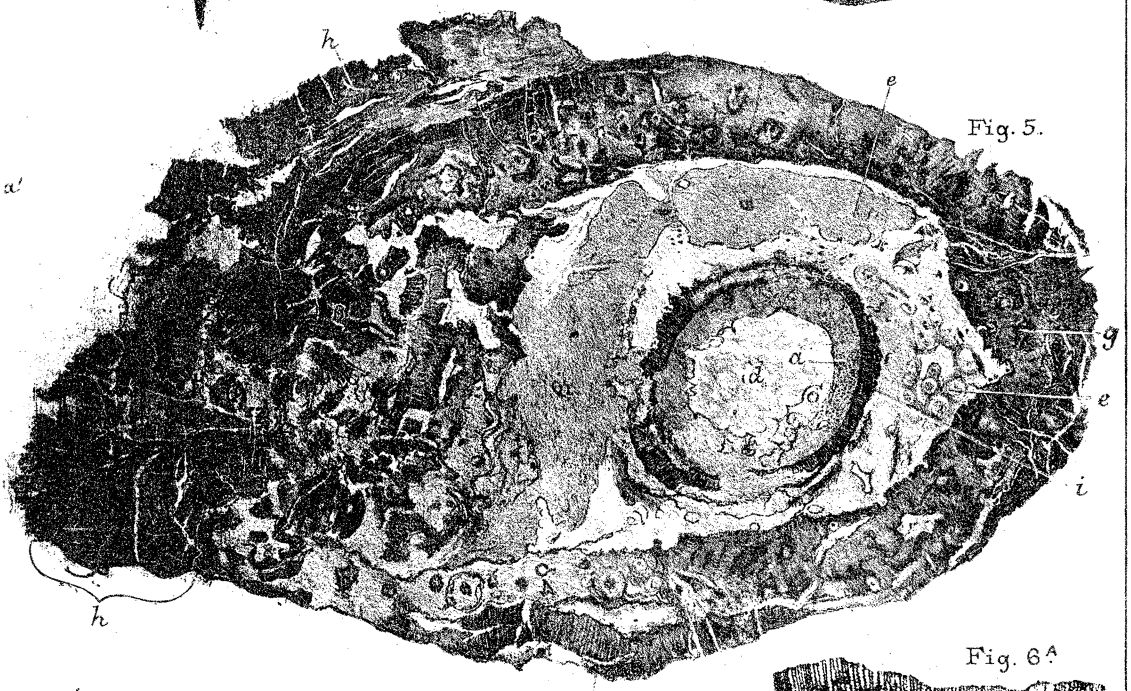

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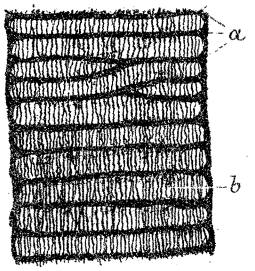
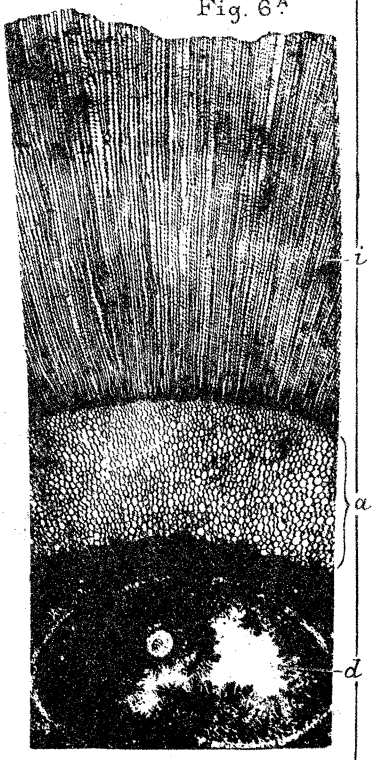
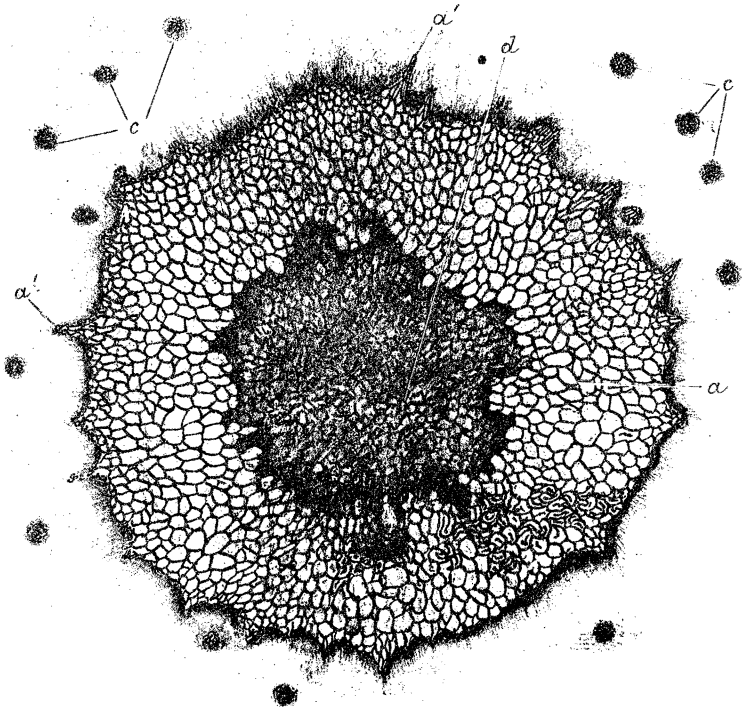


Fig. 4.*

Fig. 6.^





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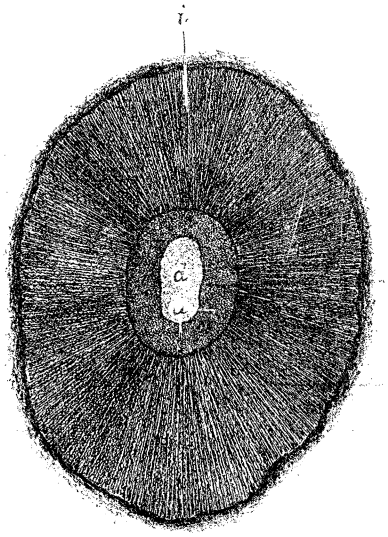
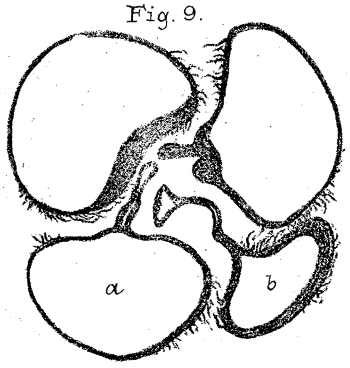


Fig. 6.

Fig. 9.



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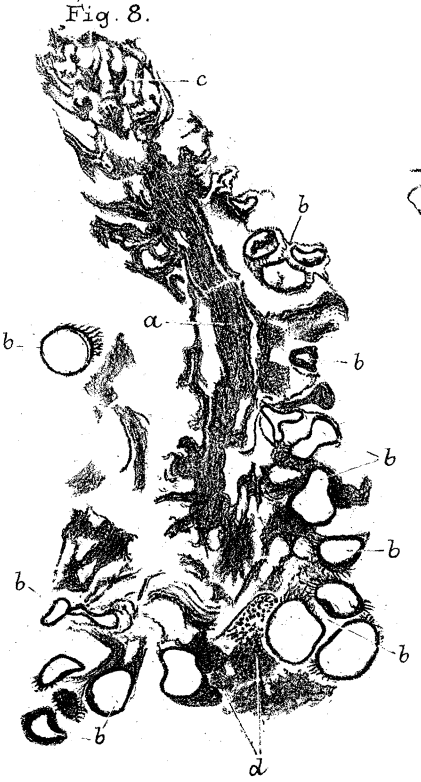

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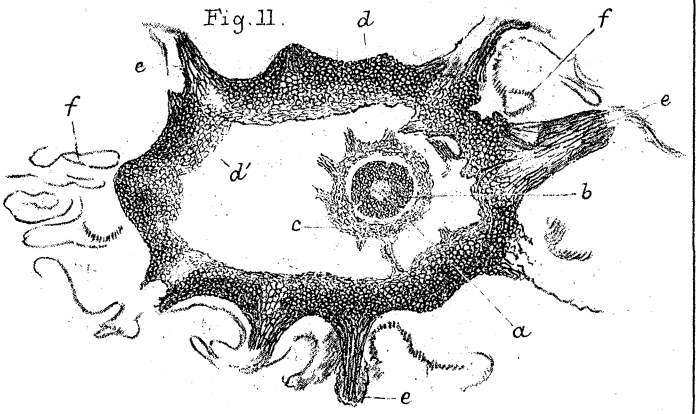

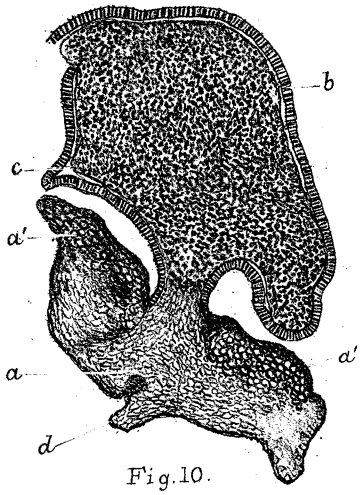

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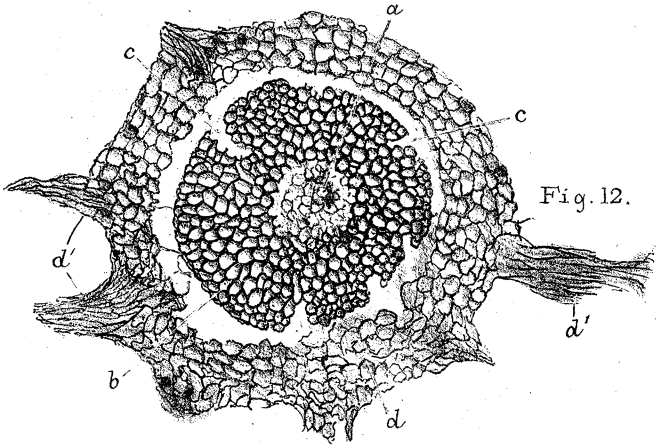
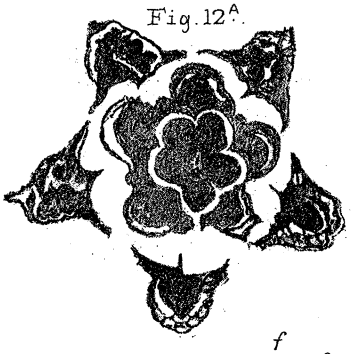


Fig. 12.

Fig. 12A.



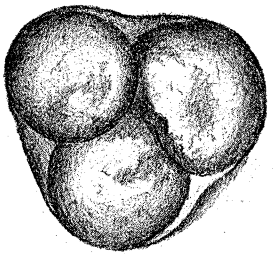
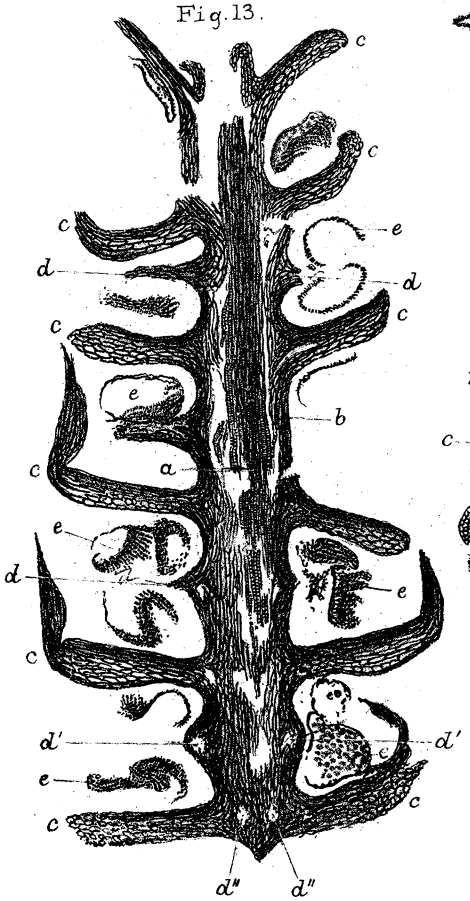
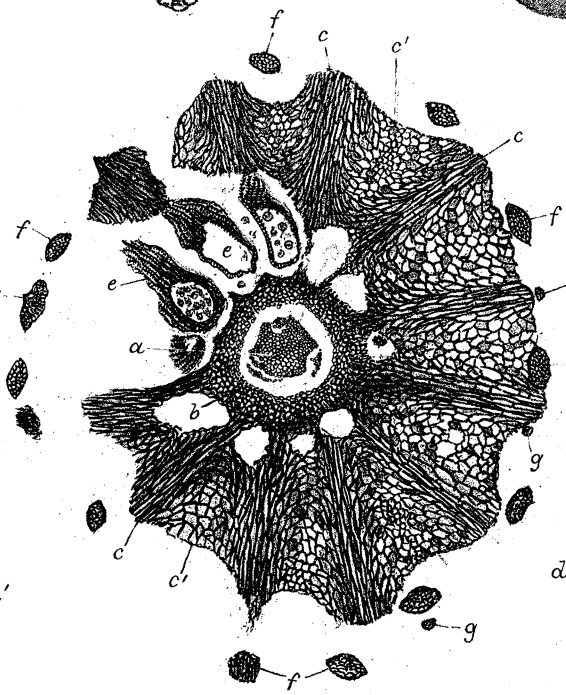


Fig. 17.

Fig. 13.





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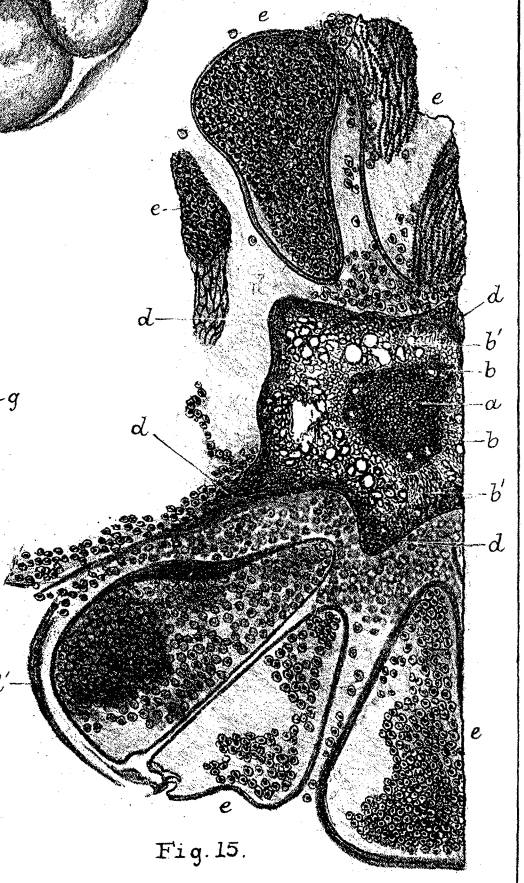
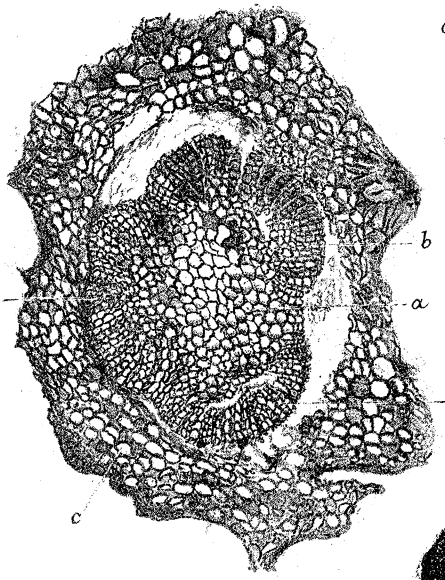


Fig. 15.

Whiteman & Bass, *Photo-Litho* London.

Fig. 16.



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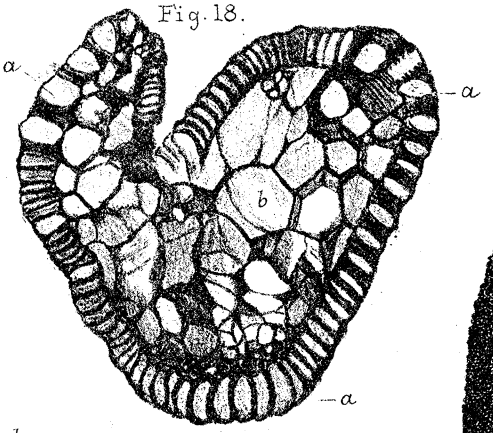

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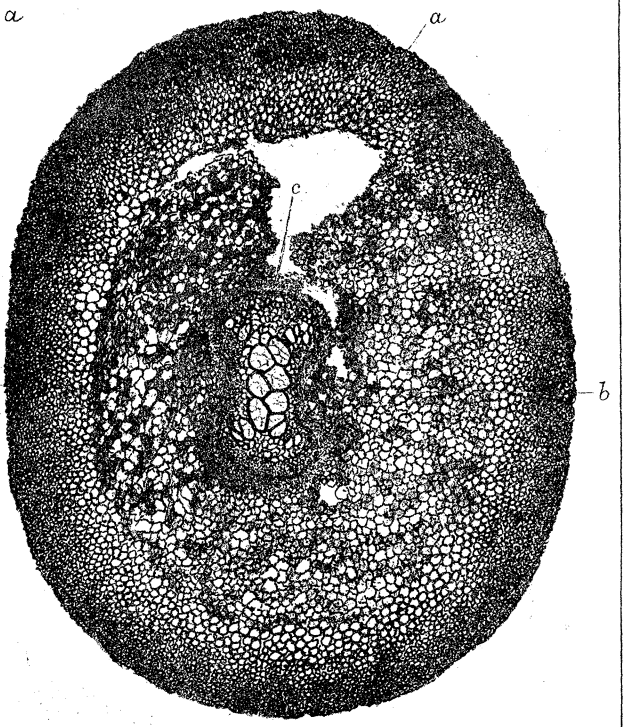

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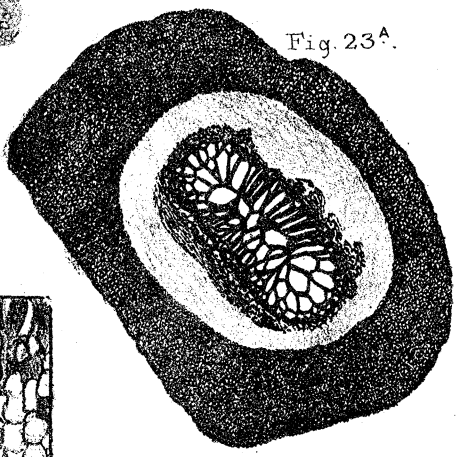


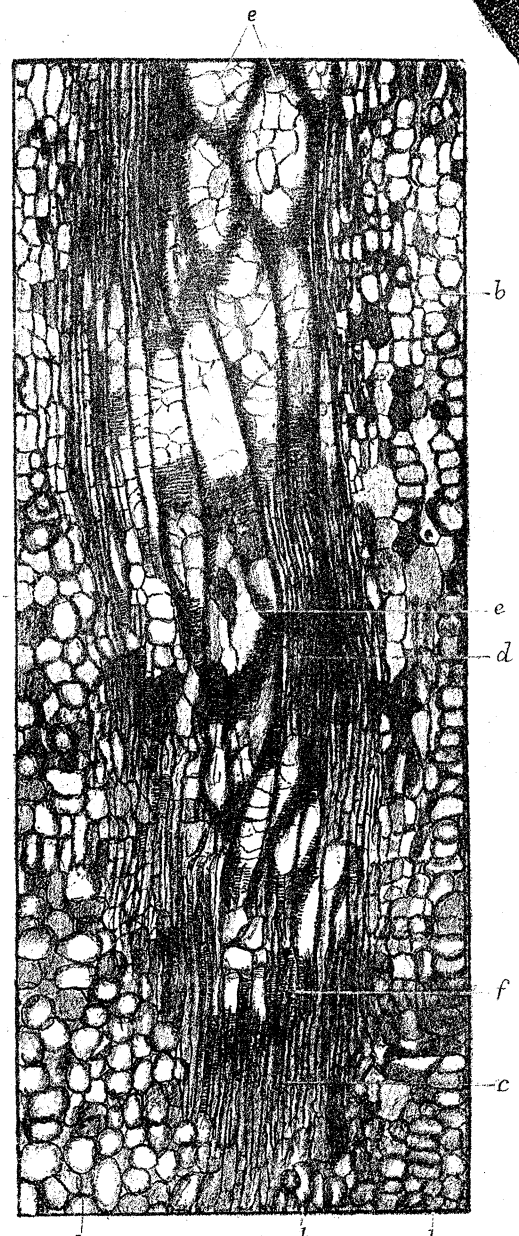
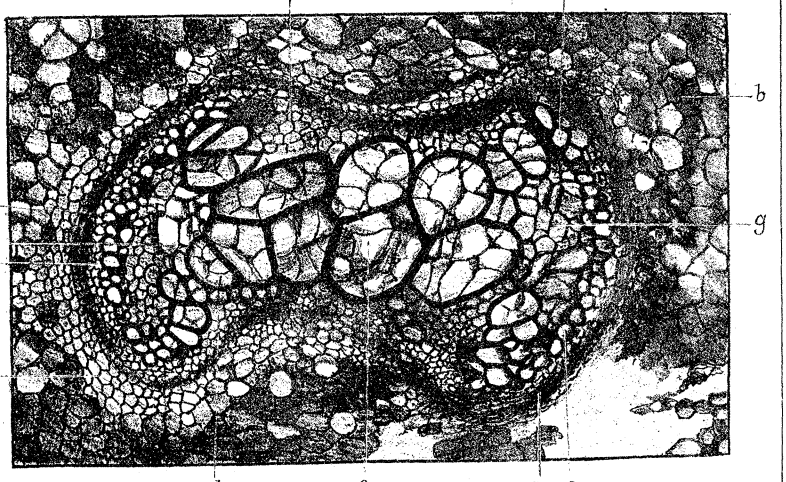


Fig. 21.

Fig. 20.



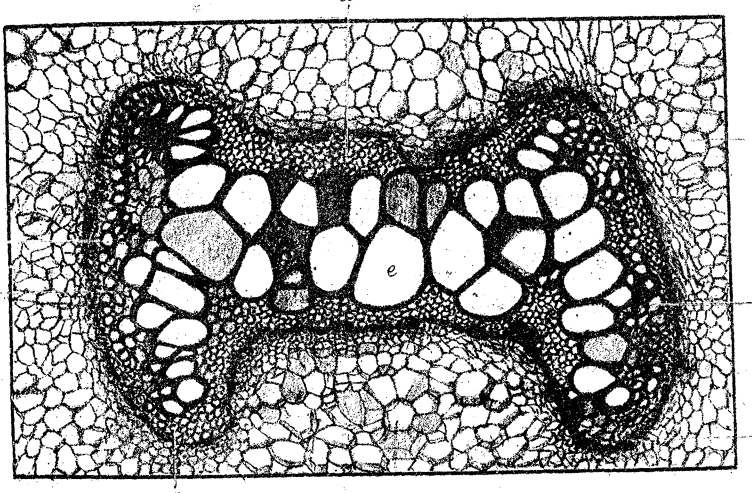
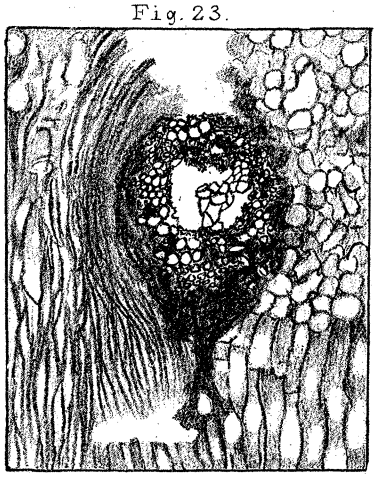
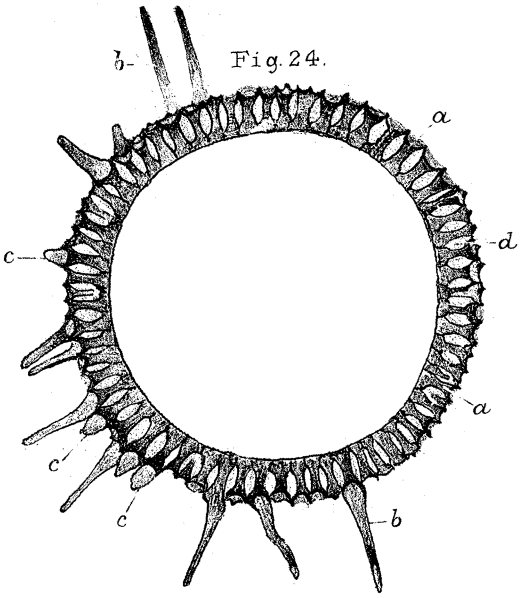


Fig. 22.

Whiteman & Bass, *Photo-Litho* London.

Fig. 23.





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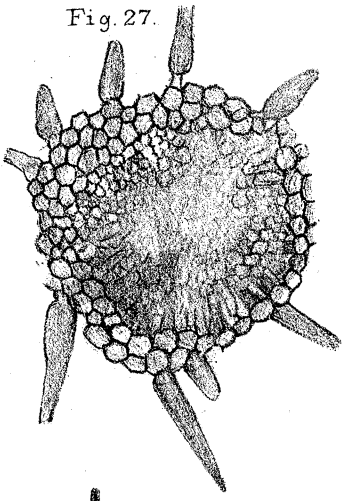

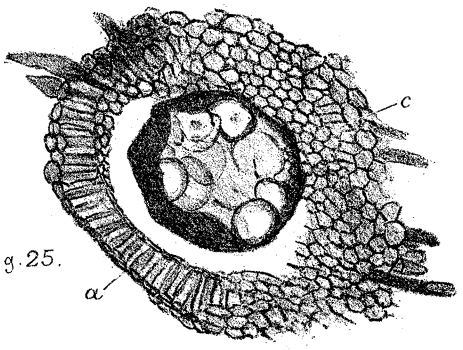

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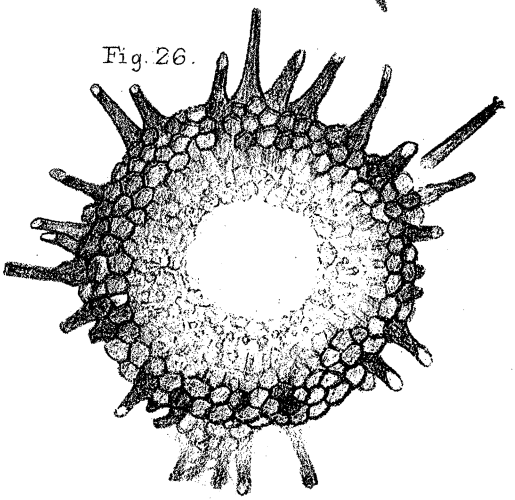

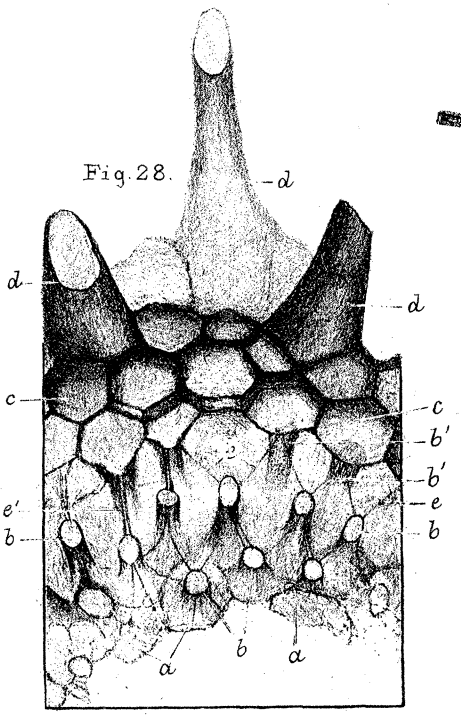

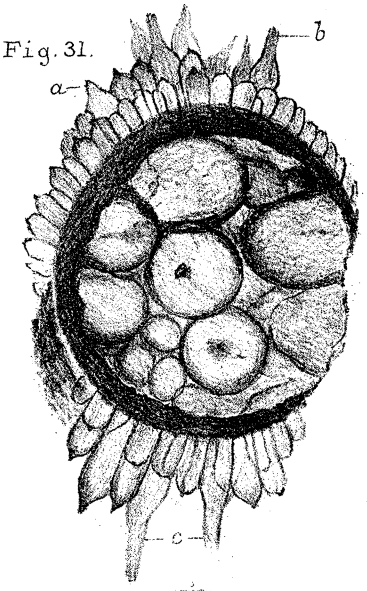

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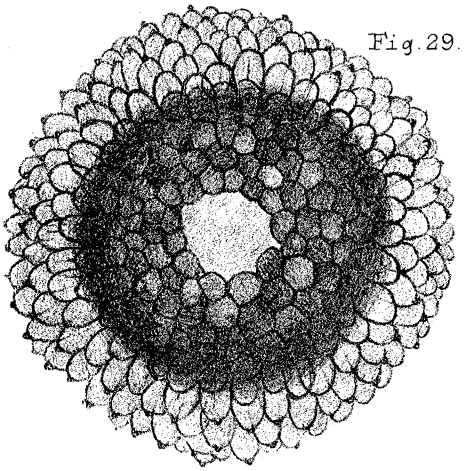

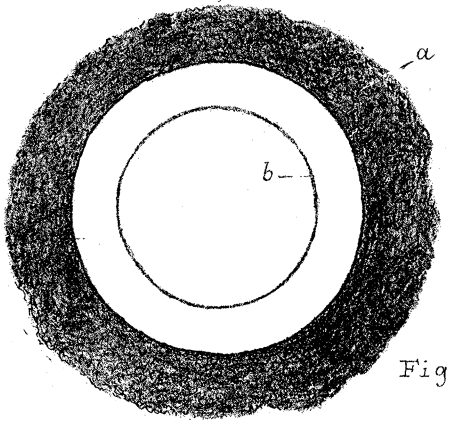

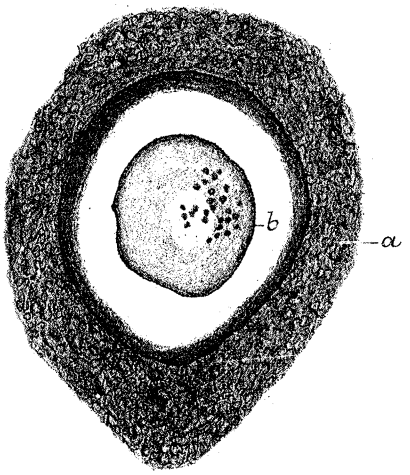

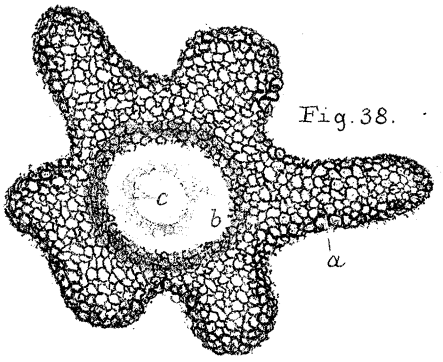

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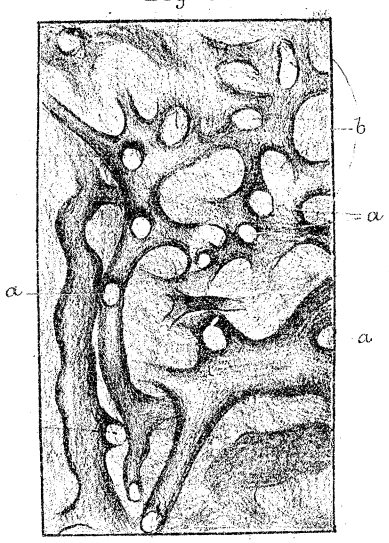
Fig. 37.



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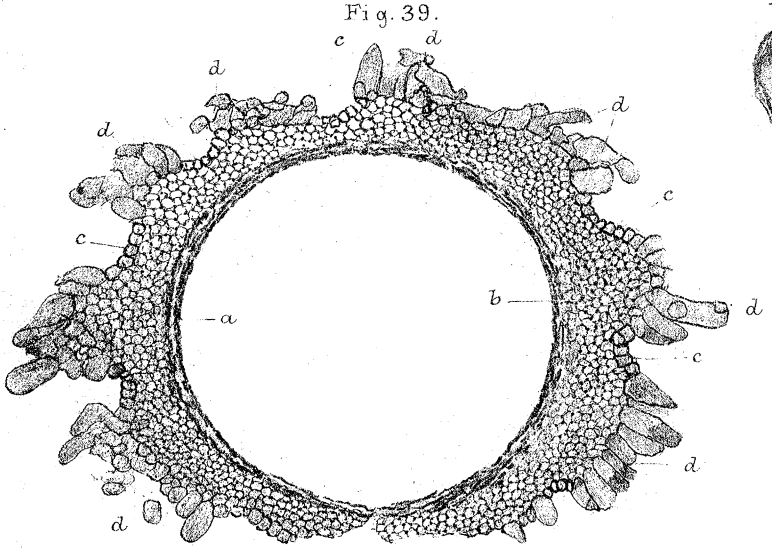


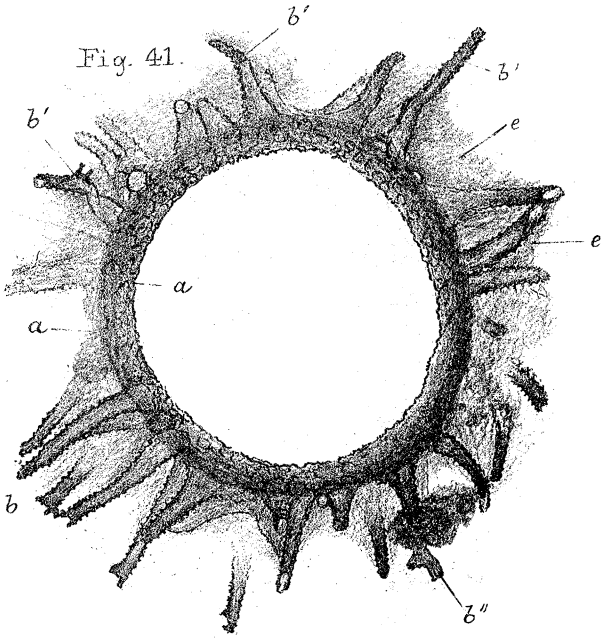
Fig. 32.

Fig. 33.

Fig. 34.

Fig. 30.

Fig. 41.



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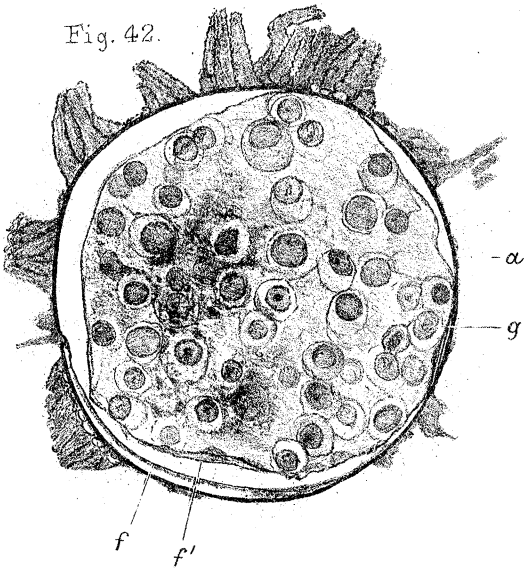

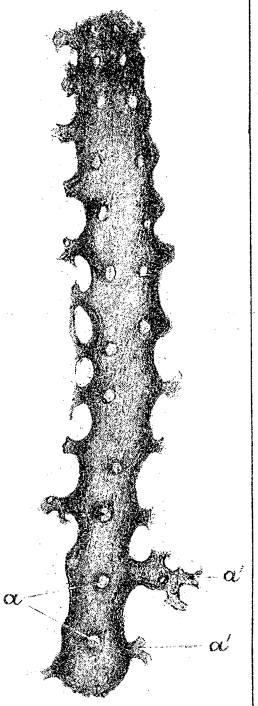

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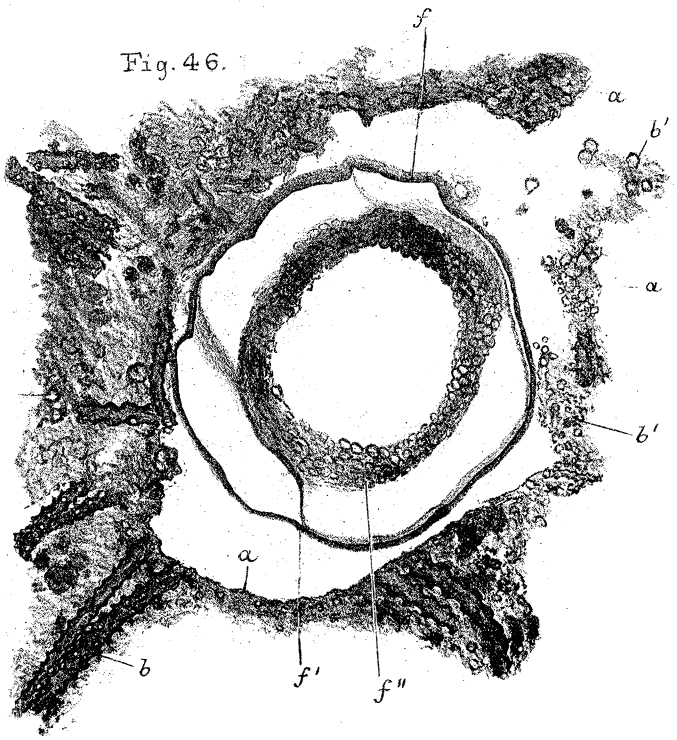

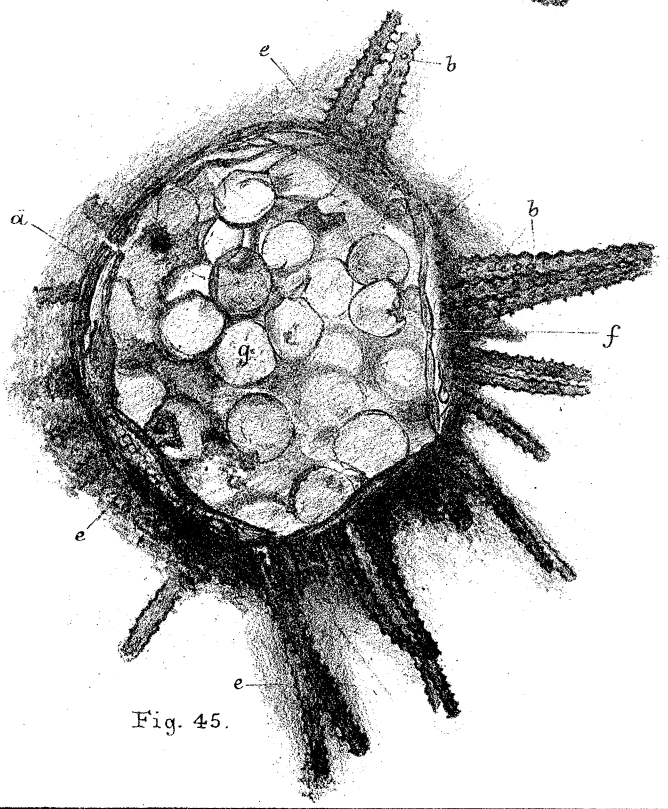

Fig. 45.

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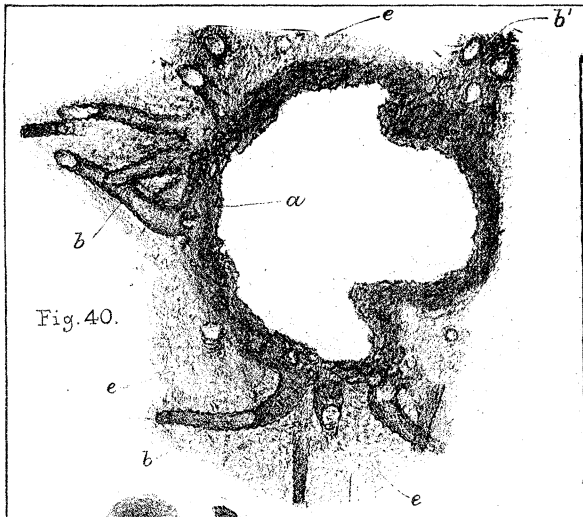

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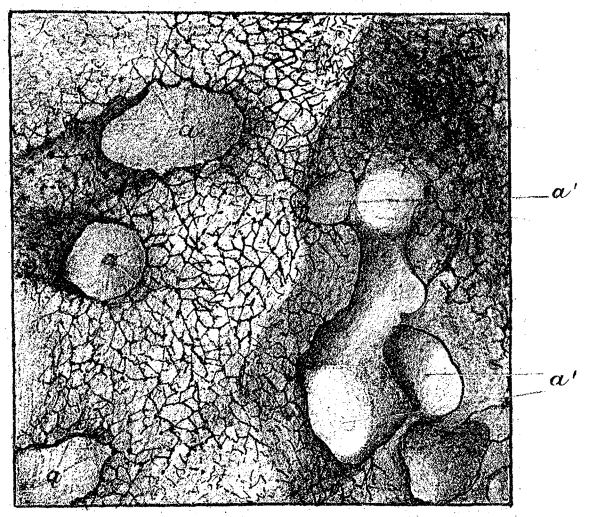

Fig. 44.

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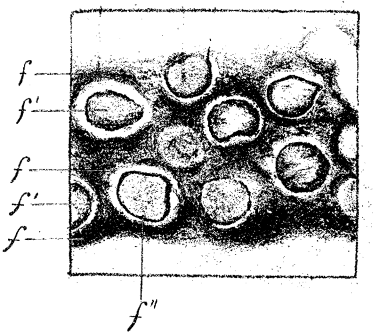

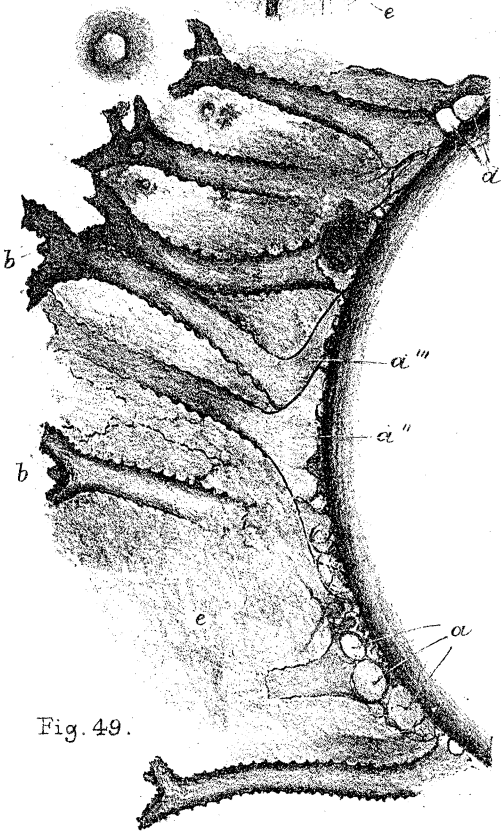

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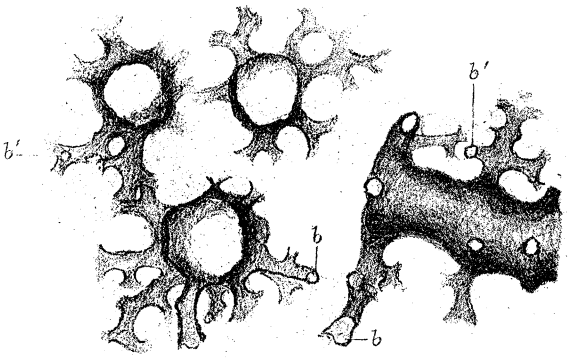
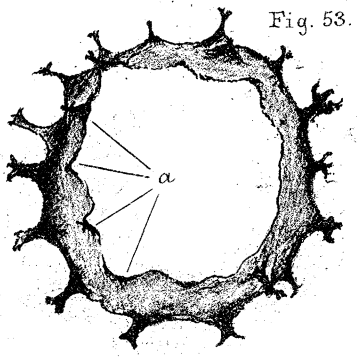


Fig. 50.

Fig. 53.



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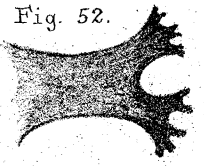


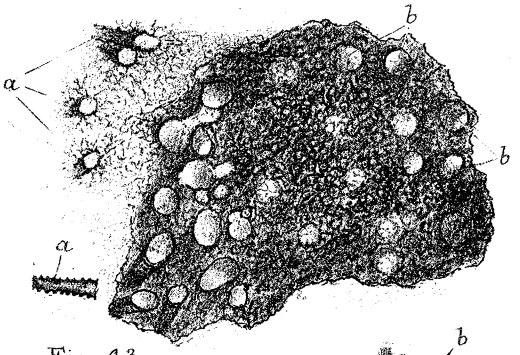
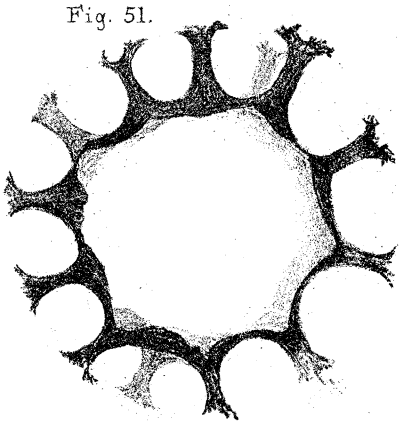


Fig. 43.

Fig. 51.



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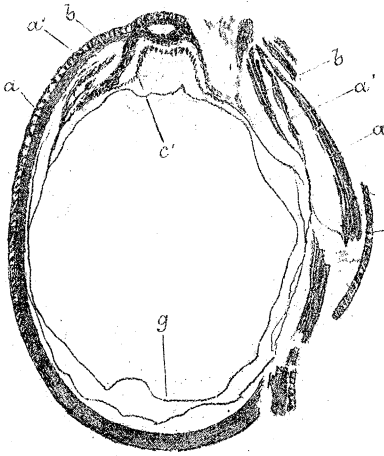

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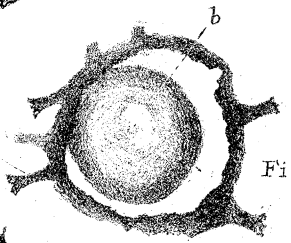

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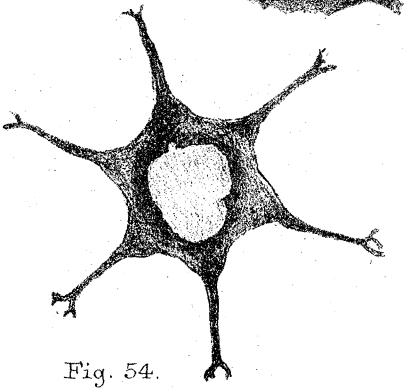

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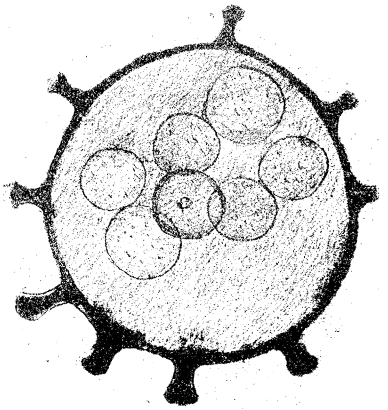
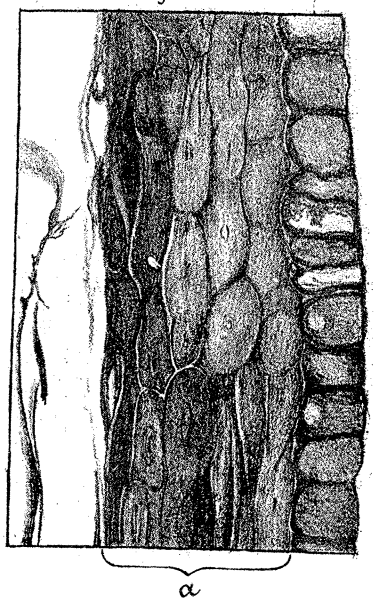


Fig. 55.

Fig. 62.



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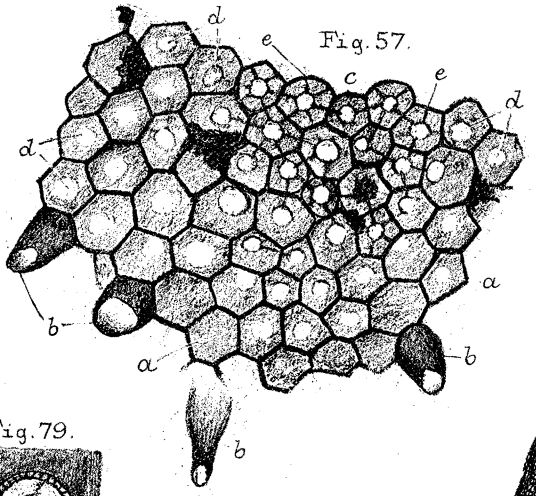

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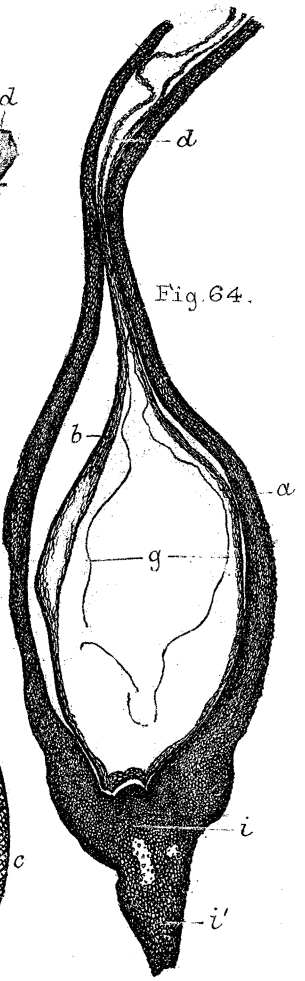

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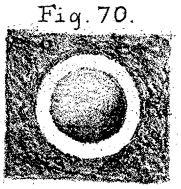

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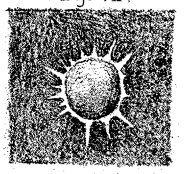

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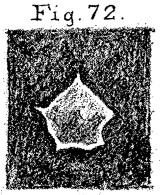
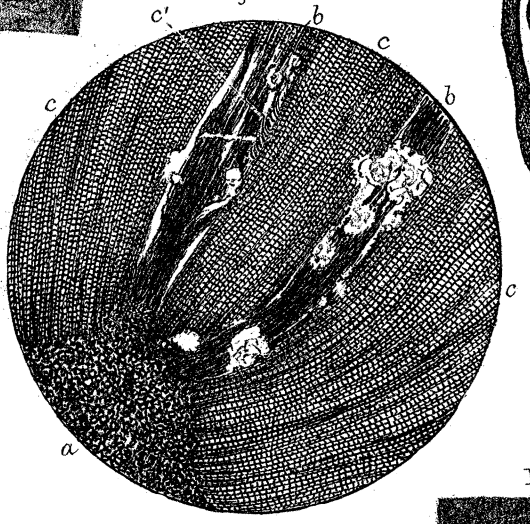


Fig. 79.

Fig. 60.



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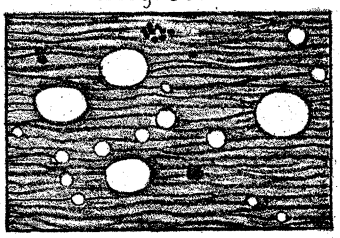

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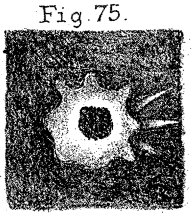

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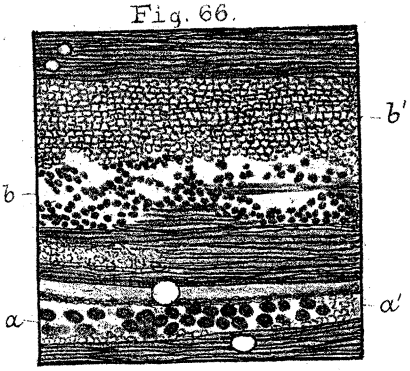

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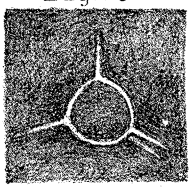

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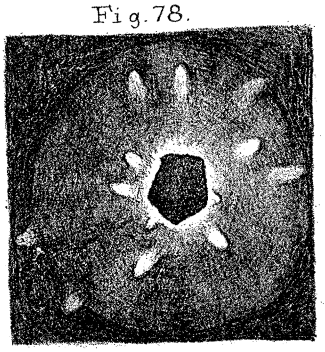

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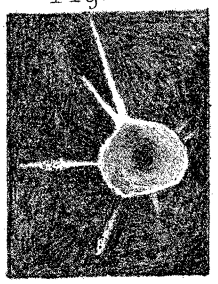

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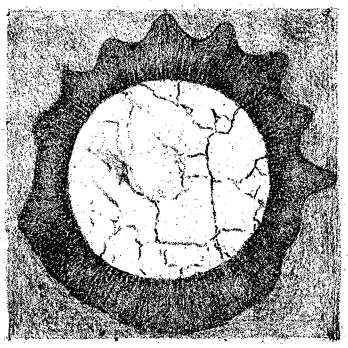

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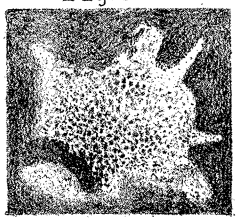

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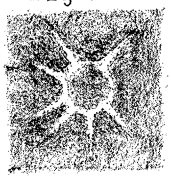

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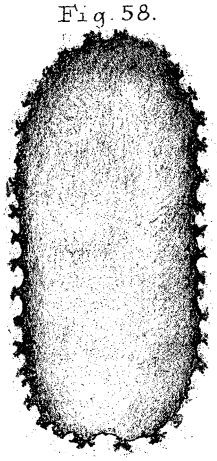

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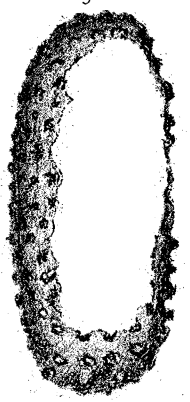

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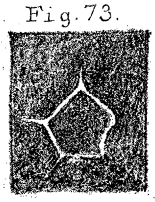

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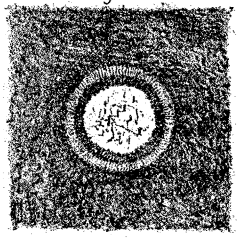

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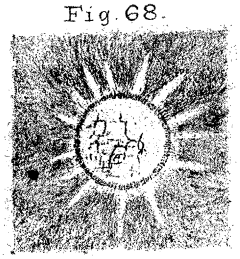

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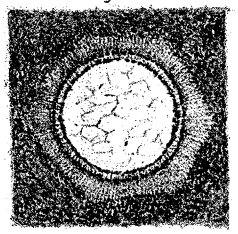

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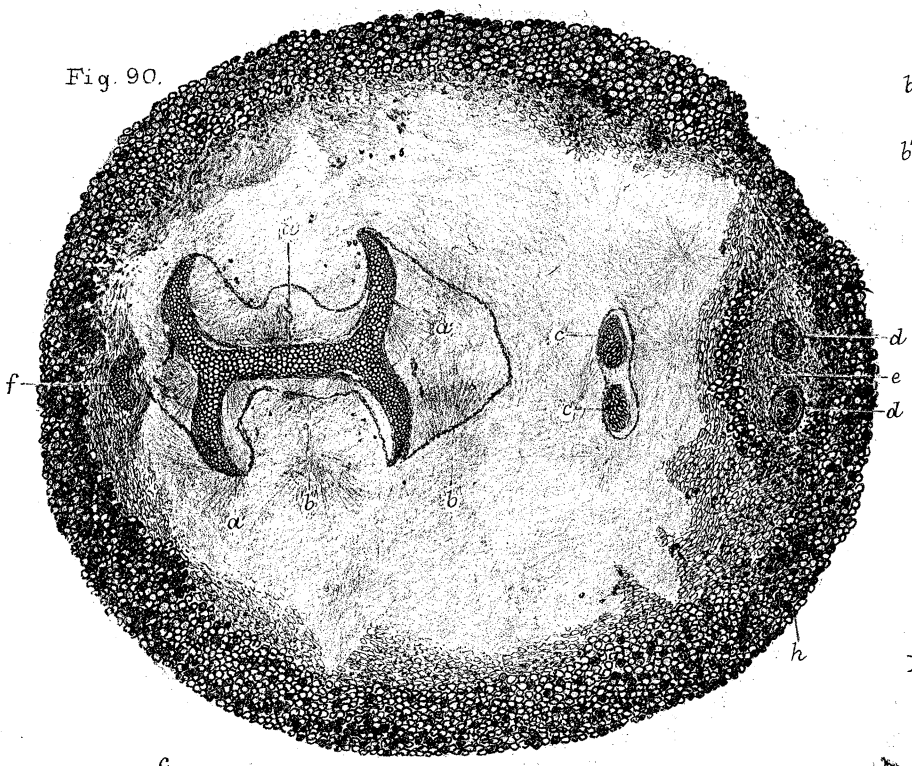
Fig. 90.



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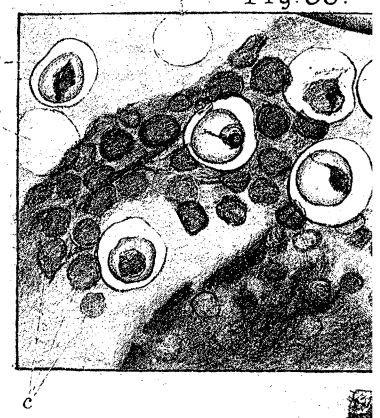

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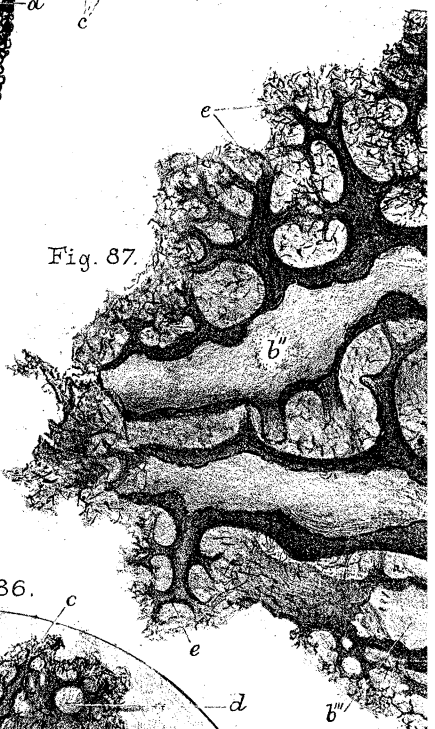

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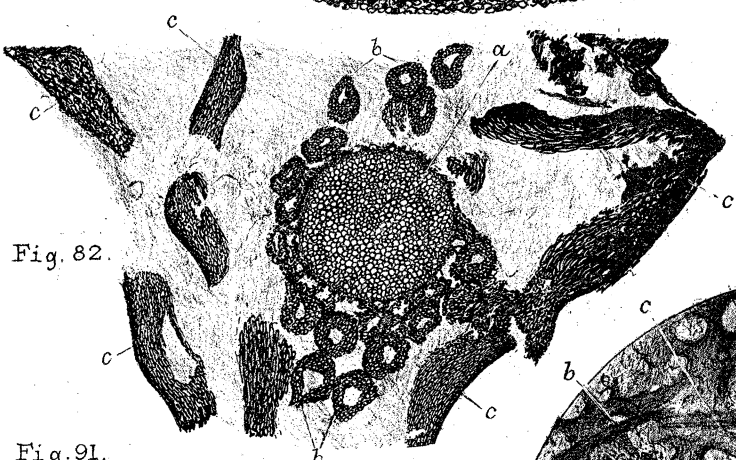

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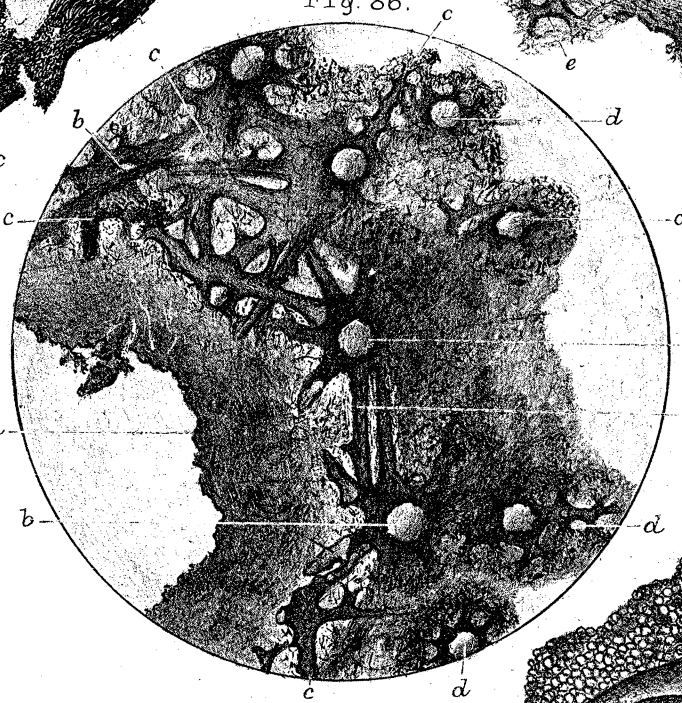

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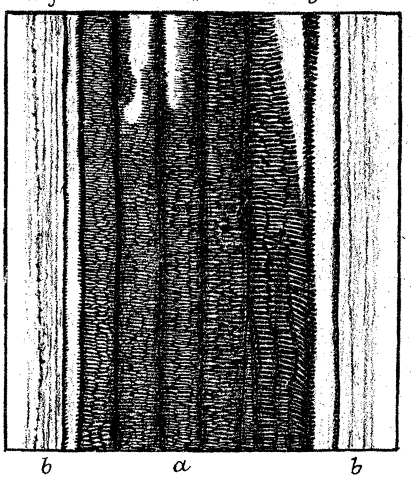
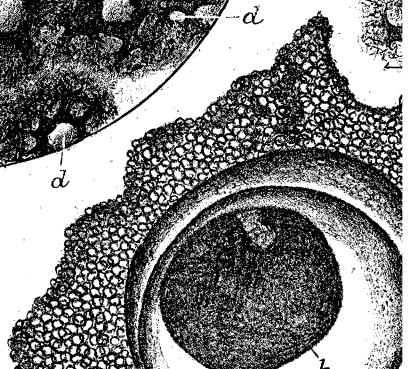
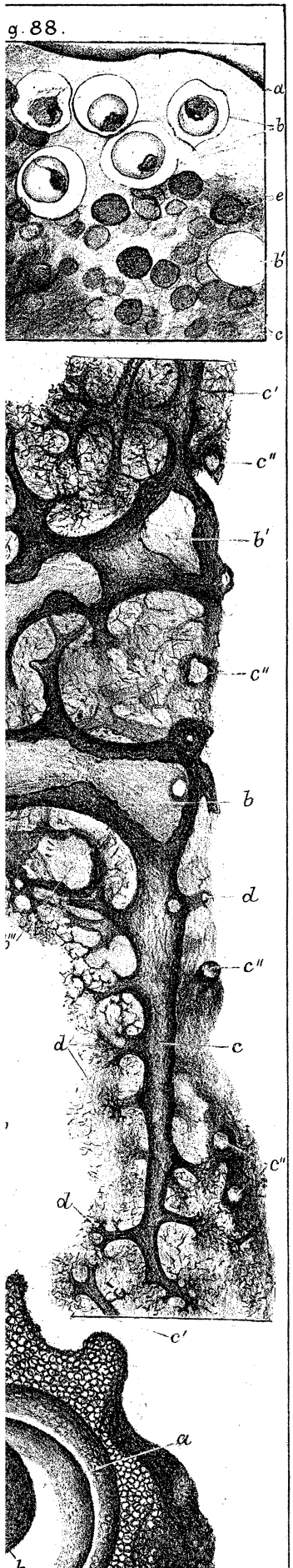


Fig. 83.

Fig. 84.




g. 88.
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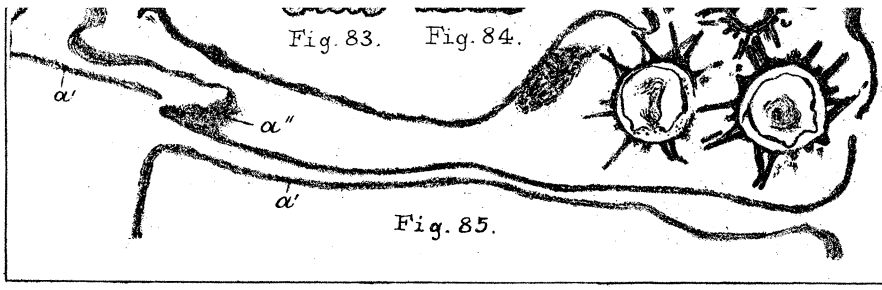


Fig. 83. Fig. 84.

Fig. 85.

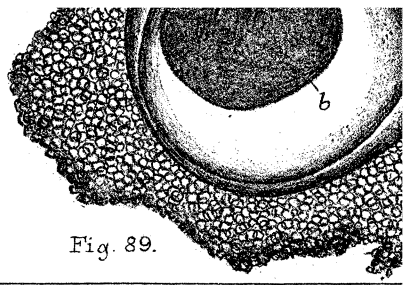
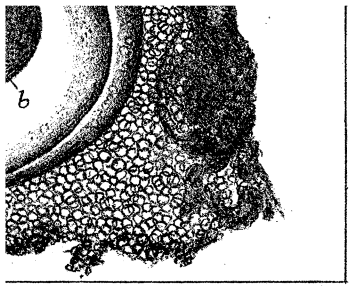


Fig. 89.

W. C. Williamson, Del.



Whitehead & Bass, Print. Strike, London.

Fig. 90.

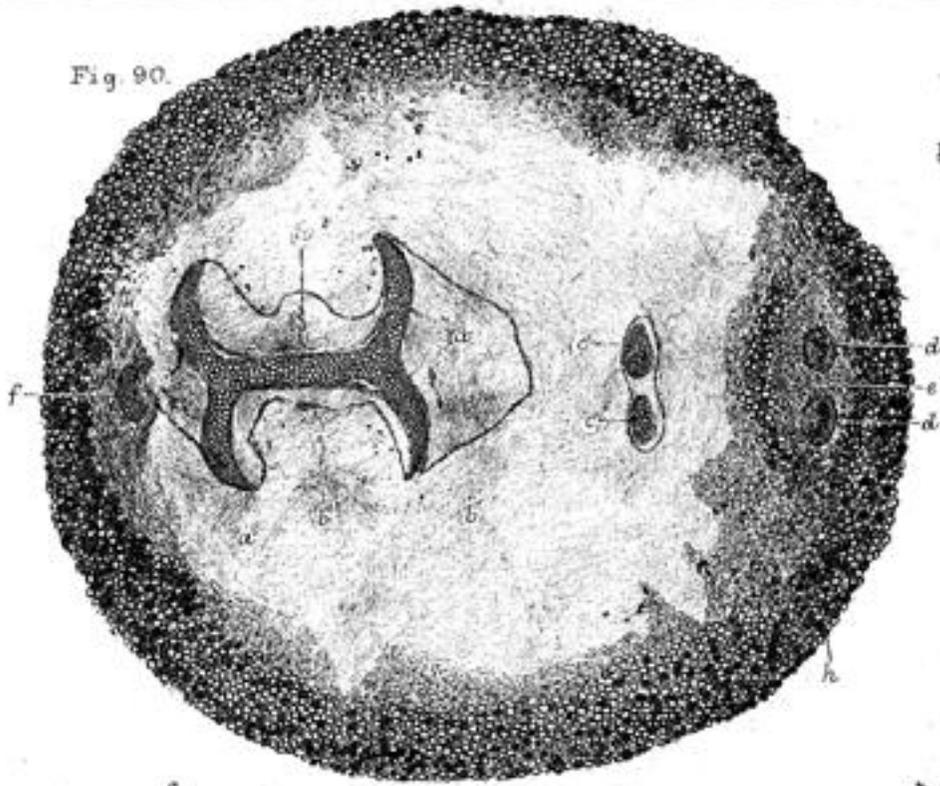


Fig. 88.

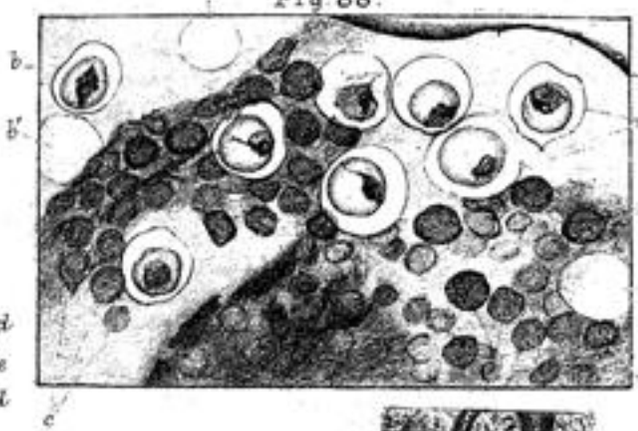


Fig. 87.

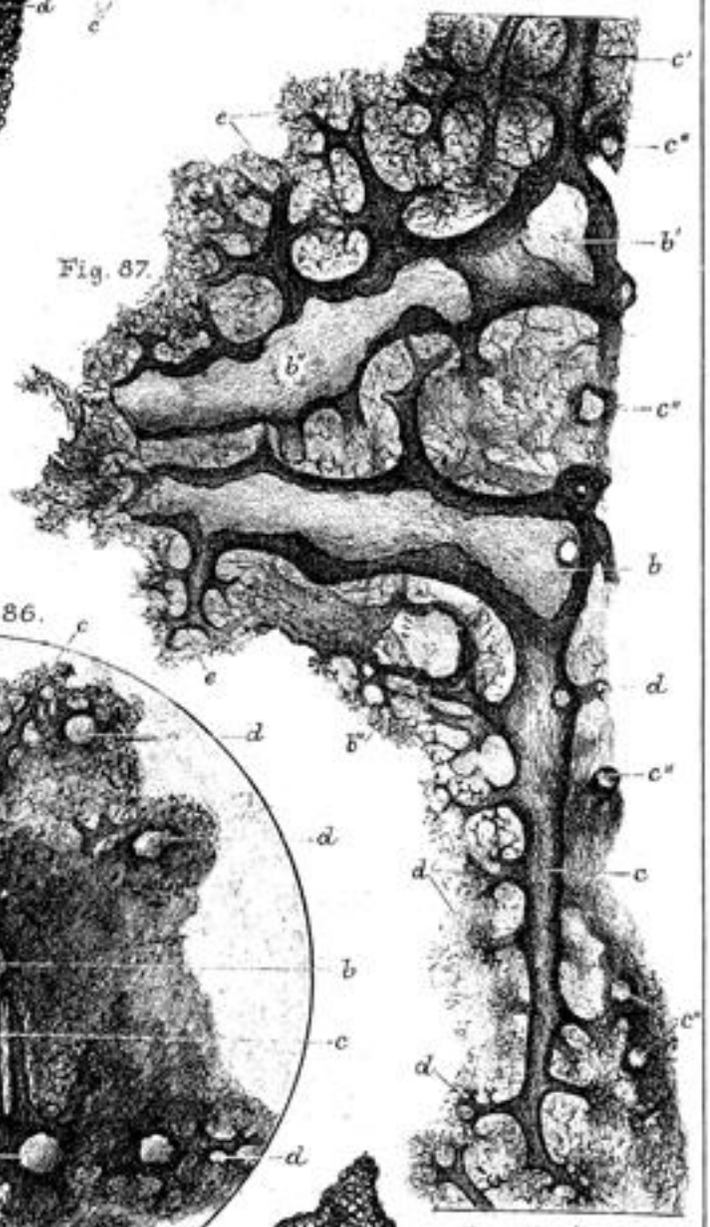


Fig. 82.

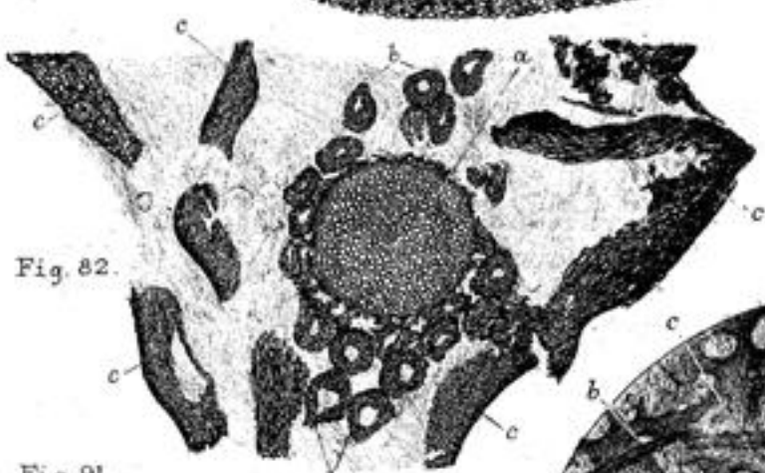


Fig. 86.

Fig. 91.

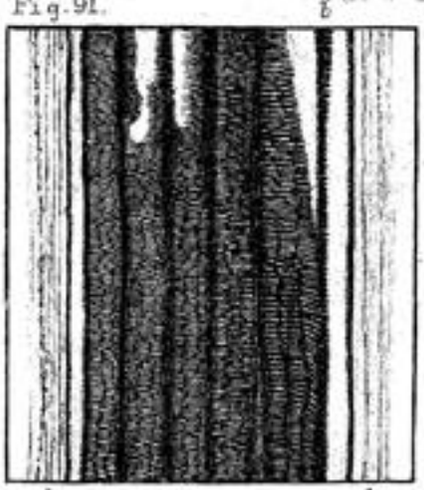


Fig. 83. Fig. 84.

Fig. 85.

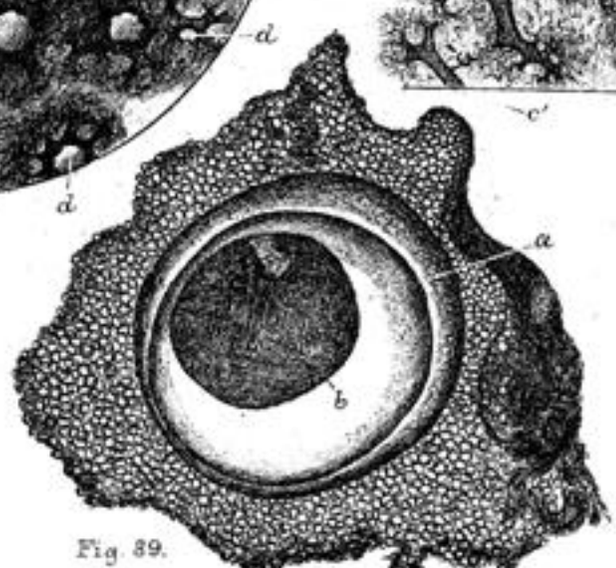


Fig. 89.