VII. *On the Organization of the Fossil Plants of the Coal-measures.*—Part VIII. *Ferns* (continued) *and Gymnospermous Stems and Seeds. By* W. C. Williamson, *F.R.S., Professor of Natural History in the Owens College, Manchester.*

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[Plates 5–16.]

In one of his valuable Memoirs on the Fossil Plants of the Carboniferous deposits of France* M. Renault has described the stems of two fossil Ferns, to both of which examples characteristic petioles are attached. In these stems the chief vascular or pseudo-vascular elements are not scattered over the transverse section of the stem in detached bundles, as is usual amongst living Ferns, but they are gathered together so as to form an axial cylinder, enclosing an irregular, central, radiating medulla composed of parenchymatous tissue. In the sixth of this series of memoirs I figured (plate 58. fig. 51) a transverse section of a similar vascular axis, but without either petioles or even any investing cortical layer attached to it. In one of M. Renault's examples the petioles associated with the stem were identical with those to which Corda gave the name of *Zygopteris*. In the second species, to which M. Renault assigned Corda's generic name of *Anachoropteris*, the transverse section of the petiolar vascular bundle resembles that of *Osmunda* and *Todea*, as M. Renault has correctly indicated (*loc. cit.* p. 176). He also points out the difference existing between the closed vascular cylinders of the stems of these two Ferns and the corresponding bundles of most living types, but thinks that something similar to them may be found amongst the *Ophioglossums*.

I am indebted to my indefatigable auxiliary, Mr. J. Butterworth, for an interesting stem of the same type which he obtained from the rich reservoir of fossil plants near Oldham. The specimen was about $1\frac{1}{2}$ inch in length, whilst its somewhat oval, transverse section had a maximum diameter of about an inch. The external surface was strongly marked by an irregular series of transverse ridges and furrows, represented in fig. 1, and which may some day contribute to the identification of the fronds with which this stem should be associated. There are about twenty-four of these ridges, with corresponding intermediate furrows, to each vertical inch of the stem. On making a transverse section of the specimen I found a central vascular cylinder closely resembling that seen in M. Renault's specimen of *Zygopteris Brongniarti* (*l. c.* pl. 3. fig. 1, *a*), along with two or three secondary ones, of varying dimensions, dispersed over the area of the

* "Étude de quelques végétaux silicifiés des environs d'Autun," par M. Renault, Annales des Sciences Naturelles, 5e série, Bot., t. xii. (Cahier no. 3).

section. Utterly unable to interpret the relations of these several structures, I adopted the plan which proved so successful in the case of *Heterangium Grievii* (Phil. Trans. 1873, pl. xxx. figs. 37–44), and had about an inch of the specimen cut up into the series of closely consecutive, transverse sections represented in figs. 2–12. By this process a partial interpretation of these sections, at least, has become sufficiently easy.

Vascular cylinder.—The central vascular cylinder (figs. 2–12, *b*) consists of from five to seven clusters of vessels, which clusters are intimately blended together at their peripheral borders. This arrangement is more clearly shown on the enlarged scale of 18½ diameters in fig. 13.

Medulla.—The medullary cells constitute a central mass (*a*), which sends off several irregular, narrow, diverging radii (*a'*, *a'*). These diverging portions, which occasionally dichotomize, as is the case with the one descending to the lower portion of fig. 13, partially separate the clusters of vessels from each other. The cells, as seen in the transverse section, are of the ordinary parenchymatous type, varying in size from ·003 to ·00125*. Some of these cells either contain isolated secondary cells within their cavities, or distinct primordial utricles, detached from their proper cell wall. Scattered amongst them also are some small vessels. In the longitudinal section (fig. 14) the cells of the medulla are seen to be of irregular shapes and sizes, but often narrow, elongated longitudinally, and square-ended. The vessels of the surrounding cylinder are generally of large size, ranging from ·007 to ·005 in diameter, and with strong, sharply defined walls; but at the inner and outer boundaries of the cylinder we have many small ones, not exceeding ·002, resembling, in this respect, some vessels which are scattered through the medullary parenchyma. On examining the longitudinal section (fig. 14) of this axial cylinder, we find that the vessels are of the usual barred type, and that the largest of them occupy the central parts of each cluster—a fact also shown by fig. 13. But the most remarkable feature of these vessels is further illustrated by figs. 15 & 16. In fig. 15 the dark, strongly marked walls of the vessels enclose densely packed masses of cells (*i*). The longitudinal section, made nearly through the centre of a single vessel (fig. 16), shows it to be similarly crowded with *tylose* throughout its entire length. The existence of this singular tissue in the vessels of recent plants has long been known to botanists, and Professor W. T. THISLETON DYER has described a similar tissue existing in a fossil Tertiary exogenous wood from Herne Bay and the Isle of Thanet†; but so far as I am aware this is the first recorded example of its appearance in a fossil Cryptogam, and especially in one from these ancient Carboniferous deposits. The fact of the existence of *tylose* at this remote period affords a striking example of the persistence of types of elementary tissue, additional to those which we already possess.

Bundle-sheath.—The axial vascular cylinder is enclosed in a somewhat irregular sheath of cellular tissue seen at figs. 13, *g* & 14, *g*. This consists of three or four rows

* As in the preceding Memoirs, all these measurements are recorded in the decimal parts of an inch.

† "On some Fossil Wood from the Lower Eocene," by W. T. THISLETON DYER, B.A., B.Sc., F.L.S., 'Geological Magazine,' vol. ix. no. 6, June 1872.

of long, narrow, square-ended cells of variable length and about ·0005 in diameter; but interspersed amongst them are many scattered cells of larger dimensions, as shown in fig. 13.

Cortex.—External to the vascular bundle-sheath we have a thick mass of ordinary parenchyma, figs. 4, *e*, 14, *e*, & 20, *e*, the cells of which are remarkably uniform, both in texture and size, their diameters chiefly ranging between ·005 and ·003. This parenchyma is invested by a thin outer layer about ·04 in thickness (figs. 4, *f*, & 2, *f*), composed of denser and darker-coloured cells.

Secondary bundle.—I have already remarked that, besides the large central vascular cylinder, each transverse section of the stem reveals two or more secondary bundles. Of these the largest and most conspicuous is the usually solitary one of this type represented in fig. 4, *c*; and in the subsequent figures the same bundle is indicated by the same italic letter. An enlarged representation of this bundle, as it appears in the section, fig. 4, is seen in fig. 17. Its outline is reniform. The greater part of the vessels, *g*, of which it is composed are nearly as large as those of the central cylinder; but those seen clustered together at each extremity of the transverse section, g', are very much smaller than the others. This vascular bundle is surrounded by a sheath of narrow elongated cells (fig. 4, g''), identical with that investing the axial cylinder, and this, in turn, is enclosed within the ordinary parenchyma of the inner cortex (fig. 4, *c*).

The origin and destination of this bundle would be alike obscure were our study of it limited to a single section; but by following the ascending series of sections included in the figures 2–12 we obtain information on both these points. In the sections from figs. 2–8, *c*, we see but little change in the position and surroundings of the bundle; but in fig. 9 we find that the outermost cortical layer of the stem (fig. 9, *f*) is obviously bending inwards at two points, f', f', tending towards the enclosure and detachment of the bundle from the main stem. In fig. 10 this enclosure is complete. The bundle *c* is now the centre of what has every appearance of being the base of a leaf-petiole. In fig. 11, *c*, the bundle has been accidentally broken away in the preparation of the section; but at f' we find the petiole freeing itself from the central stem, whilst in fig. 12 the part of the stem, f', from which the orientation took place is now encircled by the normal investment of outer cortex. In its original state the outer surface of the specimen exhibited several rounded areas not marked by defined cicatrices, but irregularly fractured, from which points similar petiolar extensions seem to have been broken off. Fig. 18 represents a section of one of these detached petioles enlarged 7½ diameters. I am indebted for this section to Mr. BUTTERWORTH, by whom it was prepared. Its central vascular bundle (*c*) is virtually identical in size and contour with that of fig. 17, whilst the inner (*e*) and outer (*f*) cortical layers are, in like manner, identical with those of the parent stem. The large rounded lacunæ in the inner bark are merely accidental results, probably of partial desiccation before the specimen was imbedded in its matrix.

Origin of the primary bundles.—On returning to the series of sections, we observe that at the point b' of fig. 6 the central vascular cylinder is undergoing a change. The arrangement of the tissues at this point is seen in fig. 19, which is an enlarged representation of the part of the central cylinder enclosed between the points fig. 6, *b'*, *b'*. At fig. 19, *b'* we find a cluster of the vessels bending outwards from their normal vertical course. In fig. 7, *b'** we find that a further outward extension of these divergent vessels has taken place. Fig. 20 is an enlargement of this part of the cylinder. In it we see that the vessels which bend outwards in the direction of the arrow through a part of their course (*b''*) are again bending upwards at *b'*, so as to be intersected transversely. In fig. 8, *b'* we find the bundle completely detached from the central vascular axis, and now it is evidently a bundle like *c* of fig. 2, only located on the opposite side of the stem†. In figs. 11 & 12 we have manifest evidence that this bundle *b'* is about to follow the course of its predecessor on the opposite side of the stem, since the outer bark (*f'*) is rapidly approaching to the conditions seen at *f'* in the figures 8 & 9.

Fig. 21 exhibits a somewhat oblique longitudinal section which passes through the central cylinder at *b*, and is nearly in the plane of the primary bundle *c*, the sheat of the latter being seen at *g*. This little section is important, since it shows that the ascending direction followed by this primary bundle is also followed by certain smaller ones yet to be described, as at fig. 21, *d*.

Where the vessels are about to leave the central cylinder to form one of the primary bundles just described, as at fig. 19, *b'*, several of my sections reveal a curious change in the structure of some of the elementary tissues. As already stated, the vessels composing both the central cylinder and the primary petiolar bundle are of the barred type so common amongst the Carboniferous plants. Fig. 22 exhibits a cluster of the tissues seen at fig. 19, *b'*, enlarged 62 diameters. At *b* we see *barred cells* which, yet further to the right of the section, pass into the ordinary barred vessels of the axis; but at *b'* we find similar cells, but with reticulate instead of barred walls, and at *b''* similar reticulated structures are being elongated, approaching the form of the ordinary vessels of the plant. This conversion of the barred into the reticulate type, the latter being a mere modification of the former, is merely a local phenomenon. I only detect it where the central cylinder is about to give off a petiolar branch, and here only in a very limited measure; no trace of reticulate vessels is to be found elsewhere, either in the central or the lateral bundles.

Secondary bundles.—In addition to the large vascular bundles supplying the petioles we find in several of the sections smaller bundles, some of which are given off directly from the central cylinder, others from the primary petiolar bundles. Instances of the former of these orientations are found in figs. 3, 5, 7, 10, & 12, and an example of the latter occurs in fig. 5. In fig. 3 a bundle is separating from the upper part of the

* The arrows of the figures 7 and 20 indicate the directions in which these two figures should be turned to place them in identical positions.

† In figs. 8 & 9, 10, 11, & 12 the sections have been slightly twisted round to make them fit more symmetrically upon the plate; hence, whilst the vessels *b'* of fig. 7 point downwards towards the *lower* right-hand corner of the section, in all the subsequent sections referred to the bundle which these divergent vessels have formed is situated directly to the right of the cylinder.

cylinder at *d*. In fig. 4, *d*, we discover this same bundle completely detached from the central axis and proceeding direct to the periphery of the cortex. In the longitudinal section, fig. 21, we have, at *d*, a corresponding bundle. In both these examples these *secondary* bundles obviously *ascend* through the stem as they proceed outwards, in exactly the same way as the larger *primary* petiolar ones do. Though following the same course, the former are very much smaller, both in their aggregate diameter and in the size of their component vessels, than the latter are. The entire series of sections appears to exhibit them of two sizes. In figs. 4, *d*, 7, *d*, & 8, *d*, each bundle has a diameter of ·032, whilst in figs. 5, *d*, 10, *d*, & 12, *d*, it is only ·01 in thickness. It is another notable point in these eleven consecutive sections, that whilst we only find two of the large primary bundles (*d*) emanating directly from the central cylinder, we have certainly five of these smaller ones doing so. In fig. 7, as shown in the enlarged representation, fig. 20, *d*, the secondary bundle is seen springing almost from the central axis simultaneously with the primary one *b'*.

But we further find secondary bundles arising from the primary petiolar ones. We have one such originating at *d'* from the primary bundle, fig. 5, *c'*. In fig. 6, *d'*, we find that this secondary bundle has reached the periphery of the stem, and, as seen in fig. 24, *d'*, which represents this bundle and its surroundings enlarged $18\frac{1}{2}$ diameters, it is now the centre of a distinct organ somewhat similar to fig. 18, but having little more than one third the mean diameter of the latter section. Traces of this appendage are still seen in figs. 7, *d'* & 8, *d'*, but in fig. 9 it has wholly disappeared. The correctness of this description depends upon the identification of the bundle, fig. 6, *d'*, with fig. 5, *d'*. But on recurring to figs. 2, 3, & 4 we find a curious bundle unaccounted for at *d* in each of these sections. It must be remembered that fig. 2 is the lowest of this series of sections, and that as we ascend in the series we ascend in the stem. Observing that the small bundle, fig. 2, *d*, is further removed from the primary bundles *c* than in the sections figs. 3 & 4, it appears possible that these latter bundles may be identical with *d* in fig. 5. If this be the case, we have here an instance in which a secondary bundle *descends* as it passes outwards through the bark, instead of ascending, as we have seen to be the case with the small bundles given off from the central cylinder. Such an arrangement would correspond exactly with that so common amongst such living ferns as *Aspidium Filix Mas*, where the bundles of vessels supplying the adventitious roots spring from the petiolar bundles, subsequent to the separation of the latter from the true axial bundles of the stem. The discovery of fresh specimens can alone settle this point.

Two questions still remain to be answered, viz., what is this stem? and what is the morphological significance of its various parts?

As I have already observed, M. RENAULT has described two stems which have the axial vessels arranged as in the subject of the above description, an arrangement which differs very widely from what is seen in any known ferns, recent or fossil. The detached bundles of fibro-vascular tissue seen in recent ferns, whether of the herbaceous or of the arborescent type, exhibit no arrangement exactly corresponding to the closed cylinder seen alike in my fossil and in the *Zygopteris Brongniarti* and the *Anachoropteris Decaisnii* of M. RENAULT. In all these three plants the vessels form a distinct vascular cylinder which encloses a medullary tissue, reminding us of the simpler types of Lepidodendroid stems rather than of true ferns. Yet there seems to be no reason for doubting that M. RENAULT'S plants are true ferns; and if so, my specimen corresponds with them too closely in all its essential features to be separated from *Anachoropteris* and *Zygopteris.* Assuming that this is the case, what are the lateral organs into which my stem obviously branched? My primary divergent bundles, indicated in all the figures by the letter *c*, went either to secondary branches or to petioles. The analogies of M. RENAULT'S plants, as well as the general aspect of fig. 18, indicates that the latter was the case; but if so, what were the smaller secondary bundles indicated by the letter *d*? Springing directly from the central axis, and *ascending through the cortex* like the primary bundles, their direction seems to indicate that they also went to petioles, but to some of smaller size than those to which the larger and less numerous primary bundles were distributed. In his recently published memoir on *Botryopteris forensis* (Annales des Sciences Naturelles, 6e série, Bot., tome i. pl. 8. fig. 1) M. RENAULT has figured similar secondary bundles, given off, as in my plant, both from the central vascular axis and from the primary vascular petiolar bundle. The learned author does not hesitate to regard them as supplying rootlets. These moot points can scarcely be finally settled until we meet with additional examples of this curious stem.

So distinctly characterized a stem requires an appropriate name. In my last memoir I endeavoured to avoid a needless multiplication of generic terms by grouping together a number of unidentified petioles under the common name of *Rachiopteris*. But we have now three examples of these petioles identified with stems, all of which latter exhibit a common type of internal organization, though their petioles display differences in the arrangement of their vascular tissues. But the latter fact constitutes no reason why the three plants should not be united in one common genus. In my previous Memoir* I pointed out that such differences of structure in the petioles did not prevent *Adiantum trapeziforme* and *A. cuneatum* from being placed in one genus, or *Pteris umbrosa* and *P. aquilina* in another. Neither should it prevent M. RENAULT'S *Zygopteris Brongniarti*, *Anachoropteris Decaisnii*, and my new plant from receiving a common generic name. But a new difficulty now springs up. CORDA assigned each of his two generic terms, *Zygopteris* and *Anachoropteris*, to special forms of petioles. Hence if we select either of these names to represent the triad of plants in question it can only be done by giving an entirely new definition to an old generic name, and one, moreover, in the case of *Zygopteris*, that is still required for several petioles, such as *Z. Lacattii* and *Z. bibractiensis*, of which the stems have not yet been found. Hence, though *Zygopteris Brongniarti* must be included in the new genus, it seems undesirable to employ separate generic names for the three stems.

Under these circumstances it appears to me to be wiser, for the present, to compre-

* Phil. Trans. vol. 164. part 2, p. 676.

hend all these fragmentary stems and petioles in a common group, such as *Rachiopteris*, without pretending to assign to that term a true generic value, and then to subdivide the group into subsections, according as the specimens appear to have features in common, such as that of *Zygopteroides*, *Stauropteroides*, &c. By this plan we avoid the absurdity of creating numerous meaningless genera, each one of which is only represented by fragmentary parts of plants. Hence I would designate the plant which I have just described *Rachiopteris corrugata*, and include it, along with M. RENAULT'S *Zygopteris Brongniarti* and *Anachoropteris Decaisnii* *, in the subgroup of *Anachoropteroides*, the distinguishing features of this group being the possession of a central vascular axis which forms a virtually closed cylinder surrounding a cellular medulla—two features in which these stems of Ferns approach very closely to those of the type of *Lepidodendron* represented by *Lepidodendron Harcourtii*. In the adoption of the above plan of classification I have benefited by some valuable hints from Dr. HOOKER, who kindly gave me the advantage of his vast experience in the study of systematic botany.

It has long been noticed as a remarkable fact that whilst the Oolitic ferns of the Gristhorpe shales so frequently exhibit sori attached to their fronds, ferns with sporangia *in situ* are rare in the true Coal-measures. BRONGNIART long ago figured a solitary leaflet of *Neuropteris flexuosa* which affords indications of sori upon its surface (Vég. Foss. pl. 65. figs. 3, 3 A, & 3 B). CORDA figured two examples, under the names of *Senftenbergia elegans* and *Hawlea pulcherrima* †, in which these conditions exist; and more recently M. RENAULT has described two other examples under the names of *Botryopteris dubius* and *B. forensia* ‡, in which also the sporangia are found attached to a branching axis. One of these species was from Autun, the other from St. Etienne. Prof. SCHIMPER has figured a fertile frond of *Palæopteris Hibernica* (Traité de Pal. Végét. vol. i. pl. xxxvi.). Mr. Bailey has represented the same fern in his 'Figures of Characteristic British Fossils' (pl. xxviii. fig. 1), and, still more lately, Mr. CARRUTHERS has figured the same plant with fertile pinnules in the 'Geological Magazine,' vol. ix. No. 2. The latter Memoir also contains figures and descriptions of some detached sporangia from the Oldham deposit, which its author believes to be of the type found in the recent Hymenophylleæ.

During my long-continued researches I have failed to discover a solitary fern-frond in the Coal-measures of Lancashire, Yorkshire, or Durham in which sori were to be seen *in situ*, and in my large collection of sections I have met with extremely few traces of detached sporangia. Here and there a fragment of an annulus has been observed, but too imperfect for identification with any special type §. Mr. BUTTERWORTH has been

* Annales des Sciences Naturelles, 5e série, Bot., t. xii. (Cahier No. 3).

† Flora de Vorwelt, Taf. lvii.

‡ Annales des Sciences Nat., 6e série, Bot., tome i. pl. 10.

§ This remarkable fact indicates that the fossil fronds have been exposed for a long time to the action of water before they became buried in silt and mud. At the same time, remembering how common fern-fronds are in the coal-shales, and what myriads of sporangia they must have set free, it is strange that we do not find detached ones more abundantly than is the case. (Since the above remarks were penned, I have obtained additional examples of such sporangia from Messrs. BINNS and SPENCER, of Halifax.—June 2, 1877.)

more fortunate in discovering the fine specimen represented in fig. 25. Its mean diameter is nearly ·03. Its annulus (*a*) is obviously of the common type found amongst the Polypodiaceous ferns. *b* is clearly part of the peduncle; hence the annulus has been a vertical one of the usual form, differing in this respect from the examples described by Mr. CARRUTHERS. The interior of the sporangium is crowded with small spores, some of which are spherical, others apparently angular; but this latter appearance may merely result from defective mineralization. Fig. 26 represents one of the spherical spores enlarged 320 times. Their actual diameter is about ·0018. This specimen is from the Oldham nodules. We have no clue to the frond to which it belonged.

Figs. 27 to 32 exhibit the fructification of a Fern of an altogether different type. Figs. 27 & 28 represent lateral views of two sporangia of which *a* indicates the point of attachment. No peduncle is seen in any of the specimens, hence I presume that these sporangia have been sessile ones. They are slightly pyriform in shape, and their walls consist of large, strongly defined prosenchymatous cells. Fig. 29 is a transverse section of what appears to have been the upper part of the sporangium, and has passed through a horizontal annulus, whilst the internal cavity contains a small number of large spores. Fig. 30 is also a transverse section, but apparently made yet nearer to the upper extremity of the sporangium *above* the termination of the annulus. One solitary spore is seen within the internal cavity. The mean diameter of the two specimens, figs. 28 & 29, is ·02.

There can be no doubt that in these sporangia the annulus formed a conspicuous cap near the upper or free extremity of each sporangium. The spores are much larger than those of fig. 25, as is seen in figs. 31 & 32, which are drawn to the same scale as fig. 26. Each spore is about ·0023 in diameter, and consists of an outer cell wall (figs. 31 & 32, *a*) and an inner or primordial utricle (*b*). These sporangia are apparently of the type seen in the modern families of Gleichenieæ and Schizæeæ, but especially approaching those of the latter family. Somewhat similar sporangia have already been figured by CORDA associated with his *Senftenbergia elegans*, and most probably also in the case of his *Hawlea pulcherrima*. Speaking of the former plant, M. BRONGNIART says, "Mais quoique ce genre fossile se rapproche beaucoup du *Mohria*, il en diffère, non seulement par la forme générale de la fronde, mais surtout par les capsules, dont l'anneau élastique est formé, dans le *Mohria*, d'un seul rang de cellules linéares, radiées, tandis que dans le *Senftenbergia*, d'après M. CORDA, il est composé de plusieurs rangées régulières de cellules"*. The peculiar arrangement characteristic of *Mohria* and other allied genera, but which is lacking in *Senftenbergia*, is precisely that which is seen in my examples†.

* 'Tableau des genres des Végétaux fossiles.'

† I am indebted to Professor OLIVER, of the Kew Gardens, for examples of Gleichenieæ and Schizæeæ, with which he supplied me for the purpose of comparison with my fossil specimens. This is only one amongst several instances in which my applications for assistance to the Kew establishment have received the most prompt and liberal responses.

M. CORDA's plants were obtained from the Bohemian coal-field. It is now probable that the remarkable group of the Schizæeæ is represented amongst our British Carboniferous ferns.

The next plants to which I would call attention bring us to one of the most debatable and earnestly debated of all the problems which the study of the Coal-plants has suggested. They are the Coniferæ, or, to employ a more comprehensive term, the Gymnospermæ. In his 'Prodrome d'un Histoire des Végétaux Fossiles,' published in 1828, M. BRONGNIART says of the Gymnospermous Phanerogams, "Aucune plante du terrain houiller ne paroît se rapporter à cette classe, à moins que quelques-unes des plantes que nous avons placées parmi les Lycopodes ne fussent des Conifères"*.

In 1838 WITHAM published his well-known memoir "On the Internal Structure of Fossil Vegetables found in the Carboniferous and Oolitic Deposits of Great Britain." In this he described a number of plants which he arranged in two genera, *Pitus* and *Pinites*. The former genus was one of his own institution †. The latter he adopted from the authors of the 'Fossil Flora of Great Britain,' who, in their first volume (p. 9) figured and described portions of the celebrated Craigleith Tree under the name of *Pinites Withami*. WITHAM also inclined to the belief that his *Anabathra pulcherrima* was a plant of Coniferous affinities. I have already pointed out, in a previous memoir ‡, that this latter plant was undoubtedly a Diploxyloid *Lepidodendron*. As to the remainder of WITHAM's plants I have tried in vain to form an accurate conception of their true character. Unfortunately WITHAM was wholly ignorant of the distinction between two very different classes of markings seen on the surfaces of prosenchymatous fibres, cells, and vessels. He evidently confounded the reticulations, which are merely deposits within and in close union with the cell-wall, and which are mere modifications of true spiral tissues, and the *disks* seen in Conifers and Cycads, and which, as is now well known, are lenticular spaces connecting two contiguous fibres. Accurately made tangential sections, in which the true medullary rays are intersected at right angles to their course, also exhibit sections of these lenticular cavities, appearing like very delicate vertical lines of chain-work. Of this eminently characteristic difference between two varieties of structure WITHAM knew nothing, as is demonstrated by his typical, tangential sections of recent examples represented in Plate 2. figs. 3–6 & 9, in which no traces of these intervascular structures are shown. I have no doubt that some of his supposed Conifers belong to the groups of plants which I have described in my fourth memoir § under the names of *Lyginodendron* and *Heterangium*, which I believe to be Cryptogamic genera ‖, whilst others doubtless do belong to the group which palæontologists

* *Loc. cit.* p. 175.

† *Loc. cit.* p. 38.

‡ Phil. Trans. 1872, pp. 299 & 309.

§ Phil. Trans. 1873, p. 379 *et seq.*

‖ Even LINDLEY and HUTTON had strong doubts respecting the coniferous character of WITHAM's stem, which in their 'Fossil Flora' they designated *Pinites Withami*. They say, "Notwithstanding the great similarity between the transverse sections of this wood and those of recent Coniferæ, and notwithstanding the total absence of ducts in what seems to have been a tree having an exogenous structure, yet that as the very remarkable still regard as the nearest relatives of the modern Conifers that the Coal-measures have yet furnished.

In September, 1851, I laid before the Literary and Philosophical Society of Manchester a memoir "On the Structure and Affinities of the Plants hitherto known as *Sternbergiæ*." Dr. DAWSON, of Montreal, had previously shown* that some fragments of wood "much resembling the wood of the Coniferæ" had internal "stony casts having irregular and often large transverse markings." In my memoir referred to I arrived at the conclusion that *all* the Sternbergian specimens hitherto found in our British Carboniferous deposits were casts of the internal pith-cavities of stems and branches belonging to ENDLICHER'S genus *Dadoxylon*, a conclusion which more than twenty years of further research has thoroughly confirmed. CORDA, in his classic volume, had previously figured and described, under the name of *Lomatophloios crassicaule*, a Lepidodendroid plant with a Sternbergian pith-cavity, and Dr. DAWSON believes that a similar pith is characteristic of some Sigillarian stems which he has discovered in the Coal-measures of the Dominion; but British observers have hitherto failed to detect any similar Lepidodendroid or Sigillarian forms in our Coal-measures. I repeat that every fragment of *Sternbergia* hitherto found in our Islands, the surrounding tissues of which show satisfactory indications of structure, belongs to the genus *Dadoxylon*.

In 1849 M. BRONGNIART published, in the 'Dictionnaire Universel d'Histoire Naturelle,' his very important "Tableau des genres de Végétaux Fossiles." On comparing his views as enunciated in this memoir with those embodied in his earlier 'Prodrome,' we find that they underwent a vast change, so far as the question of Carboniferous Gymnosperms is concerned. In his later publication he included in that group *Calamodendron*, *Asterophyllites*, *Sphenophyllum*, *Annularia*, the entire group of *Sigillariæ* with their Stigmarian roots, the *Diploxylons* of CORDA, the *Medullosæ* of COTTA, and a number of other less important plants. It is not necessary to say that I altogether reject these arrangements. I have, in previous memoirs of this series, given my reasons for believing that the *Calamodendra* are all Equisetacean, that *Sigillaria* and *Diploxylon* are Lepidodendroid, that *Asterophyllites* and *Sphenophyllum*, if not Lycopodiaceous, cannot possibly be regarded as Gymnospermous, and that *Medullosa* is certainly a Marattiaceous Fern. But M. BRONGNIART also included in that Gymnospermous group several of the recently established genera of Carboniferous plants, such as the *Pinites medullaris* and the *P. Withami* of LINDLEY and HUTTON, which he placed in his genus *Palæoxylon*. In like manner he placed the *Pinites Brandlingi* in ENDLICHER'S genus *Dadoxylon*, and the *Pitus primæva* and *P. antiqua* of WITHAM in ENDLICHER'S genus *Pissadendron*. These and other supposed fossil coniferous woods BRONGNIART threw into two groups according

organization of the walls of the woody tissue of recent Coniferæ does not exist in this fossil, but is supplied by another kind of structure of an equally unusual nature, the inference that this tree belonged to the coniferous tribe cannot be considered altogether just."—*Loc. cit.* p. 12.

* Proceedings of the Geol. Soc. London, No. 6, Jan. 1846.

to whether the individual medullary rays, as seen in vertical tangential sections, consisted of one or more vertical series of cells. BRONGNIART having unhesitatingly accepted all WITHAM's descriptions and figures, his conclusions respecting the British Carboniferous Conifers are as untrustworthy as I have shown those of WITHAM to be. Notices of various Carboniferous Conifers occur in Dr. DAWSON's numerous and valuable contributions to the history of Cryptogamic vegetation; but he more especially grapples with the complicated definitions of previous authors in his "Report on the Fossil Plants of the Lower Carboniferous Millstone-Grit Formations of Canada." In p. 15 of that report, published in 1873, after indicating the way in which various genera of supposed coniferous plants had been distributed and redistributed by preceding writers, he describes and figures the *Dadoxylon antiquius*, which species he had previously described in his 'Acadian Geology;' a second species, also described in the 'Acadian Geology,' appears under the name of *Dadoxylon Acadianum*; a third is the *D. annulatum*; and a fourth is the *D. materiarium*, all of which are in like manner described in the writer's 'Acadian Geology.'

In August, 1869, I published a brief memoir in the 'Monthly Microscopical Journal,' in which I endeavoured to distinguish those stems in which the vessels were merely reticulate modifications of scalariform tissue, from those in which vessels or fibres exhibited true bordered pits or disks, such as are seen in the *Coniferæ* and other plants. In making an examination of recent stems, in connexion with that inquiry, my attention was arrested by some peculiarities in the vascular tissues of the *Cycadeæ*, a further study of which led me to the following conclusion:—"I have for some time been convinced that the discigerous vessels in *Cycas revoluta*, usually supposed to be of a coniferous type, were in some measure modifications of scalariform tissue. I have now found numerous vessels from the above plant which render the fact certain, since they exhibit discigerous tissue at one end of the vessel, whilst it becomes scalariform at the other extremity. My views on this point, when promulgated in private correspondence with some botanical friends, were at once rejected by them; but there is no reason for questioning their correctness. I was not aware, however, when I came to this conclusion, that I had been anticipated by the late Mr. DON, in a paper which he read before the Linnean Society in 1840. The question is of some importance, since it affects the possibility of a glandular coniferous fibre being developed out of a reticulated one"*. The true nature, and still more the origin, of these disks seen on coniferous fibres was exceedingly obscure up to a very recent period. Even HENFREY, in his 'Elementary Course of Botany,' speaks of "the existence of a lenticular cavity *between the contiguous outside walls* of pitted cells, as in Coniferæ (fig. 480)," and in the figure referred to he represents this lenticular cavity as having walls of its own, in addition to those of the two vessels between which it is located. It is obvious that these views respecting the nature of the bordered disks made the passage of reticulated into discigerous fibres very difficult of apprehension. But the appearance of SACHS's

* Monthly Microscopical Journal, August 1, 1869, p. 69.

'Lehrbuch der Botanik' altered the position of this question. SACHS showed (*loc. cit.* p. 25) that what is essential in the formation of these pits is primarily due to a mere variation in the deposition of the lignine *in the interior* of the cell or fibre, corresponding exactly in this respect with what takes place in the formation of a scalariform or spiral vessel, the only material difference being found in the location of these internal deposits and their greater or less close adhesion to the cell-wall within which they are formed. This is a very different thing from what it was believed to be when it was supposed that the lignine was deposited *inside* the cells or vessels, whilst the disks depended upon something *external* to their walls. In the latter case the gradual transition from the one form to the other was unintelligible. *Now*, on the contrary, nothing is more simple.

This physiological inquiry is not foreign to the subject of this memoir, but forms an essential part of it, since it gives us some clue, helping us to determine what may and what may not have been Coniferous plants. It affects the position in which special genera should be located, besides having a very important bearing upon the general question of evolution. Though at present unable to see my way to the acceptance of this doctrine in connexion with the origin of extinct plant forms, I am anxious to place on record all the facts which my studies in palæo-botany supply which appear to support that doctrine. Hitherto the difficulty of explaining the transition from the ordinary types of fibro-vascular cells and vessels to that of the discigerous types has been one very great hindrance to my accepting the doctrines of the evolutionists in reference to fossil plants; this one difficulty, at all events, has now been removed. But its removal is also an important fact bearing upon another branch of the present inquiry.

M. BRONGNIART, Dr. DAWSON, and Professor NEWBERRY have long held the view that many of the *Sigillariæ* and a large group of allied stems were those of Gymnospermous plants. The two first distinguished palæo-botanists also believe that many of the forms of Calamites, which they recognize under the name of *Calamodendron*, are also members of the same Gymnospermic family. But these observers have arrived at their conclusions on somewhat different grounds. M. BRONGNIART has done so from his accurate recognition of their exogenous structure and mode of growth—features which, as I think I have demonstrated, are to be found in many indisputably Lepidodendroid plants. Hence, I cannot accept M. BRONGNIART'S conclusions as a legitimate deduction from the evidence upon which the distinguished Frenchman made them rest. Dr. DAWSON has told us, in a succession of memoirs, that he has arrived at very similar conclusions to those adopted by M. BRONGNIART, but through a somewhat different line of argument, the chief points of which are prominently set forth in his memoir "On the Structure and Affinities of *Sigillaria*, *Calamites*, and *Calamodendron*," published in the Quarterly Journal of the Geological Society of London for May, 1871. In that memoir he describes a stem in which the pith was Sternbergian, whilst the inner part of the vascular cylinder "consists of scalariform tissue, passing towards the outer surface into pseudo-scalariform, reticulated with pores, and discigerous." The accuracy of this description of a Sigillarian stem appeared to most British botanists so little probable and so little in accordance with recognized views as to the relations of scalariform to discigerous tissue that it failed to meet with acceptance. The chief difficulty which stood in the way of my adopting it was the entire absence from our British deposits, in which structureless *Sigillariæ* are so common, of any stems with a structure corresponding to it; but it must be admitted that, as yet, I have obtained no trustworthy specimens which I could, *without possibility of doubt*, affirm to be the true vascular axes of *Sigillariæ*. Portions of the bark are, as I have shown in one of my previous memoirs, sufficiently common, whilst decorticated vascular axes of Diploxyloid types are also far from rare; and seeing that many of these latter approach so near to the Sigillarian stem figured by BRONGNIART as well as, in all essential features, to that of *Sigillaria spinulosa* described by MM. RENAULT and GRAND'EURY*, it appeared to me extremely probable that some of these Diploxyloid axes belong to true *Sigillariæ*. In no one of these have we found a trace either of a Sternbergian pith or of the discigerous fibres in the exterior of the vascular axis which Dr. DAWSON has described as existing in his American examples. Nevertheless we must not conclude from this that Dr. DAWSON is in error, either in the accuracy of his description or in his belief that the stems described are those of true *Sigillariæ*, even though we may be convinced that these plants are Cryptogams and not Gymnosperms, as Dr. DAWSON thinks probable†. That Sternbergian piths *may* occur in Lycopods, as well as elsewhere, is shown in the case of CORDA'S *Lomatophloios crassicaule*; and, if SACHS is right in his explanation of the real structure and origin of the bordered disks of coniferous fibres, there is no morphological or physiological reason why the barred vessels forming the *inner* zones of the axis of a Lepidodendroid plant should not gradually change towards its periphery, first into what Dr. DAWSON terms pseudo-scalariform tissues, and still more externally into discigerous ones. But even admitting all this to be true in the fullest sense that Dr. DAWSON would demand, it does not bring me one bit nearer to the admission of *Sigillariæ* amongst Gymnospermous plants, or to their separation from the *Lepidodendra*. With the bark of our common ribbed Lancashire *Sigillariæ* we are now thoroughly familiar, and its very remarkable structure is as identical with that of the *Lepidodendra* as it can possibly be, whilst it is as different as possible from any known Gymnosperms, recent or fossil. In one of his latest popular works, speaking of *Sigillariæ*, Dr. DAWSON says, "Some regard it as a Gymnosperm, others as a Cryptogam. Most probably we have under this name trees allied in part to both groups, and which, when better known, may bridge over the interval between them"‡. Dr. DAWSON has recently forwarded to me his latest definition of *Sigillaria*, with permission to make use of it. It is as follows:—

* Mémoires présentés par divers Savants à l'Académie des Sciences de l'Institut National de France, tome xxii. no. 9.

† In a letter to the author, dated April 14, 1876, Dr. DAWSON says, "I have never held that any *Sigillariæ* are Conifers, but only that *some Sigillariæ* in their tissues closely resembled the Cycads and were Gymnosperms. I have also held, on the evidence of form of scar and leaf, that some so-called *Sigillariæ*, especially those of the *Clathraria* type, are of humbler structure and allied to Lycopods."

‡ 'The Story of the Earth and Man,' p. 124.

Genus SIGILLARIA.

Roots stigmaroid.

Trunk Sternbergia pith. Double woody cylinder pseudo-scalariform within and discigerous without, with medullary rays and oblique pseudo-scalariform leaf-bundles. Inner bark thick, cellular, with many bundles of prosenchymatous tissue. Outer bark dense, cellular *.

Leaf-bases hexagonal or elongated, or confluent on a vertical ridge, placed in vertical rows, except in young branches.

Leaf-scars hexagonal or shield-shaped, with three vascular scars ; the two outer largest.

Fruit-scars in transverse rows or bands, each with a central vascular scar.

Fruit Trigonocarpon, borne in racemes attached to the fruit-scars.

If Dr. DAWSON is correct in making this last statement in reference to *Trigonocarpon*, all doubt as to the Gymnospermous character of *Sigillaria* would be at an end, because we cannot possibly conceive of that seed belonging to any Cryptogamic plant. But I have yet seen no evidence whatever, either in his memoirs or in those of Professor NEWBERRY, who entertains the same opinions as Dr. DAWSON does, that any such relationship exists. Under these circumstances, in the subsequent pages I must include *Trigonocarpon* amongst the Gymnospermous plants, but must exclude the *Sigillariæ*, and still regard the latter as Lepidodendroid Cryptogams.

In my original memoir on the *Sternbergiæ*, published in the 'Transactions of the Literary and Philosophical Society of Manchester' in 1852, I described a small branch of a *Dadoxylon* from Coalbrookdale, for which I was, many years ago, indebted to Professor PRESTWICH. This specimen continues to be incomparably the most perfect example of its class yet discovered; hence I have felt it necessary carefully to restudy my sections of it, and now proceed to give the results of this renewed examination.

The specimen has been a young branch about half an inch in diameter. In this respect it corresponds with many that we find in the Oldham deposits; but the interest of the specimen lies in the exquisite manner in which all the tissues are preserved.

The medulla (figs. 33, *a*, & 35, *a*) has a diameter of about ·3, and consists of a regular, but rather thick-walled, parenchyma, the cells of which are about ·0025. In the vertical section (fig. 35) these cells are seen to be somewhat depressed vertically, their horizontal diameter being greater than their vertical one. They also exhibit a tendency to arrange themselves in vertical lines. This medulla is an undivided mass for a thickness of about ·03, but more internally it separates into innumerable thin laminæ, which are very conspicuous in the broken fragments of the specimen, but of which I have found it impossible to prepare microscopic sections, owing to the extremely friable nature of the ferruginous matrix occupying the interlaminar spaces. This matrix appears to consist of

* Since the above description was written, Dr. DAWSON has discovered a *Sigillaria* with a true Diploxyloid axis, corresponding exactly with those which I have already described and with the *Anabathra* of WITHAM. This discovery would probably lead him to modify some of the above definitions.—June 18, 1877.

small botryoidal granules (some infiltrated) of ferruginous oxide, which have loosely and imperfectly filled the cavities separating the medullary disks. This explanation is the more probable since the entire specimen was originally enclosed in a nodule of the ordinary Clay Ironstone so common in the Coal-measures of Coalbrookdale. There is no doubt whatever that these cellular laminæ are identical with those of the ordinary forms of *Sternbergia*, only more closely aggregated than is usual with specimens of larger size.

The ligneous part of the stem is a cylinder of wood-fibres (figs. 33 & 35, *b*), the thickness of the cylinder from the medulla to the bark being about ·05. At its innermost surface, *b*′, we find a few very small, but distinct, barred vessels occupying the position of a medullary sheath, which element of exogenous stems they apparently represent: three of these vessels are enlarged in fig. 37. In the transverse sections the vessels are arranged in very regular radiating lines. They have a mean diameter of ·0012, which corresponds with those of *Salisburia adiantifolia* and *Araucaria Braziliensis*; but their walls are thinner than in the corresponding twigs of either of those living Conifers. These vessels terminate in fusiform extremities. Their length varies, but many of them are not more than ·012; others are somewhat longer. These proportions show that the tubes do not differ materially from the ordinary woody prosenchyma of living Conifers. The magnified representations (figs. 38 & 39) show that the two surfaces *which are parallel with the medullary rays* are marked with very regular geometric areolæ, each of which has a mean vertical diameter of ·0005. Their transverse diameter varies. Sometimes a single row runs down the centre of each fibre, each areole then stretching across almost the entire diameter of that fibre. In others, as in fig. 39, which represents their ordinary arrangement, we have two such rows. Occasionally, as seen in fig. 38, there are three vertical series of these areolæ. On turning to the tangential sections, fig. 40, we obtain in the beaded lines, *g*, *g*, clear proof that these areolæ are not those of ordinary reticulated fibro-vascular tissue, but true bordered pits, to the formation of which, as explained by SACHS, reference has already been made*. In the plant under consideration there is no central aperture in each of these areolar pits, such as is usually seen in living Coniferous plants; SACHS's explanation of their origin supposes that secondary deposits are formed within each fibre, but that there are thin circular spaces within each fibre in which the deposit does not rest upon the primitive cell-wall, but gradually rises up from it, like a circular dome, in the centre of which there remains a small, unclosed aperture, like that left for the reception of a skylight in a dome-shaped roof.

SACHS further shows that similar deposits take place at exactly corresponding points on the cell-walls of two contiguous fibres. Such growths would form two opposed semi-lenticular or plano-concave cavities, with the two thin coalesced cell-walls separating them. These latter become absorbed in living plants, so that the two plano-concave spaces become converted into one double concave one. In figs. 38 & 39 we see that no central aperture exists in each areole. Here nature has set the example to a builder

* Lehrbuch der Botanik, pp. 26, 27.

who gradually raised the walls of his dome, but who, instead of leaving a central aperture for a circular skylight, built up his brickwork to the very keystone of the closed arch. So far as my specimens throw light upon this physiological feature, most of our Lancashire *Dadoxylons* have been constructed upon this type with imperforate pits.

All the sections exhibit medullary rays. These are radially disposed lines of mural cells (figs. 35 *f*, 38 *f*), which cells are often cubical, having a diameter of from ·00125 to ·0007. In the tangential section (fig. 40) we see that these cells are arranged in single vertical lines. The number of cells in each vertical series varies from one (fig. 40, *f'*) to fifteen, such variable numbers being distributed indiscriminately over each section. Whilst the specimen under examination is remarkable for the preservation of the tissues just described, it is especially so in the case of the bark, which is unequalled by any other example of a Carboniferous *Dadoxylon* that I have met with; at the same time some of its outermost tissues are most probably wanting. The entire bark, as it now exists, is about ·05 in thickness, and is separable into two very distinct portions—an inner and an outer one. In the transverse section (fig. 34) the inner bark, *d*, appears as an indistinct tissue, in which traces of small cells, or of the orifices of oblique tubes, are visible. On the other hand, the outer layer (fig. 34, *e*) consists of a strongly marked form of parenchyma composed of cells of various sizes, the majority of them being about from ·002 to ·0025. On turning to the vertical section (fig. 36) we see that the inner bark, *d*, contains numerous parallel longitudinal lines, which are evidently the thin walls of tubes in which I can occasionally trace transverse septa. In all probability some of these latter are the representatives of *vasa propria.* They appear to have a diameter of from ·001 to ·0006. Some of these apparent tubes may be resin-canals. Whatever their physiological nature, the abrupt transition from them to the outer bark, as seen in the same section, is very marked. The latter tissue (fig. 36, *e*) is composed, as I have just observed, of coarse parenchyma, the cells of which are arranged in irregular vertical lines which tend somewhat outwards as the linear rows ascend through the stem.

Traces of divergent vascular bundles in this *Dadoxylon* will be considered after examining some similar organs in other specimens.

Fig. 41 is a vertical section of a specimen for which I am indebted to Mr. BUTTERWORTH. It consists wholly of the Sternbergian medulla of a *Dadoxylon*, and is drawn of the natural size of the original. At its upper part it exhibits extremely well the regular arrangement and unbroken continuity across the medullary cavity of the successive layers of the medulla. When I published my original memoir on *Sternbergia* I was uncertain whether or not these medullary disks were perfectly continuous, or whether they were perforated along the centre of the medullary axis. It is now certain that they were continuous. This specimen is further peculiar because of the two thick lateral masses of undivided pith (*a*, *a*), which, in this specimen, has evidently formed a rather thick layer of parenchyma lining the inner surface of the ligneous cylinder, the more central portion being split up into the characteristic Sternbergian disks. As we have already seen, this is the condition existing in the small Coalbrookdale specimen; but it is not the usual state of the pith in larger *Dadoxylons*, in which the Sternbergian laminæ are only enclosed within a very thin cylinder of undivided medullary parenchyma.

Fig. 42 is a transverse section of a large branch of the natural size. The medulla has been three quarters of an inch in diameter, and the entire stem, exclusive of its bark, was, when perfect, $2\frac{1}{2}$ inches in diameter, the ligneous cylinder having a maximum thickness of nearly an inch. Though the woody wedges composing this cylinder have been disturbed by mineralization, it is obvious that the medullary extremities of the larger ones projected into the medulla, as is so commonly the case in the branches of living Conifers (*e.g. Araucaria imbricata*), giving to the transverse section of the pith a stellate outline, large pointed rays of the latter being prolonged outwards between the convex extremities of the wedges. This specimen, for which I am indebted to JOHN AITKEN, Esq., of Bacup, came from the Halifax Bullion or Ganister bed at South Owram. The matrix is full of small Goniatites. The longitudinal section (fig. 43) of the above branch displays some peculiarities. Thus the medullary layer lining the vascular cylinder is very thin, soon breaking up into thin disks, but which are very regularly thickened at their circumferential portions; hence, in the vertical sections, each disk appears as a pillar standing upon a rapidly swelling base (fig. 47, *a*), which latter rests upon the interior of the woody cylinder (*b*). Then the laminæ of the several disks, instead of extending straight across the medullary cavity, subdivide into two, one half joining the corresponding half of the lamina above, and the other half being united in a similar manner to the lamina below. Thus there is formed a central pile of lenticular cavities, *a*, which alternate with a more marginal series of lenticular rings, a', a'.

Fig. 44 is a transverse section of a small branch from one of the bullions above the two-foot coal at Oldham; and fig. 45 is a vertical section of the same specimen. Its diameter is half an inch, of which the *medulla* occupies nearly ·19. This latter tissue not only divides into the usual disks, *a*, but each one of these again exhibits the strongest tendency to split up into numerous yet thinner layers, each one of which consists apparently of a single horizontal layer of cells*. It is obvious that in this instance the medullary cells have arranged themselves in successive vertical series of horizontal layers, and thus predisposed the tissue to break up into thin laminæ along the lines intervening between

* In pointing out the fact that the Balsam fir (*Abies balsamea*) has a discoid pith, Dr. DAWSON says:—"This modern *Sternbergia* is not produced by the mere breaking of the cellular tissue transversely by elongation of the fibre, but, as I pointed out many years ago in the case of the Coal-formation *Sternbergiæ* ('Canadian Naturalist and Geologist,' 1857), is a true organic partitioning of the pith by diaphragms of denser cells opposite the nodes, as in *Cecropia peltata* and some species of *Ficus*. The transverse diaphragms are composed of denser cells flattened horizontally, and they are, as in *Sternbergia*, accompanied by constrictions of the medullary cylinder."—*Nature*, May 15, 1873.

In my *Sternbergia* described above I find no evidence of two kinds of cells; but there is an unmistakable horizontal stratification of them which obviously approximates closely to Dr. DAWSON's description.

these layers, as well as along the fewer lines indicated by the thickened peripheral margin of each primary disk.

Fig. 46 is another transverse section from the same locality as the last, enlarged $4\frac{1}{2}$ diameters. It is peculiar inasmuch as it is one of the very few examples of a *Dadoxylon* in which I have seen concentric lines of growth in the woody zone. Two or three of these lines are sufficiently distinct. The more peripheral ones are more faintly marked.

There yet remains to be considered some peculiar divergent elements which exist in several of the specimens. These are best seen in the transverse sections figs. 44 & 46. In fig. 44, *g*, *g*, two narrow vascular bundles arise from near the innermost margin of the woody cylinder, and move in nearly parallel lines towards the periphery. Fig. 47 represents a portion of the vertical section fig. 45, enlarged fifteen times, but from a part not represented in the latter figure; we here see, at *g*, one of the bundles corresponding to those of fig. 44, *g*, *g*, intersected almost, though not quite, radially. We here discover that the vessels *b'*, bending outwards to form the bundle *g*, are derived from the innermost layer of the woody cylinder *b*. This orientation of these small bundles from the innermost layers of the wood is suggestive of their primary relation to leaves rather than to branches. A similar bundle departs from the interior of fig. 43 near *g*. Fig. 46 exhibits two of these pairs of bundles at *g*, *g*. This example is valuable, because it demonstrates, through their angle of divergence, that these bundles do not proceed to distichous peripheral appendages. Fig. 48 is part of a tangential section of the specimen fig. 44, enlarged 15 diameters. It has intersected two of these bundles at right angles to their direction, and is interesting as demonstrating their perfect twin-like character. The elementary tissues in the two bundles of this section are destroyed by mineralization, but the other examples clearly show that, when preserved, they consist of the ordinary discigerous fibres of the woody zone.

Fig. 49 is part of a tangential section of the ligneous zone of the Coalbrookdale branch, figs. 33–40, enlarged 62 times. The section was made close to the medulla. In fig. 38 we see a number of cells, *f*, identical with those of the medullary rays, and which, like the latter, doubtless constitute outward prolongations of the medulla. The fibres which are in contact with these cells, whether coming from above or from below, have their regular arrangement disturbed, so as to be cut through by the section; they become suddenly deflected, to make way for the cellular rays pursuing their horizontal course towards the periphery.

In the specimen, fig. 42, I find a solitary bundle given off from the inner margin of the ligneous zone at *g*; and in the vertical section of the same example, fig. 43, there is near *g* a bundle, the position and course of which correspond exactly with that seen in fig. 47. I find no traces of these bundles near the outer margins of such sections of large branches as I possess *.

The question arises, what is the destination of these bundles? On making a series of sections of the large-leaved *Araucaria imbricata* and of *Taxus*, I find in their young

* This bundle is not distinctly shown in the figure.

branches and twigs an abundance of precisely similar bundles; but in these plants they are single, not in pairs. They are unmistakably the leaf-bundles of the *Araucariæ*; and I have no doubt that such is also the character of those in the fossil branches. Their greater number in the small branches than in the larger and more fully grown ones, their invariable origin from the innermost surface of the ligneous cylinder, and their apparent disappearance in the peripheral portions of the larger branches, are all facts which point in the same direction. But why are these bundles arranged symmetrically in pairs? Either two bundles went to one leaf with a double midrib, or the leaves were arranged in pairs, either of which conditions may prove a possible means of identifying these stems with their foliage, not to be lost sight of by those who are working amongst the plant-impressions of the Coal-measures.

Fig. 50 is part of a radial section of a fragment of the ligneous cylinder of a *Dadoxylon* from Binns Cliff, in Burntisland, Fifeshire, for which I am indebted to my friend Mr. Grieve. Fig. 51 is the lateral surface of one of its fibres. Its structure differs in no material respect from those already described. The disks are sometimes in two rows, sometimes in three, as represented in fig. 51. Though coming from so much lower a geological horizon than those described in the preceding pages, I can detect no material difference between it and the *Dadoxylons* from the beds above the Millstone Grit.

Fig. 52 is a portion of another fibre from a fragment from near Oldham. In it each of the disks shows a vertical central line, partly crossed by an oblique one coming from above downwards, but which becomes very indistinct after it has reached the more distinct vertical one. This is the only example I have met with from the Oldham deposits in which a trace of the central spot so universal in the bordered disks of living Conifers is to be seen.

These facts appear to me to justify the conclusion that the specimens described really belonged to Gymnospermous plants allied to the Coniferæ. On comparing the sections of the Coalbrookdale specimen (figs. 33 & 36) with several recent forms we see at a glance how close is the resemblance between them. Thus, on examining a longitudinal section of a young branch of *Taxus*, we obtain an exact copy of fig. 36, the portion *d* being the liber, with its vasa propria and longitudinal resin-canals, whilst the parenchyma (*e*) is a phelloderm layer, the cells of which, in the recent stem, are full of chlorophyl grains. Young shoots of *Araucaria braziliensis* present similar resemblances. The bark of my fossil exhibits no development of the phellem layer seen in *Salisburia adiantifolia* and similar stems. The other tissues equally display characteristic resemblances. Thus the medulla is encased in a medullary sheath (fig. 35, *b'*), and this in turn is invested by a xylem layer composed of thick-walled prosenchyma, without any admixture of true vascular elements. Added to this we have the orientation of the leaf-bundles; and, finally, the fine fragment, in my cabinet, figured in my memoir in the 'Monthly Microscopic Journal' for Aug. 1869, plate xx. fig. 7, exhibits a thick branch passing straight through the wood of the stem, the layers of which latter surrounding the "knot" are thrown into undulating folds, exactly as would be the case with a piece of pine-wood that had been split by means of a wedge in a plane at right angles to the direction of the imbedded branch. Hence we have every reason for continuing to class *Dadoxylon* amongst the Gymnospermæ. I refrain from attempting to assign specific names to any of these fragments, being unable to discover any distinctive features whereby to characterize them.

The larger branches found in the Ganister-beds, associated with Goniatites, rarely display any trace of bark, and what little does exist is much disorganized—an additional indication that they have been drifted from a distance and long exposed to the action of water.

Seeds.—Most of the writers who have illustrated the Flora of the Coal-measures have described some form or other of what they supposed to be seeds; but nothing was known of the internal organization of any of these objects until Dr. HOOKER and Mr. BINNEY published their memoir on *Trigonocarpon**. In this memoir the *Trigonocarpon* described, which appears to have been the *T. olivæformæ* of LINDLEY and HUTTON†, is shown to bear a close resemblance to the true drupaceous seeds of *Salisburia adiantifolia.* Though no further light was thrown upon their internal organization, numerous additional forms of Carboniferous seeds were described and figured, especially from the Coal-formations of the New World, by Mr. NEWBERRY‡. This scanty knowledge was suddenly increased through the discovery of a thin bed of silicified rock at St. Étienne, one of the many results of the important researches of M. GRAND'EURY. This deposit abounds in fossil seeds, many of them being of considerable size and having much of their structure exquisitely preserved. Twenty-four species of these, distributed through seventeen genera, have been recently described by M. BRONGNIART§. In this important memoir, which was read to the Academy of Sciences in August 1874, the veteran author merely gives small outlined sketches of the various seeds; but it was his intention to make them the subjects of a separate volume, in which the minuter details of their organization would have been elaborately illustrated. Unfortunately his recent death has robbed the Geological world of what would have been one of the most important contributions yet made to Carboniferous literature.

M. BRONGNIART unhesitatingly determined that his specimens are true seeds referable to the Gymnospermous group of plants, though he discovers in them numerous secondary modifications which are not seen in matured recent Gymnospermous seeds. His remarks on one of these modifications are so important that I quote them here:—

"Dans plusieurs de ces graines, cette extrémité (supérieure) du nucelle, que j'ai

* "On the Structure of certain Limestone Nodules enclosed in seams of Bituminous Coal, with a Description of some *Trigonocarpons* contained in them." By JOSEPH DALTON HOOKER, M.D., and EDWARD WILLIAM BINNEY, Esq. Phil. Trans. vol. cxlv. part i. p. 149, 1855.

† 'Fossil Flora,' iii. t. 222. figs. 1, 3.

‡ 'Report of the Geological Survey of Ohio,' vol. i. part ii. Palæontology. "Descriptions of Fossil Plants," by J. S. NEWBERRY.

§ "Études sur les Graines fossiles trouvées à l'état silicifié dans le Terrain Houiller de Saint Étienne," par M. AD. BRONGNIART. 'Annales des Sciences Naturelles,' Botanique, 5e série, tome xx.

désignée dans d'anciens travaux sous le nom de *mamelon d'imprégnation*, a la forme d'un cône terminé par une sorte de bouton papilleux, et se montre ainsi avec l'aspect qu'il a dans beaucoup de graines lorsqu'on cherche le tissu mort et sphacélé de ce mamelon dans la graine mûre. Mais, dans plusieurs de ces graines, on peut même dire dans la majorité d'entre elles, et particulièrement chez celles qui s'éloignent le plus par leurs formes extérieures des graines des Conifères et des Cycadées, ce mamelon du nucelle présente une structure toute particulière, dont on n'a pas signalé d'exemple parmi les végétaux vivants. Le sommet du nucelle offre une cavité qui paraît circonscrite par un tissu cellulaire, taché et très-délicat, dont la disposition et la structure ne pourraient être bien comprises que par des figures exactes. Cet espace vide paraît s'ouvrir supérieurement au-dessous du micropile du testa. Cette communication est quelquefois bien distincte, mais souvent elle est masquée par le rapprochement des bords supérieurs de cette cavité, qui, au contraire, est largement ouverte du côté qui correspond à la partie supérieure du sac périspermique, dans laquelle devrait se trouver l'embryon. Dans un assez grand nombre de cas, on voit dans cet espace vide des graines elliptiques entourées d'une membrane bien définie, ordinairement assez colorée, quelquefois marquée d'un réseau régulier, qu'il est difficile de ne pas considérer comme des grains de pollen ayant pénétré par le micropile jusque dans cette excavation du nucelle au moment de la fécondation.

"Je suis, en effet, porté à penser que dans la jeunesse de la graine, lorsqu'elle était encore à l'état d'ovule, cette cavité du nucelle ne formait qu'une dépression, une sorte de cupule, dont les bords se sont ensuite rapprochés comme cela à lieu pour le testa lui-même, dont la large ouverture de la primine forme plus tard le micropile. Ce rapprochement des bords de la cupule nucellaire formerait ainsi une sorte d'endostome, qui différait seulement de l'endostome ordinaire, résultant du rapprochement des bords de la secondine, en ce qu'il serait formé par les bords du sommet du nucelle lui-même."

The peculiar structure here described is found developed in a remarkable manner in several of the seeds which I have obtained from the Coal-measures of Lancashire and of Burntisland. At the same time there is one remarkable difference between my examples and the French ones. Most of the latter are large and conspicuous objects. With the exception of *Trigonocarpon* mine are of small size. Most of them also exhibit features so peculiar to themselves that, with one or two exceptions, I am unable to locate them even in the genera established by M. BRONGNIART. That author throws his forms into two groups, in one of which the seeds are more or less flattened and bicarinated, whilst in the other the transverse section is either a circular one, or exhibits three, six, or eight radiating elements symmetrically disposed around a common axis. So far as this method of grouping goes, it is applicable to my own examples; but since one of my circular forms exhibits the peculiar structure described in the words of M. BRONGNIART which I have just quoted, in the most remarkable manner, I will reverse his order of arrangement, and deal first with the seeds belonging to his second division.

The first seed which I will describe is one to which I propose to assign the generic name of *Lagenostoma*. Though it is rare in our Lancashire nodules, yet it is the one which I have found most frequently, with the exception of the *Trigonocarpon*. Owing to their small size I found it impossible to make a linear series of sections of each seed; and yet nothing could be more misleading than any isolated section is, whether longitudinal or transverse. Hence I was led to adopt what I have found to be a most useful method of examination. I ground down each seed slowly and with the utmost caution, and then carefully sketched the various characteristic appearances as they presented themselves during the progress of the grinding process. The adoption of this plan rendered it almost impossible for any important feature to escape my eye. At the same time the more important of these appearances are permanently illustrated in my cabinet by the adoption of another method which is rendered possible by the peculiar mineralization of these seeds. On reaching any structure for which it seemed desirable to retain an available voucher, I affixed the surface with balsam to a microscopic glass slide in the usual manner. I then ground away the opposite side of the seed until I arrived at a repetition of the appearances on the presentation of which my first grinding had been arrested. Having thus obtained a second verification of these appearances I advanced slowly until I reached the centre of the seed, which I protected in like manner by a covering of balsam and thin glass. Thus many of my specimens exhibit *two* sections, a central and a tangential one, both sections being examined as opaque objects by means of reflected light. The various tissues being generally dark-coloured and carbonaceous, whilst their cavities have been filled with white, infiltrated carbonate of lime, nothing can be more beautifully distinct than many of these specimens are when thus examined. Most of the specimens have been of my own finding; but I am indebted to Mr. BUTTERWORTH for an example of a *Trigonocarpon* and a *Lagenostoma*, and also to Mr. NIELD for a specimen of each of these genera, which specimens these indefatigable auxiliaries kindly allowed me to grind away, sacrificing their treasures in the interests of science.

In its perfect state the seed under consideration has the form of a nutmeg, being so broadly ovate as to approach the figure of a sphere. Its length is about ·16 and its breadth about ·1. At its upper extremity there appears to have been a slight central prominence, in the middle of which was the micropyle.

The first series of figures of *Lagenostoma* to which I would call attention represent successive sections made from Mr. BUTTERWORTH'S specimen. Fig. 53 is a rather obliquely transverse one made near the extreme micropylar end of the seed. *a* is a part of the dense testa; *d* is the uppermost extremity and central micropilar orifice of the peculiar flask-shaped cavity which I propose to designate the *lagenostome*; at *a'* we have the opposite half of the testa detached from *a* by pressure, and also intersected lower down in the seed than at *a*. We have here some crenulated outlines, *e*, becoming separated from the testa. In fig. 54, which is a section made yet a little lower down in the seed than 53, we find that the testa (*a*) has its internal surface regularly crenulated, whilst the lagenostome (*c*) appears as a small mass of parenchymatous cells, enclosed in a firm and well-defined membrane. The crenulated arches at *e*, springing from the portion of the testa at *a'*, have now increased in size. Fig. 55 is the third of this descending series of sections. We now see that two of the crenulations of the testa, at *e*, *e*, are assuming the form seen in fig. 53, *e*, whilst those at *e'* have now wholly detached themselves from the testa, *a'*, with which they were connected in figs. 53 & 54. The fourth section (fig. 56) now shows the testa *a* as a strong well-defined membrane of uniform thickness, whilst the crenulated outlines, *e*, of fig. 55 are now yet more entirely separated from the testa.

The value of this unique, though crushed, fragment lies in the clear proof which it affords us that the remarkable structure *e*, *e'*, which I propose to designate the *canopy* of the *lagenostome*, originates superiorly in the hard testa of the seed. Fig. 57, which represents a portion of the testa *a*, with the crenulations of the canopy *e* intermediate between the sections figs. 55 & 56, further demonstrates the origin of some other curious structures seen in sections to be described. At *a'* a cross bar of the testa unites that structure with the centre of each of the crenulated curves of the canopy *e*. In the other crenulations this bar is imperfect, only projecting from the testa like a tooth and not reaching the concavity of each crenulation. It is now, in fact, a small projecting ridge running down the inner surface of the testa, but which has disappeared before reaching the section 56, *a*. Figs. 58, 59, 60, & 61 represent a series of four vertical sections of another specimen made in parallel planes. Fig. 58 is made nearly midway between the most prominent lateral surface of the seed and its centre. Fig. 59 is made midway between fig. 58 and fig. 60, which latter has been carried exactly through the central axis of the seed; whilst fig. 61 is from a plane nearly corresponding with fig. 59, but on the opposite side of the seed to the latter section. Fig. 58 exhibits the testa *a*, which appears to have been a hard, dense, sharply defined structure, having a thickness of from ·01 to ·005, but usually having a mean thickness of ·006. I have not been able accurately to determine its composition, but there are indications that it consists of an assemblage of oblong cells. Immediately within it is a second and much thinner membrane *f*, but which obviously has adhered closely to the inner surface of the testa, as is shown by the numerous irregular shreds of tissue which still link the two together. I have designated this the *nucular* membrane. This term seems conveniently to represent M. Brongniart's term "membrane nucellaire." Within this again is the third membrane *g*, which is also extremely thin. This I regard as the membrane immediately investing the endosperm, the "membrane périspermique" of M. Brongniart.

In fig. 59 all these tissues reappear at the lower part of the seed, as in fig. 58; but at its upper part we find new conditions. The endospermic membrane *g* is there removed much further from the testa than at its opposite end. The nucular membrane *f* splits into two portions at *f'*, *f'*. The outer layer, *e*, *e*, ascends towards the upper part of the testa, where it is inflected into four or five crenate curves, the concavities of which are directed towards the inner surface of the testa, the outermost ones on each side being the largest. Within this structure, which I have designated the *canopy*, we find another space partly filled by a very delicate parenchyma, *h*, and enclosed superiorly by the innermost, *c*, of the two layers into which the nucellar membrane splits at *f'*, *f'*.

In fig. 60 definite relationships become assignable to each of these tissues; *d* clearly represents the position of the micropile, immediately below which we have the flask-shaped cavity, *c'*, which I have designated the lagenostome, the *cavité pollinique* of M. BRONGNIART. This cavity is bounded by a thin but very well-defined membrane, *c*. Its length, from the surface of the testa at the micropile *d* to the base where its walls appear to converge, is about ·04. In its interior is a mass of very delicate and regular parenchyma, *h*, the densest portion of which extends upwards into the neck of the lagenostome towards the micropile, but which neither here nor yet lower down entirely fills the cavity of the lagenostome. The single nucular membrane *f* subdivides at its upper portion into three parts; one of these, *f'*, is deflected on each side so as to become united with the upper part of the endospermic membrane at *g'*. The second one, *f''*, proceeds upwards and inwards, on each side, to unite at an acute angle with the lower part of the wall of the lagenostome. A third part passes upwards, on each side, to form the canopy *e*. This latter structure appears in this specimen as if it was a membrane of considerable thickness; but such is not the case. This structure is thrown into remarkable longitudinal folds, and the section has here cut through the membrane in the superficial plane of some of these folds. Its thin sharp edge can readily be discerned in the original specimen. The endospermic membrane, *g*, is here seen to be detached some distance from the base of the lagenostome; but this will be shown not to have been the normal condition of the seed. A faint line connects the two sharp basal angles formed by the walls of this lagenostome; but this line has evidently not been a continuous tissue, but merely some minute and detached organic atoms which have been torn from some other tissue upon which the base of the lagenostome rested. So far as this section is concerned the centre of that base has been an open one.

Fig. 61 is a tangential section which has passed through the oblate sides of the lagenostome but has not intersected its narrow neck. In its leading features this section corresponds with fig. 59. Thus we have the testa, *a*, connected with the nucular membrane, *f*, by numerous shreds of tissue. That membrane divides at its upper part, on each side, into three layers, as in fig. 60, whilst at its upper part it further exhibits the crenulated contour of fig. 59; but here the crenulated curves are but three in number. The thin wall (*f''*) of the lagenostome *c'* is now seen to exhibit a clear wavy outline, whilst within the interior of the cavity we have a well-defined mass of parenchyma (*h*). This being an important section I have, in fig. 62, enlarged the upper part of it to 80 diameters. The testa (*a*) exhibits the three crenulations *a'*, *a'* which are just detaching themselves to form three of the folds of the canopy *e*. The wavy outline of the wall of the lagenostome appears at *c*. The nucular membrane has united itself to the endospermic membrane at *f*; but at *f'* traces of the separation of these two membranes present themselves. At *g* the nucular membrane seems to be firmly adherent to the delicate parenchyma (*h*) of the lagenostome, whilst that parenchyma has shrunk away from the lateral wall (*c*) of the cavity in a very regular manner, leaving an open space (*c'*) all round the cellular mass. This last point is, as we shall shortly perceive, an important one.

Figs. 63 to 68 represent a second consecutive series of sections of another example of *Lagenostoma ovoides*, of which fig. 67 is the central one. This specimen exhibits some new features. Fig. 63 is the most peripheral section. Here we see the testa (*a*) evidently deprived of some of its outer portions; hence the apparent reduction of its thickness. The specimen was almost wholly detached from its matrix before I became aware of its nature; hence part of the testa was left adherent to the stone. In this example also the perispermic membrane has either disappeared altogether, or it is in close contact with the surrounding nucular membrane *f*. At *e* the section has passed nearly in the plane of several folds of the canopy. Fig. 64, *e*, shows two of the folds of the canopy intersected longitudinally, whilst a third intermediate one has been crossed tangentially, forming the central loop in the section. In fig. 65 the central fold of the canopy (*e'*) has been divided close to the micropyle, bringing into view, at *c*, a tangential section of the wall of the dilated portion of the lagenostome. In fig. 66 we have nearly the same appearance as in fig. 65, only the section has now laid open the cavity of the lagenostome (*c*). Fig. 67 is, as already stated, the central section of the series, and since it shows some instructive features at its upper extremity I have given an enlarged sketch of this portion of it in fig. 69. Fig. 68 is also important. It is obvious that the structures *e*, *e* are the boundary walls of the canopy, whilst at *e'* we have two intermediate folds cut off near the micropyle. At *a'*, *a'* the inner portions of the testa have been detached from the outer ones, which latter have adhered to the matrix (*a*). In the centre of the seed is a dark-coloured patch which looks like an embryo-sac, but I believe it to be merely an effect of mineralization. At *i* we have an organic thickening of the nucular membrane uniting it with the testa *a*, and projecting from the same part we have the cellular mass *k*, which is either a funiculus or a small portion of the foliar or peduncular structure upon which the seed has been planted in a sessile manner; whichever was the case we have here clear proof that *Lagenostoma ovoides* was an orthotropous seed.

Fig. 69, which represents the upper part of fig. 67, enlarged 80 diameters, exhibits the testa (*a*) split into two layers at *a'*, two folds of the canopy at *b*, *b*, and the upper part of a third intermediate fold intersected tangentially at *b'*. The latter one hides the narrow upper portion of the lagenostome *c*. In this specimen we have a clear demonstration of the composition of the membrane forming the canopy. It consists of a single layer of prosenchymatous cells, and other examples show that this is also the structure of what I have called the nucular membrane, of which the canopy is but an extension. The lagenostome is again seen to be largely occupied by a mass of delicate parenchyma. Assuming that the nucular and perispermic membranes are united in this specimen, it appears that the base of the lagenostome rests directly upon the upper end of the perisperm or nucleus, and that the detachment, through contraction or other causes, of the base of the lagenostome from the perispermic membrane in fig. 60 has caused the nucular membrane to split up into the multiplied layers seen at *f'*, *f''* in that section.

Immediately below the right hand side of the base of the lagenostome in fig. 69 there are traces of an indentation (*x*) into the substance of what I presume has been the nucleus, and which contains some dark-coloured granules. These have most probably been derived from the lagenostome, yet the position they occupy may be merely an accidental one.

Fig. 70 represents the upper extremity of another very instructive specimen, enlarged 80 diameters. A portion of the testa remains at *a*. The nucular membrane (*f*) is in near approximation to the testa, whilst the perispermic membrane (*g*, *g*) is now so much distended as almost to occupy the entire cavity of the seed. At *f'*, *f''* we again see, as in figs. 60 & 61, the nucular membrane *f*, splitting into three layers. On the left hand, one of these (*f* 1) goes to the upper surface of the perispermic membrane (*g*), the second (*f* 2) goes to the base of the lagenostome (*c*), whilst the third and uppermost (*f* 3) forms the canopy. On the right hand, the innermost layer (*f'* 1) first comes into contact with the perispermic membrane, but soon leaves it again, bending upwards so as to reach the base of the lagenostome. The second (*f'* 2) goes direct to the lagenostome, as on the opposite side; whilst, in like manner, the outermost layer (*f'* 3) again forms the canopy, additional shreds of which are seen on both sides, yet more externally. Here, again, the membrane of the canopy appears to be thick, but it is not so. Its true thickness is represented by the dark boundary line at the inner margins of *f'* 3 and *f* 3; the rest is merely a continuation of one of the folds seen perspectively, as in fig. 69.

The lagenostome is here very clearly shown to be open inferiorly so as to bring the base of its internal cavity into intermediate contact with the upper part of the perispermic membrane *g'*. But this fine section further demonstrates that the membranous wall of the lagenostome (*c*, *c*) is composed of prosenchymatous cells like those constituting the canopy and nucular membrane, whilst it differs altogether, as I shall be able to demonstrate, from the structure of the perispermic membrane, *g'*.

But the most interesting feature of this section appears in the interior of the lagenostome *c*. Its central portion is occupied by the usual delicate parenchyma, but in the vacant space remaining between this parenchyma and the prosenchymatous wall of the lagenostome are twelve or thirteen round clearly defined bodies (*l*, *l*), which are unquestionably identical with those seen by M. BRONGNIART, and regarded by him as pollen grains. These little spherical bodies have a mean diameter of about ·0023, and exhibit every appearance of being true pollen grains. We shall find them again in the next specimen to be described.

Satisfactory, and in some degree conclusive as all these several features of the vertical sections proved to be, there yet remained some important unsolved problems; but my materials were exhausted. I had no satisfactory evidence respecting the horizontal arrangements of the lagenostomal region. To relieve me from this dilemma my friend Mr. BUTTERWORTH sacrificed his only specimen of this seed; unfortunately it proved to be so crushed that it failed to give me all the information I sought, though, as we have seen from figs. 53–57, it revealed what none of my other specimens had done, the horizontal arrangement of the parts near the mouth of the micropyle. One other seed remained in the cabinet of my equally valuable auxiliary Mr. NIELD, and this he, too, resigned to the grinding-wheel. Nothing could be more satisfactory or rewarding to so true a lover of science than the results of this devotion. Unfortunately Mr. NIELD had ground away a little of the extreme micropylar extremity of his specimen before he became aware of its value. When it came into my hands the ground extremity exhibited the appearance seen in fig. 71, which, enlarged 15 diameters, reveals the exquisitely symmetrical arrangements characterizing the membranes in the lagenostomal region when undisturbed by pressure, mineralization, or the shrivelling of the tissues prior to fossilization. This seed was wholly detached from the matrix, which had, as is so usual, carried away with it the greater portion of the testa. Nevertheless the outline of its inner surface *a* is perfectly preserved. Within this testa we have the crenulated outline *e*, which represents the transverse section of the canopy, consisting of ten crenulated curves, the rounded concavities of which face outwards, where they are separated from each other by sharp projecting folds of the membrane, arranged in a regularly radiating order, but the angles of which do not reach the testa. Within this fluted canopy we have the upper part of the lagenostome (*d*), also fluted in correspondence with the canopy, though the inflexions of this membrane are much less prominent than are those of the canopy itself.

Fig. 72 is a second transverse section of the same seed made across the broadest part of the lagenostome, enlarged 30 times. At *a* we have a portion of the testa. At *e* is the canopy exhibiting the regular crenulated outline already described; we here see that it presents a sharply defined margin at its inner border, whilst externally it has a torn and shredded aspect, indicating a former attachment to the inner surface of the testa *a*. This attachment is further indicated by the innumerable delicate fragments of cellular tissue which occupy the concavities of the folds of the canopy. In the centre of each of those concavities there is a dark spot (*n*). I cannot detect at these points any specialized structure beyond traces of a few dark-walled cells, and it seems extremely probable that these may have been elements left behind for some purpose by the transverse bars (a') seen in fig. 57. On the opposite side of the seed (e') the regular crenulations of the membrane forming the canopy have disappeared, probably as the result of shrivelling prior to mineralization. At *c* we have a section of the wall of the lagenostome. We have already seen from fig. 70 that it was composed of prosenchymatous cells. We now find that it consists of a single layer of such cells.

Fig. 74 represents a few of the prosenchymatous cells composing the canopy, as seen in the specimen fig. 70. In fig. 72, *c*, these cells are intersected transversely; at *c*, c' we see indications of the regular crenulations which originally characterized this lagenostomal membrane, but which have here in a great measure disappeared, through shrivelling; mineralization also has somewhat modified its normal aspect at c''.

Near the centre of the lagenostomal cavity we have a small portion of the parenchymatous tissue (*h*) seen in the same position in so many of the other sections, only here it is reduced to an exceedingly small amount. Scattered throughout the open space surrounding this parenchyma are numerous small rounded bodies (*l*), apparently identical with those seen in fig. 70. These are the supposed pollen grains.

Fig. 73 is another section of the same seed, made parallel to fig. 72, only nearer the base of the lagenostome. The tissues reappear as in the last section, except that the upper half of the wall of the lagenostome, *c*, exhibits the crenulated figure of that membrane in a more regular manner than before, and at *g* we now see the uppermost surface of a portion of the perispermic membrane. The appearances presented here are extremely significant. This membrane is altogether different from those already described; a small portion of it, enlarged 175 times, is seen in fig. 75. It is apparently structureless, except that it is full of minute translucent spaces usually exhibiting sharply defined angular contours, and which look as if the membrane had been filled with minute crystals*, which I believe to have been the case, unless these objects were crystalloids, which is not improbable. It is perfectly obvious from this section that the prosenchymatous wall of the lagenostome did not extend across the base of the latter structure, but that, in its normal state, the cavity of that lagenostome was in direct contact with the membrane of the perisperm, and that consequently nothing intervened between the pollen grains in the lagenostome and the perispermic cells but this thin membrane. Thus it follows that in this seed the lagenostome (the "cavité pollinique" of M. BRONGNIART) has been formed by a separation of the nucular membrane from the perispermic one at the upper extremity of the perisperm.

I have entered upon the minute details of the preceding description because I believe this remarkable seed to be essentially a typical one. It appears to be much more elaborate in its organization than most of those described by M. BRONGNIART, yet it obviously belongs to the same class of seeds as those discovered by M. GRAND'EURY.

That no known recent seed corresponds exactly with these has already been pointed out by M. BRONGNIART. But that distinguished botanist read a brief memoir to the Academy of Sciences in Paris in September, 1875†, in which he indicated the probability, from observations which he had made upon the fertilized ovules of some recent Cycads, that *in their young states* the seeds of this class of living plants exhibit conditions not dissimilar from those found in the Carboniferous fossils; but the notice published in the 'Comptes Rendus' is too brief to contain the details needful for a thorough settlement of the exact degree of identity. On the other hand it appears to me very important that the early development of the fruit of the *Salisburia* should be studied in reference to this question. Dr. HOOKER long ago pointed out the many features in which this Chinese fruit resembled the fossil Trigonocarpons; but there is one peculiarity in it which he has not noticed, but which appears to bear upon the present inquiry. On opening the hard endotesta (fig. 76, *a*) of one of the dried seeds we discover immediately within

* This appearance is almost identical with that presented by the surfaces of the spicular sclerogen cells observed by Dr. HOOKER in the parenchyma of the stock of *Welwitschia mirabilis* (Trans. Linnean Society, vol. xxiv. pl. xii. figs. 5, 6).

† Comptes Rendus, tome lxxxi. no. 47.

that structure, and in close contact with it, the firm membrane (fig. 76, *f*) described by Dr. HOOKER. In its lower or chalazal half this membrane is much more dense than at the opposite end of the seed. In the former part it consists of a thin, almost structureless membrane, thickened by the addition of the numerous reticulated cells, already described by Dr. HOOKER, and derived from the innermost portion of the hard endotesta; but near the middle of the seed, not only do these cells disappear from the membrane, but the latter now splits into two layers—an inner one (f') which closely invests the perisperm, and an outer one (f'') which lines the endotesta, the subdivided membranes thus leaving a dome-shaped cavity between them. Fig. 76 is a diagram representing this arrangement, but exaggerating the distances beween the several tissues*. At all events the position of the cavity corresponds closely with that of my lagenostome, whether viewed in its relation to the nucleus or to its investing membranes.

When making a few observations on these seeds at the Bristol Meeting of the British Association in 1875, I proposed for a second seed the generic name of *Physostoma*; but since my only specimen of it does not exhibit its outer layer it may be better to unite it generically with the last species under the name of *Lagenostoma physoides*.

Having found but a single example of this very distinct seed I have only been able to study it under the two aspects represented in figs. 77 & 78. The former of these is a longitudinal section made nearly through the centre of the seed, and the latter is one made in the same vertical plane, but nearer to the periphery of the seed.

* Throughout this memoir I have employed the two terms *perispermic* and *nucular* to designate the two membranes usually found within the testa of these seeds. I have done so for the purpose of making my nomenclature harmonize with that of the late M. BRONGNIART's memoir on similar Carboniferous seeds from St. Étienne. At the same time I may point out not only the extreme difficulty of identifying these membranes with those of the seeds of living Cycads and Conifers, but also the objections which British botanists may reasonably entertain to the nomenclature employed. On the former point we must remember that during the long protracted development of the ovules of the varied members of the Cycadean and Coniferous families the equivalents of the spermoderm and embryo-sac undergo very important changes, rendering the exact comparison of the recent and fossil forms very difficult. The second difficulty referred to is equally important. British botanists apply the two terms perisperm and endosperm very definitely: viz. the former to the tissues of the nucleus, and the latter to the contents of the embryo-sac. The nomenclature of M. BRONGNIART has not recognized this distinction. He speaks of the "sac périspermique, dans laquelle devrait se trouver l'embryon." "Malgré l'altération des ces parties intérieures, on peut y reconnaître presque toujours deux enveloppes membraneuses; l'une, plus externe, naît au pourtour du chalaze ou sur sa surface supérieure, et se termine supérieurement par une extrémité conique qui correspond à l'orifice du micropyle du testa, mais qui en est souvent assez éloignée: c'est la surface du nucelle; l'autre, beaucoup plus altérée, libre et flottante au-dessus de la chalaze et se terminant à quelque distance au-dessous de l'extrémité conique de la précédente, correspond à l'enveloppe du périsperme."

These definitions make it clear that the "perisperme" of M. BRONGNIART is the endosperm of British botanists, whilst his "membrane périspermique" is the true primary embryo-sac. His "membrane nucellaire," on the other hand, is the spermoderm of other writers. With this explanation of the sense in which I employ M. BRONGNIART's terms, I can continue to use them in order to avoid confusion on comparing his descriptions of the St.-Étienne seeds with mine. At the same time a different use of these terms would have been preferable. —July 19, 1877.

As already observed, the outermost tissues of this seed are missing, and those of its micropylar extremity are also somewhat deranged. Its present entire length is about one sixth of an inch. Its nucleus (*n*) has a total length of ·09 and a maximum diameter of ·04, but a mamilliform projection exists at its micropylar extremity (*n*′), which is rather more than ·02 in length and rather less than ·02 in diameter. The nucleus is invested by a thick layer of prosenchymatous tissue (*b*), of which the cells are of great length; whether this tissue is an endotesta, or an extremely thick nucular membrane closely united to a perispermic one at its inner surface, I am unable to say; but I am inclined to adopt the latter explanation. Above the nucleus is a curious lagenostome, figs. 77, *c*, & 78, *c*. In fig. 77, which intersects the lagenostome through its centre, we see that this organ overlaps the mamillated extremity of the nucleus on every side, as if it were a soft bladder half full of water, allowed to rest upon and overhang the neck of one of the old-fashioned soda-water bottles. The upper extremity is imperfect in fig. 77, but it has apparently been prolonged upwards towards the micropyle *d*. The structure of this lagenostomal part of the seed is further illustrated by fig. 79, which represents another section of the lagenostome made so very close to fig. 77 as virtually to represent the same elements. The dark line *e*′, *e*′ is evidently the innermost portion of the tissue *b*, *b*. We see that this line passes downwards on each side of the nucleus to *e*″, *e*″, where it becomes deflected upwards, for a short distance close to the nucleus, *n*, after which it first bends rapidly outwards and then gradually inwards, forming the outer wall (*c*′) of the lagenostome *c*. At the upper part, especially where this membrane contracts to form the narrow neck of the lagenostome, we discover a cellular structure in its interior. In fig. 77 we see that the two lines *e*′, *e*′ are prolonged upwards in connexion with two masses of prosenchymatous tissue *e*, *e*, which latter I doubt not form several of the folds of a crenated canopy. Their aspect in fig. 78, *c*, *c*, *c* tends to confirm this conclusion, because we here have clearly shown their crenated outline. The circumstance that the prosenchymatous tissue, *b*, extends upwards in all the figures, to constitute the tissues of this canopy, seems to indicate that the whole of this structure is merely a thick nucular membrane, even the endotesta of the seeds being entirely absent. In fig. 77, *c*′, we have the outer wall of the lagenostome; but this section being virtually a tangential one, it has intersected that organ externally to the canal of the micropyle; hence it appears here as a closed cavity.

At fig. 79, which is an enlarged representation of the upper part of fig. 77, we have a mass of delicate parenchyma, seen on both sides of the seed, adhering to the inner wall of the lagenostome. This tissue has apparently extended as an interrupted ring round the interior of that organ. It is not seen in fig. 78; but it may have been deficient in the part of the lagenostome intersected in that section. I think there can be little doubt but that this parenchymatous tissue is identical with what I found in the lagenostome of *L. ovoides*, figs. 60 & 61, *h*. The nucleus *n* appears to be surrounded by an unusually thick perispermic membrane (*g*), which is continued round its mamillated extremity; but since this membrane merely appears as a dark outline, I cannot ascertain its structure; it seems to merge in the prosenchymatous tissue (*b*) with which it is invested. It is possible that this latter tissue may have formed the true endotesta. I have already shown that the nucular membrane of *Lagenostoma ovoides* appears as if little more than the innermost layer of the true testa, with which it is often more or less united by torn fibrous threads. Hence it is not improbable that in the seed under consideration all these structures, including the perispermic membrane, may have remained permanently adherent to each other, excepting near the apex of the seed, where the formation of the lagenostome involved their partial separation. This seed is also from the Oldham nodules.

The next examples belong to a somewhat different modification of this Carboniferous type; and since in both the two forms of it which I have found, what appears to represent the supposed lagenostome has a curious funnel-shape, I have assigned to them the provisional name of *Conostoma.* Figs. 80, 80*, & 81 are three sections of a distinct species from the Oldham nodules for which I propose the name of *Conostoma oblonga.* Fig. 80 is a longitudinal section made nearly through the centre of the seed, enlarged 15 diameters. The testa (*a*) is here thin throughout the greater part of the seed, but thickened at its apex. Fig. 80 *a* represents a longitudinal section of this latter part, broken away from the end (*p*) of fig. 80, and enlarged 35 diameters. Before I made a section of this fragment its inner or lower surface displayed a small central projection which fitted into the upper end of fig. 79. It is composed of numerous long narrow cells or fibres, arranged in parallel lines more or less perpendicularly to the surface of the seed at its apex, but which, at its sides, are curved, so that, at their inner extremities, the fibres verge towards parallelism with the surface of the nucleus. Some of these long, narrow cells have a diameter of ·001, others of ·0007. Each apparent fibre usually consists of more than one cell arranged in each continuous line. Their transverse subdivisions are most frequently square, at others they are oblique. Their internal cavities are filled with dark carbonaceous matter, hence the dark lines giving to the testa its fibrous aspect. The regularity of their arrangement, combined with the equally regular external outline of the seed, indicates that this testa has been hard and dry. I have not detected the micropyle in fig. 80 *a*, though I searched for it. It has probably been a minute one, and hence, having escaped my observation, the section has passed on one side of it. Within the testa, and running parallel with it, is a very thin membrane (*f*), which is apparently the nucular membrane. On reaching the level of the apex of the nucleus (*n*) this membrane splits into two layers. The outer one (f'') curves upwards and then inwards and downwards on each side, terminating in a little mass (*p*) of what appears to be cellular parenchyma, and which I presume is a dwarfed modification of a lagenostome. The inner layer (f') of the nuclear membrane proceeds horizontally inwards from each side, and then curves upwards so as to form a dome-shaped arch, the keystone of which is again the cellular mass (*p*). The breaks in its continuity in this specimen are obviously accidental ones. Within this nucular membrane and completely detached from it is the perispermic membrane (*g*), investing the nucleus (*n*). I have not been able to satisfy myself whether the lower layer of the nucular membrane (f') passes under the cellular mass (p) or whether it merely becomes merged in its cells; but I think that the former is its real condition.

Fig. 80* is a second longitudinal section made a little on one side of the last. To the left of the figure the nucular membrane (f) is closely united to the inner surface of the testa (a). Above the nucleus the nucular membrane (f) still subdivides into the two layers (f', f''), the former of which still forms a dome (c), whilst the latter is in contact with the testa. But the little point of parenchyma (fig. 80, p) is no longer seen, the section having passed on the outer side of it. In the interior of the nucleus (n) is some carbonaceous matter which appears as if composed of remnants of the perispermic cells.

Fig. 81 is a yet more lateral or tangential section which corresponds with the last, except that having passed on the outer side of the dome-like space (fig. 80*, c) it has intersected the shelf-like extension of the nucular membrane (f'), which here stretches across the seed in a straight line, whilst the upper part (f'') is in the closest connexion with the testa a'.

Fig. 86 represents a vertical section of what I believe to be a second example of this species. It has lost some parts of its testa (a), but on the other hand it adds somewhat to our knowledge of the arrangement of the membranes near the apex of the seed. The nucleus (n) is large, and is full of minute dark points, which at the first sight resemble microspores, but which I believe are merely remnants of the cells of the perisperm. At one point near the centre of the seed a mass of these cells is aggregated into a dark-coloured mass. Towards the lower part of the seed we only see traces of one membrane (f) investing the nucleus, and which I presume consists of the two membranes (f & g) of fig. 80 united into one. Above the apex of the nucleus we find this membrane splitting, like the membrane f in fig. 80, into the two portions f' and f'', which follow the same course as in the latter figure. But the small mass of cellular parenchyma (p) is now larger than it is in fig. 80, besides which we here find on each side of the seed a third membrane f''' f''', which has evidently followed the curvatures of the inner surface of the testa, and though now slightly detached to the left, its apex has evidently fitted into the base (d) of what has evidently been the micropyle. These conditions clearly demonstrate, what my own specimen failed to do, that the parenchyma (p) occupies the interior of a lagenostomal cavity. In all probability the peculiar cavity (c) was originally occupied by a mamillated prolongation of the nucleus. Fig. 86 clearly demonstrates that the nucleus entirely filled the cavity enclosed within the membrane f of fig. 80, so far as the sides and base of the seed were concerned, and most probably also at its apex. If so, the lagenostomal parenchyma (p) would rest, as in *Lagenostoma ovoides*, directly upon the apex of the nucleus. The mean length of *Conostoma oblonga* has been about ·18 to ·2.

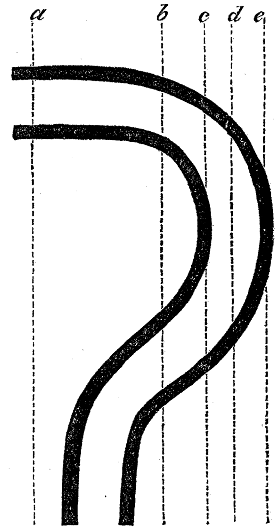
The rich deposit at Burntisland has hitherto only furnished me with good examples of one seed, which appears to be of the same generic type as the last; I propose for it the name of *Conostoma ovalis*. Fig. 82 is a vertical section through the centre of one of this species. In it the membranes are much disturbed, still they are not difficult of identification. There is an external testa (a) of uniform thickness. At the lower part of the seed we find an outer membrane at f, separating from an inner one at g. I presume that the former is the nucular membrane, and the latter the perispermic one. The perisperm, n, has obviously been much shrivelled before mineralization. The upper or apical part of the seed is so important that I have given an enlarged view of it in fig. 83, magnified 60 diameters. The testa (a) surrounds this end of the seed. At f we find an inner membrane separated from the testa. Fig. 82 shows that this is the nucular membrane, if not that and the perispermic membrane, g, united into one. At $f'f'$ a portion of this membrane turns horizontally inwards, as in figs. 79 & 80, whilst, in a similar manner, another portion of it ($f'f'$) arches round the apex of the seed in close contact with the inner surface of the testa. The parts forming the representative of the lagenostome perplexed me until I discovered the specimen (fig. 84), which is an oblique section passing along a plane corresponding with the line x in fig. 83. In fig. 84 we have the testa at a, but apparently splitting into two layers at the upper part of the figure (a', a'). At ff is a distorted membrane, of which the portions $f'f'$ obviously correspond to the parts indicated by the same letters in fig. 83. Above this the membrane rises into a dome-shaped structure at c', and is now very distinctly seen to consist of prosenchymatous cells. As these cells approach the central axis of the seed, they obviously bend inwards and downwards, forming a central funnel-shaped depression leading to the representative of the lagenostome (c). It thus appears that the part represented by fig. 83 (c') is in its normal position, whilst the corresponding rounded lip of the funnel on the opposite side (c'') has been accidentally lifted up from its true position. At fig. 83, c''', we have the semblance of a horizontal continuation of the tissues of c', c'' uniting the extremities of these two curved structures; but I do not believe that this is actually the case. We see a similar condensed tissue occupying the same position in fig. 84, but without exhibiting any trace of the conspicuous prosenchymatous structure characteristic of the wall (c') of the lagenostome. Within the lagenostomal cavity we have both in figs. 83 & 84 a mass of delicate, thin-walled parenchyma (c), which I think must be identical with that seen in the lagenostome of *Lagenostoma ovoides*, and which, occupying, as it does in the seed under consideration, a central position, apparently closing up the entrance from the micropyle into the lagenostome (c), throws some light upon the similarly placed tissue (p) in fig. 79. At f'' in fig. 84 we have a layer of membrane which appears to be identical with the layer f'' in fig. 83. The length of this seed is about ·1, and its diameter about ·05 to ·066. Fig. 87 is a longitudinal section of a seed from Burntisland, which may possibly be a state of *Conostoma ovalis*, but which I am inclined to regard as distinct. It is longer and narrower than that species, besides which I cannot identify the tissues in the two forms. In its general contour it resembles *Conostoma oblonga*. There is a thin testa at a, within which are other membranes difficult of identification. Thus at b' we have one thickish membrane; at b'' b'' this membrane splits into two. At the apex of the seed we have an outer membrane at *b*, which appears to be a continuation of b''. At the upper part of the seed we have an arrangement which appears to correspond approximately with that of fig. 79. Thus the membrane *f* divides above the apex of the perisperm into the two layers f' & f''. At first I regarded f' as the perispermic membrane; but the transverse portion f' distinctly exhibits a coarsely cellular structure, as at f'' we have an equally distinct prosenchymatous one,—conditions that differ from all the unmistakable perispermic membranes of other examples. I find at *h* a small mass of cellular tissue which appears to me to be part of the parenchyma of the interior of the nucleus. If this is so, it follows that the true perispermic membrane is here blended with the nucular one throughout the greater part of its course, as in fig. 86. Since the seed thus appears to occupy an intermediate position between *Conostoma oblonga* and *C. ovalis*, it may be provisionally recognized as *Conostoma intermedia.* Its length is about ·13 and its diameter ·07.

Fig. 85 represents the external aspect of a small seed obtained by Mr. AITKEN, of Bacup, from the Ganister bed near Oldham, in which such objects are very rare. I believe it will prove to be a distinct species of *Conostoma*; but unfortunately its internal structures are imperfectly preserved, but enough remains to show that it is distinct from all those which I have described.

Figs. 88–93 represent five sections of another remarkable seed which is very distinct from those already described, but of which I have only found one solitary specimen. Hence I have adopted the plan which I have followed in several other cases. I began grinding at the exterior of the seed, where I first obtained the appearances represented in fig. 89; and as I ground deeper into the seed I sketched the structures which successively presented themselves until I reached what appeared to be nearly the centre of the seed, as seen in fig. 93. I believe that the centre of the apex of the seed is approached in fig. 92, but I was nearer the centre of the chalazal extremity in fig. 93. The irregularities in the outline of this seed demonstrate that the outer layer (*a*) was a fleshy sarcotesta, capable of being irregularly shrivelled up. It consisted, as is seen in figs. 88 & 93, of parenchyma composed of very minute cells. The greater part of fig. 89 is a tangential section made in the plane of this sarcotesta, with a small projection (*k*) at its chalazal base, which, I presume, has been part of a funiculus. Near the apex the tissues of the sarcotesta open out to form a wide micropyle, terminating, in this section, in two thin and converging margins (a' a')*. Within these margins there is a ring (*h*) of delicate parenchymatous tissue. The opening in its centre obviously shows that the section has here intersected a cylindrical canal. In fig. 90 we find that the section has not only reached, but partly passed through a thin and delicate prosenchymatous structure (*f*), which is apparently the nucular membrane. At the micropyle we still have the upper ring (*h*), but we now find a similar one (h') at the lower end of the

* Dr. DAWSON has figured a seed from the Devonian Beds of New Brunswick, under the name of *Cardiocarpon cornutum* ("The Fossil Plants of the Devonian and Upper Silurian Formations of Canada," Geological Survey of Canada, 1871, p. 60, pl. xix. fig. 214), in which the testa "divides into two inflexed processes at top."

micropylar cavity. Fig. 91 shows still more clearly the tissues of the sarcotesta (*a*) and the nucular membrane (*f*); but we now see, in addition, a small portion of the surface of a yet more internal membrane (*g*), which I presume is the perispermic membrane. At the micropylar end we still find what may be termed the exostome, or orifice of the sarcotesta, open; but the two rings *h* and *h'* are now linked together by a continuous band of parenchyma, though their open canals are still distinct. In fig. 92 we advance still further. The section has now passed *through* the perispermic membrane (*g*), whilst the two rings *h*, *h'* are now united into a common oblong cavity, *h*. These sections make it clear that the rings of parenchyma of the other figures and the blended portions of fig. 92 form parts of a tube or canal bent into the form of a tube, which the section fig. 89 has intersected at *a* in the accompanying woodcut, fig. 90 at *b*, 91 at *c*, 92 at *d*, and 93 at *e*.



Whether the flexed condition of this tube was a normal one, or whether it has been the result of partial desiccation is doubtful; but I incline to the opinion that it was originally straight. In none of the sections was I able to trace any connexion between this tube and the membranes investing the nucleus; but unfortunately I had only half the seed to work upon; had I had the other half, so as to have been able to follow up the section fig. 93 with another one, in all probability the transverse thin band of sarcocarp seen at fig. 93 *a'* would have disappeared, and the direct continuity of the micropyle from the exostome to the nuclear membrane have been demonstrated. Fig. 93 represents, as I have already pointed out, the section nearest to a central one of any of the series. At its apex, *a*, the exostome of the micropyle has disappeared. A thin extension of the sarcotesta now completely arches over the micropylar canal, from which it seems that this latter organ was somewhat curved, as well as the parenchymatous tube which it contained. In the body of the seed we see the nucular area, *n*, large and oval, nearly filling the interior of the seed, and enclosed within its perispermic membrane (*g*). External to this is the delicate prosenchymatous nucular membrane (*f*) lining the sarcotesta (*a*). But we now obtain proof that the sarcotesta was hardened at its inner border (*b*, *b*) into an endotesta, the tissues of which were much more firm than the parenchymatous elements which surrounded it. This is very distinctly seen at the chalaza (*i*), where the hardened layer of the sarcotesta is interrupted, allowing a direct communication to exist between the softer parenchyma of the sarcotesta, which is here very thick, and the prosenchymatous nucular membrane at *f'*. At this end of the seed we further see the sarcotesta prolonged into what looks like a funiculus (*k*).

Fig. 88 represents the upper part of fig. 92, enlarged 50 diameters. In this figure the differences between the three tissues of the sarcotesta (*a*, *a*), the nucular membrane (*f*, *f*), and the parenchymatous structure (*h*) within the exostome are well shown, especially that between the *parenchymatous* cells within the exostome and the *prosenchyma* of the nucular membrane, of which latter, however, the former may possibly be merely a prolongation.

Whilst I believe that I have correctly interpreted the homologies of the nucular region of this distinct seed, difficulties present themselves in reference to the micropylar extremity. It is evident that there was a very wide micropyle, so far as the sarcotesta is concerned, reminding us of what we see in the young states of *Juniperus*, *Taxus*, *Callitris*, and some species of *Pinus*; but we see, from fig. 94, that this cavity was nearly filled up with the cellular parenchyma (*h*). Is this latter tissue in any way the representative of that seen in the lagenostome of several of the species previously described in this memoir? If not, did the pollen-grains pass down the open space between it and the canal in the sarcotesta, or did they descend to reach the nucleus through the canal passing through the centre of the parenchyma? At present no satisfactory answer can be given to these questions, and I only propose them to indicate points awaiting further investigation, but for which we must await the discovery of additional specimens This seed is from the Oldham nodules. Its maximum length, exclusive of the funiculus, is ·25.

The next seed to be examined is the *Trigonocarpon** *olivæforme*, which was long ago made the subject of the memoir by Dr. HOOKER and Mr. BINNEY already referred to, published in the 'Philosophical Transactions,' vol. 145. These seeds are found in great abundance in a quarry of sandstone belonging to the Upper Coal-measures, known as the Peel Delph, near Worsley, in Lancashire. The chief accumulation of them in that quarry is in a very thin seam, in which they are clustered together in the greatest profusion, having evidently been drifted from some locality where the trees producing them overhung the water, and into which they had been shaken, when ripe, by some violent primæval tempest, and then drifted upon a neighbouring sand-beach. Other drifted plants of the Coal-measures are frequently met with in the same locality. These seeds are very rare in the calcareous nodules of the various localities near Oldham. Mr. Binney met with great numbers of them in a deposit at some other place in Lancashire, but of which he has not recorded the name, beyond saying that they were from one of the Ganister coals of the Lower Coal-measures.

My two valuable auxiliaries, Mr. J. BUTTERWORTH and Mr. NIELD, have met with but very few specimens of these seeds in the Oldham deposits, which belong to the same geological horizon as that from which Mr. BINNEY obtained his examples. Some of these specimens my two friends have kindly placed in my hands†.

* There is much confusion in the spelling of this generic term. In his original 'Prodrome' BRONGNIART adopted "*Trigonocarpum*." In his later 'Tableau' he changed it to "*Trigonocarpon*;' whilst in his yet later memoir on the St.-Étienne seeds he again alters it to "*Trigonocarpus*." HOOKER and BINNEY adopted "*Trigonocarpon*;" Dr. DAWSON writes "*Trigonocarpum*;" and Professor NEWBERRY "*Trigonocarpon*."

† Being anxious to make this renewed study of *Trigonocarpon* as searching as possible, I placed two of these specimens in the hands of Mr. CUTTELL, the well-known lapidary, with instructions to obtain for me as many

Fig. 94 represents a lateral view of the finest specimen I have hitherto obtained from the Peel Delph. These Peel specimens usually resemble the nuts of the *Salisburia* sold in the grocer's shops in China, but which are deprived of all their outermost sarcotesta. But the Peel specimens are even something more than this. There is no doubt that fig. 94 represents a sandstone cast of the interior of the hard endotesta, with a thin film of tissue remaining upon the cast, and which, even in these sandstone specimens, retains superficial traces of the prosenchymatous structure of the endotesta, within which the cast was moulded. Such specimens do not, in any way, represent the external form of the seed, as will be shown in my description. The *entire* specimen in fig. 94 represents the exact form of the interior of the testa, the lower or tumid portion of it corresponding to the nucleus with its thin investing membranes, and the prolonged upper portion, with its three diminishing concave surfaces, of which only one appears in the figure, representing the interior of an elongated micropyle. It is important that this fact should be correctly understood, since many of even the most recent references to these seeds are rendered erroneous by a confusion between their external contours and their internal casts. Thus Dr. BALFOUR describes *T. olivæforme* as "an ovate, acuminate, three-ribbed, and striated fruit or seed" ('Palæontological Botany,' p. 63), whereas it was twelve-ribbed, and we have no evidence whatever that its surface was striated. Professor NEWBERRY figures a similar example to my fig. 94*, of which he says that it "has suffered little injury beyond the loss of the fleshy envelope. In this and some others I have seen, the three conspicuous salient ridges which traverse the surface longitudinally are shown to be the remains of broad and delicate wings; so delicate that they are generally all torn away with the exception of their thickened bases"†. All this is, I am satisfied, a mistake, which so acute an observer as Professor NEWBERRY would be one of the first to correct, after seeing my sections and specimens. In the valuable memoir published by Dr. HOOKER and Mr. BINNEY the only sections figured are longitudinal ones. The publication in that memoir of figures of transverse sections would probably have prevented the perpetuation of these erroneous notions.

I have not much to add to the descriptions of longitudinal sections of *Trigonocarpon* published by these authors, except on one or two points on which fresh light is now thrown. Dr. HOOKER and his coadjutor have described accurately the general features of these sections, including the two layers constituting the sarcotesta and endotesta. In their figures 7, 8, & 12 they also delineate the organ which apparently represents the lagenostome, but, as might be expected from the date of their publication, without recognizing its significance.

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longitudinal sections as possible out of one of them and of transverse ones out of the other. Out of the first of these, which was less than ⅞ of an inch in diameter, he obtained for me *nine* beautiful sections, and from the other, less than an inch in length, he obtained no less than eighteen equally fine transverse sections! The more characteristic of each of these two series of sections have been figured in the accompanying Plates.

* Report of the Geological Survey of Ohio, vol. i. Geology and Palæontology, part ii. pl. 42. fig. 1.

† *Loc. cit.* p. 366.

Fig. 95 is the outermost or most tangential of the consecutive series of five vertical sections, selected from the nine of which I have already spoken as being made from one of Mr. NIELD's specimens. There is a small portion of the outermost investment, or sarcotesta, seen at *a*, within which is the denser endotesta at *b*: the minute structure of each of these layers will be referred to presently. The oval outline *b'* merely represents the complete contour of the inner surface of this endotesta, where it is in contact with the white calcareous spar with which the internal cavities of these seeds are usually filled; *f* is the nucular membrane, which doubtless was originally in immediate contact with the interior of the endotesta, but which has shrunk away from it; whilst *g* is a yet more internal membrane, apparently identical with the perispermic one of the previously described seeds.

Figs. 96 & 97 are two sections made near to the central axis of the seed, so that the long narrow micropyle (*d*) comes into view in both; we also see in each of them the appendage (*c*), on the apical extremity of the nucular membrane (*f*). In each section the inner or perispermic membrane (*g*) has become shrivelled and collapsed. Fig. 98 is a tangential section, which has just avoided passing through the micropyle, and in which the lagenostome (*c*) is still observable; whilst in fig. 99 we return nearly to the conditions seen in fig. 95, but on the opposite side of the seed. The perispermic membrane does not appear in this latter section, as would have been the case with a similar tangential one, made through the right-hand side of either of the figures 97 & 98. Figures 100 to 108 represent an instructive selection of the most characteristic of my eighteen transverse sections, made from one of Mr. BUTTERWORTH's specimens. Fig. 100 has intersected the seed near the base of the micropyle, the section of the open triangular tube of which is seen at *d*. The testa is here very thick in proportion to the diameter of the central canal which it encloses. At each of the angles of the latter the endotesta projects outwards with the sharp angle seen at *b' b'*, the third one having been accidentally broken away. On either side of each of these three projections of the endotesta is another smaller prominent acute angle (*b'' b''*), whilst midway between each of the three primary angles (*b'*, *b'*) the endotesta exhibits a third rounded prominence (*b'''*, *b'''*). We thus see that the hard endotesta, deprived of its soft sarcotesta (*a*), had twelve prominent longitudinal ridges, nine of which had sharp keel-like margins, and the remaining three were more rounded and swelling*. Though the external outline of the sarcotesta (*a*) is less sharply defined than that of the endotesta, we yet see that to a considerable extent the former follows the latter, the differences seen in the sections being due to shrinkage from some collapse in the soft parenchymatous cells of the outermost layer.

In fig. 101 the section is made a little below the base of the micropyle, and I doubt not that in the recent seed it would have passed through the upper extremity of the nucleus;

* Viewed in the light now thrown upon these structures in *Trigonocarpon*, it seems to me possible that some of Professor NEWBERRY's species of *Rhabdocarpus* (*loc. cit.* pl. 44) may merely be the endotesta of seeds of that genus deprived of their sarcotesta.

hence the triangular aperture (*d*) of the previous figure now exhibits oblate sides. In fig. 102 this enlargement of the nucular cavity becomes yet more conspicuous, and in fig. 103 a further expansion of that cavity has taken place, whilst in its interior we now find the upper part of the nucular membrane *f*. Unfortunately the section has just missed the lagenostome (*c*) of figs. 96, 97, and 98. In fig. 104 the nucular membrane (*f*) is further enlarged, and within it is the perispermic membrane (*g*). Similar arrangements continue to appear in the sections (figs. 105 & 106), save that in them the perispermic membrane (*g*) has collapsed to one side of the nucular membrane (*f*), and the latter is beginning to show a ragged outline on its external surface. In fig. 107 we have passed below the greatest diameter of the seed. The exterior of the nucular membrane is becoming yet more ragged, indicative of its forcible detachment from the inner surface of the endotesta; whilst in fig. 108 we have reached the base of the perispermic membrane (*g*) and approached the chalaza. Parts of two sections successively made yet lower down are represented in figs. 109 and 110, the former in the endotesta and the latter in the sarcotesta. To these further reference will be made.

The letters of reference appended to the various ridges of the endotesta in fig. 100 are similarly attached to the same parts in fig. 103, in which these ridges are very clearly exhibited. Fig. 104 shows with perfect clearness that an inorganic cast of the interior of the cavity of the endotesta made after the nucleus and its two investing membranes had disappeared would exactly correspond with what we see in fig. 94. It is sufficiently easy to discern the real nature of "the three conspicuous salient ridges" spoken of by Professor NEWBERRY. They were portions of the inorganic cast filling the three very narrow slits within the three chief prominent ridges of the endotesta (*b'*, *b'*, *b'*). The several sections (figs. 101, 104, 105, 107, & 108) show that the three radiating slits in the endotesta are the largest and deepest at the upper parts of the seed, and that they diminish in size as we approach the centre of the seed, below which they grow rapidly less as we approach the chalaza, when they almost disappear—conditions that are identical with what we find in fig. 94. The exterior of the seed exhibits nothing to correspond either with the three thin "broad and delicate wings," or with the smooth convex surface of the "nut" in fig. 94; but the internal cavity of the endotesta displays all these characteristics with the most minute exactness. I think that doubts as to the correctness of my explanation of the common sandstone specimens of *Trigonocarpon olivæforme* and its numerous near congeners can no longer be entertained.

The minute structures of the various investments of this seed have already been described by Dr. HOOKER and Mr. BINNEY; but it is obvious that they are subject to some variation. Fig. 111 exhibits a portion of a vertical section through the testa, and fig. 112 a similar transverse section through the same tissues; both of them enlarged 62 diameters.

In fig. 111 we see that the sarcotesta (*a*) consists of a parenchyma with very thin cell-walls, and with the cells approximately uniform in size. The endotesta (*b*), on the other hand, consists of cells of various lengths, which are obviously modifications of sclerenchyma. These cells meander throughout the greater part of the thickness of the endotesta in various directions, and the apparent length of the cells, itself a variable quantity, differs according to the direction in which the section has passed through them. But at the innermost portion (fig. 111, b') of this structure all these cells are prosenchymatous, and run parallel with the long axis of the seed. Dr. HOOKER found many of these innermost cells to be barred or spiral ones. Traces of the same structure appear in my sections.

In the transverse section (fig. 112) the cells (b') of the innermost layer of the endotesta are seen to be divided by the section transversely to their longer axes. On the other hand, immediately external to this layer, we find them, as at b'', meandering horizontally round the seed. The transverse sections of these latter interlacing cells are also seen in fig. 111, b''. The outermost ones in fig. 112 exhibit a strong tendency to be prolonged horizontally and radially as at b, where their extremities are in contact with the parenchymatous cells of the sarcotesta (a). It is evident that these cells are more elongated in my sections than in those figured by Dr. HOOKER and Mr. BINNEY *.

In most of the sandstone casts like fig. 94, the base of the seed exhibits a small defined ring, occupying the position of the chalaza, in the centre of which is a little point, at which I may presume that a vascular bundle reached the chalaza. My sections, however, exhibit no trace of vascular elements. Fig. 110 represents a transverse section made through the sarcotesta of the specimen figs. 100–108, enlarged 25 diameters. It consists merely of parenchyma with a central aperture, through which, doubtless, the vascular bundle of the chalaza formerly entered the seed. The corresponding part of the endotesta was damaged in making the section of it; hence I cannot identify the upward prolongation of this aperture; but fig. 109 exhibits the aspect of some of the neighbouring sclerenchymatous cells of this region enlarged 108 diameters.

The only region requiring further elucidation is the peculiar structure which appears to represent the lagenostome. In their figures Dr. HOOKER and Mr. BINNEY represent a small thickening, corresponding with c in my figures 96, 97, and 98, but no reference is made to this peculiarity in the text of their memoir. Figs. 113, 114, and 115 severally represent these structures, enlarged 15 diameters. In each of these instances the membrane f is seen to split into the two layers f' & f''. In f' I can trace no structure; but the inner layer (f'') is obviously a thin prosenchymatous tissue, as is so usually the case with these nucular membranes. This peculiar organ so evidently exists in all the specimens of these seeds that its presence cannot be regarded as merely accidental; whilst its position, and the peculiarity of the membrane out of which it is formed, alike indicate its apparent homology with the organ which I have designated the lagenostome. Fig. 113 appears to indicate that the nucleus terminated at the base of this organ, and did not enter into its inner cavity.

I am indebted to JOHN AITKEN, Esq., of Bacup, in Lancashire, for the loan of the

* *Loc. cit.* plate iv. figs. 13 & 15.

beautiful seed represented in figs. 115 *a* & 115 *b*. It is the only example I have seen from the Oldham nodules resembling M. BRONGNIART'S genus *Hexapterospermum*. Specimen fig. 115 *a* represents a side view of the seed of its natural size; and fig. 115 *b* exhibits the same seed enlarged 3 diameters. It differs primarily from *Trigonocarpon* in having six projecting angles instead of three. These ridges, which are very sharply defined, also terminate in a ring of prominent protuberances at the base of the seed, instead of gradually disappearing on approaching the chalaza. LINDLEY and HUTTON described a six-angled seed under the name of *Trigonocarpon Nöggerathii*, which they only distinguish from *T. olivæforme* in being more oblong and in having six angles instead of three. I think there can be no doubt that fig. 115 represents a young form of the same seed. I found in the Museum of the Yorkshire Philosophical Society a sandstone cast of a similar seed from Aldwark, near Rotherham, but it was fully 1½ inch in length. According to M. BRONGNIART'S description, the internal structure of his *Hexapterospermum stenopterum* is almost identical with that of our *Trigonocarpon olivæforme*, which plant he separates from the genus *Trigonocarpon* under the name of *Tripterospermum*. This division into three genera of plants which resemble each other so closely, both in their internal organization and in their general external form, is extremely objectionable. The incidental circumstance that one seed dehisced into three segments and another into six, is surely insufficient ground for more than a specific distinction. In like manner he distinguishes his allied genus *Ptychotesta* by a character which my transverse sections unequivocally show to exist equally in *Trigonocarpon olivæforme*. He says "les six ailes qui prolongent les angles de la graine à section hexagonale sont en effet formées, non par une extension du tissu du testa, mais par le testa lui-même replié à l'extérieur. Ces ailes ont ainsi une double paroi identique, pour sa structure et son épaisseur, au testa qui entoure le corps de la graine." Surely this is substantially what we do see in my figure 104 and other sections. All these genera will require to be corrected unless other distinctive characters be found presenting better reasons than we now possess for keeping them separate.

There is great confusion in the nomenclature of these Trigonocarpoid seeds, arising from our inability to determine how far size constitutes a legitimate specific distinction. At Peel Quarry I find considerable variation in the dimensions of what are unmistakable examples of *T. olivæforme*. Excepting in size, I discover no difference between the largest of these specimens and the *T. ovatum* and *T. oblongum* of LINDLEY and HUTTON'S 'Fossil Flora.' Professor NEWBERRY evidently recognizes this fact, since the two examples of HILDRETH'S *Trigonocarpon triloculare* which he has figured (*loc. cit.* pl. 42. figs. 1–13, 13 *a*) differ in size quite as much as do the *T. olivæforme* and *T. ovatum* of the 'Fossil Flora.' At the same time I cannot see any difference between the latter species and that described by HILDRETH. I have already referred to the similar difference in size between Mr. AITKEN'S specimen of *Hexapterospermum* and that in the York Museum. The *T. Dawesii* ('Fossil Flora,' pl. 221), of which I have specimens from Peel Quarry, appears to me to be distinct. In addition to its large size (2¼ inches long) it is *always* a much more oblong seed than is the case with *T. olivæforme.* How far *any* specific distinctions can be ascertained from these *internal* casts of seeds, apart from structure, is extremely doubtful.

The next seeds which I have to describe are those which have long been known by BRONGNIART'S name of *Cardiocarpus.* Until recently we were only familiar with the external aspect of various forms and sizes of these seeds, disconnected from their stems. At length the discovery, by Mr. PEACH, of some specimens described and figured by Mr. CARRUTHERS* exhibited these seeds in such connexion with the plants known as *Antholithes* as to leave no doubt that the latter are the racemose peduncles, on the secondary peduncles of which some species of these seeds were supported. But it is obvious that *Antholithes* is not the only form assumed by the peduncles of these fruits. Professor NEWBERRY figures one† where the seeds are sessile on a long straight peduncle, and Dr. DAWSON figures a small fragment‡ in which the seeds are similarly arranged; only here each seed is supported upon a short solitary peduncle, devoid of the surrounding appendages characteristic of *Antholithes.*

The genus *Cardiocarpon* was established by BRONGNIART, in his 'Prodrome,' in 1827, for the reception of "Fruits comprimés lenticulaires, cordiformes ou réniformes, terminés par un pointe peu aiguë" (*loc. cit.* p. 87). Oddly enough, his later 'Tableau' contains no notice of it as a distinct genus, but he refers to the seed as probably belonging to the Noeggerathiæ.

All the writers who followed BRONGNIART have spoken of these objects as *fruits.* In his memoir on the Devonian plants just quoted Dr. DAWSON examined these supposed fruits, and "arrived at the conclusion that the *Cardiocarpa* of the type of *C. cornutum* were Gymnospermous *seeds*, having two cotyledons imbedded in an albumen, and covered with a strong membranous or woody tegmen, surrounded by a fleshy outer coat, and that the notch at the apex represents the foramen or micropyle of the ovule" (*loc. cit.* p. 61). In the same memoir (p. 62) Dr. DAWSON further remarks:—"Though I have no doubt that the above is the correct interpretation of *C. cornutum*, I do not regard it as applicable to *all Cardiocarpa.*" Mr. CARRUTHERS, in his later memoir, referred to above, speaks of them as fruits invested by a pericarp.

I need scarcely say that this question of seeds *versus* fruits cannot be easily settled, in the case of the fossil examples, so long as Botanists hold such widely divergent views on the same question in relation to the reproductive organs of living Gymnosperms. Whilst EICHLER contends that the seeds of Conifers are really gymnospermous, and STRASBURGER thinks otherwise, it must obviously be difficult to decide the question in the case of fossil forms detached from most of their surrounding organs.

Professor NEWBERRY has figured in his work already quoted a fine series of *Cardiocarpa* from the Carboniferous deposits of Ohio, but none of these display any definite internal

* "Notes on some Fossil Plants," Geol. Mag. vol. ix. no. 2, Feb. 1872.

† 'Geol. Survey of Ohio,' pl. xli. fig. 4.

‡ 'Fossil Plants of the Devonian and Upper-Silurian Formations of Canada,' pl. xix. fig. 227, *a.*

structure. M. Brongniart has figured four species from St. Etienne in which the internal organization is preserved. The author says of this genus:—"Sa structure montre une graine orthope, la chalaze correspondant à l'échancrure basilaire, et le micropyle à la pointe opposée; le nucelle a un sommet conique sans apparence de cavité pollinique. Mais ces graines présentent, dans leur testa, deux structures très-différentes, et qui pourraient engager à y distinguer deux genres. Le *C. sclerotesta* offre un testa entièrement dur et nettement limité à l'extérieur. Le *C. drupaceus* présente, au contraire, un tissu très-dense près de sa surface interne, qui passe insensiblement à un tissu à grandes cellules plus transparentes, formant une zone probablement charnue comme celle des graines de Gingko, et présentant même des espaces plus transparents assez régulièrement disposés; correspondant sans doute à des cavités gommeuses aux oléagineuses."

I have found fine examples of this genus in the Oldham nodules, to which Mr. Butterworth has added the fine species to which I have appended his name as a memorial of the services he has rendered to Palæontological Botany, by his diligence in collecting and making valuable sections of the Oldham plants.

Fig. 116 represents a specimen which exhibits much of the external contour of the seed on the side figured, whilst on the opposite surface of the specimen I have obtained the somewhat oblique, longitudinal section represented in fig. 117. Occupying the central part of the former figure, we see a triangular nucleus with rounded angles. A prominent, obtuse, longitudinal ridge separates most of the surface of this nucleus into two triangular areas, which slope away from the ridge in each direction towards a thick, rounded, and very prominent margin, n', n', which surrounds the two sides and the apex of this nucleus. At the chalazal extremity the central longitudinal ridge dichotomizes, and is prolonged in each direction to the two obtuse latero-posterior angles, n'', n'', of the nucleus, thus defining a third or posterior area, *i*, which, though triangular, like the two lateral ones, is so much shorter as almost to constitute a truncate chalazal base of the entire nucleus. This nucleus is the thickest at the prominent point where the longitudinal and transverse ridges meet. Its superficial surface is thus seen to constitute a depressed cone, of which the apex is excentric. The maximum length of the nucleus, so far as it is visible in this specimen, is about ·11, and its diameter across the obtuse apex of its prominent conical surface is about the same. External to the nucleus we can readily discern, on each side of the seed, two investing membranes, an outer (*a*) and an inner one (*b*), which taper away together, forming a long micropylar prolongation, *c*.

Unable to obtain a transparent section, I ground away the opposite side of this fine seed, and obtained the result seen in fig. 117, which is again enlarged 15 diameters. Either the section is slightly oblique or, as other specimens indicate, the seed has been liable to become somewhat twisted instead of being always symmetrical. It now shows very clearly the distinction of its various parts. At n' we have a central nucleus, of which some of the parenchymatous cells are preserved. These cells, as in all the species of *Cardiocarpon* in which I have found this perispermic tissue, are of large size, some of them having a mean diameter of ·004; a cluster of them, enlarged 50 diameters, is represented in fig. 120.

This perisperm is invested by a very thin membrane, *g*, in which I can find no structure, and which, I conclude, is identical with the perispermic membrane of the previously described seeds. It is rounded at its apex, not being prolonged into the micropyle, resembling in this respect the Cardiocarpons figured by M. BRONGNIART*. External to this perispermic membrane we have two layers, which, though they accompany each other in their course, differ in their structure. The inner one (*b*) is very thin and delicate, consisting of a single layer of thin-walled prosenchymatous cells. Superiorly it is prolonged through the micropyle, and, in this instance, extends beyond the outer layer at *b'*; but this is doubtless an accidental result. At its base (*b''*) it has evidently been closely united with the chalazal tissues. The outermost membrane, or exotesta (*a*), is dense and well defined; though in this instance its parenchymatous structure is not very clearly shown. Inferiorly it is prolonged into a funiculus or peduncle (*k*), whilst at its apical extremity it projects in a long tubular micropyle.

I cannot determine with certainty the relation which the inner membrane (*b*) in this species bears to those seen in the other seeds which I have described. In its structure it corresponds closely with what, following M. BRONGNIART, I have designated the nucular membrane. But in its prolongation to the extreme tip of the micropyle it differs completely from the nucular membrane of the other seeds. Hence I am inclined to regard it as a thin and delicate endotesta. The other specimens to be described confirm me in this conclusion, because, though the perispermic structures have entirely disappeared from them, this membrane remains in perfect integrity. Thus fig. 118 represents a transverse section of a specimen enlarged $22\frac{1}{2}$ diameters, its mean size being about ·1. The exotesta (*a*) is very sharply defined both externally and internally, and has a mean thickness of about ·007. In the body of the seed, where it has invested the nucleus, it expands broadly into two rounded wings; but at the apex of the nucleus it has rapidly contracted into the tubular prolongation *a'*, forming the micropyle, and which has been curved laterally near its exostomal extremity, *d*. The inner membrane or endotesta (*b*) exhibits the same delicate prosenchymatous structure as is seen in the corresponding membrane in fig. 117. In like manner it is firmly united with the exotesta at the chalaza (*i*), and is prolonged as an inner layer of the micropyle to the point *d*. The nucleus and nucular membrane are wanting in this example.

Fig. 119 represents one of the finest specimens I have met with, so far as the preservation of the tissues of the testa are concerned. It is enlarged 22 diameters. Whether it is a distinct species from figs. 116 & 118, or whether it is merely a large example of the same, I am unable to say; but it is more than twice the diameter of fig. 116, and more than three times that of fig. 118. In every other respect it corresponds closely with those figures. We now see that the exotesta (*a*) consists of innumerable very minute cells with dense cell-walls, and which in some parts, as at *a'*, assume a prosen-

* 'Études sur les graines fossiles,' pl. xxi. fig. 1.

chymatous form. Thick at the base of the seed, it becomes thinner as it rapidly contracts in size to form the prolonged micropyle, *d*, which is obviously curtailed of much of its normal length. At the chalaza (*i*) the cells of the membrane curve away on either hand, in lines which bend, first, downwards, then upwards and outwards from its junction with the endotesta, *b*. This latter membrane is again seen to be thin, and composed of a single layer of delicate prosenchymatous cells, excepting at the chalaza (*i*), where they appear to be parenchymatous; but it is possible that, at this point, the section may not be exactly central, and that, consequently, the cells may be intersected across their narrow diameters. At the opposite extremity the endotesta is prolonged (b') through and beyond the micropylar extension of the exotesta; but the tissues of this region have obviously been injured. The nucleus and perispermic membrane are again wanting in this example. All the three specimens here described are from the Oldham nodules.

The application of correct specific names to these Cardiocarpons is not easy. Mr. CARRUTHERS, to whom I showed the original of fig. 116, considers it to be identical with his *C. anomalum**. Though far from certain, not having seen Mr. CARRUTHER'S specimen, the seed which I have described may remain under that name, upon the authority of its author.

I have found in the Oldham nodules several specimens of a small compressed *Cardiocarpon*, in addition to a portion of one obtained by Mr. BUTTERWORTH. Their outlines were not very clearly defined, especially at the micropylar extremity; but fig. 121 represents the general aspect of most of the specimens, allowance being made for some uncertainty respecting the external contour of the apex. There is in all a smooth, flattened nucleus, with an investing layer, *a*, which extends considerably beyond the nucleus nearly all round the seed, but which is especially somewhat prolonged at the apex. In Mr. BUTTERWORTH'S fragment there is a slight longitudinal groove running down the centre of the surface of the nucleus, as represented in fig. 121.

Fig. 122 represents one of a number of seeds on a piece of shale from the Newcastle Coal-field, and which I presume is the *Cardiocarpum acutum* of LINDLEY and HUTTON. It is possible that this may be the same species as fig. 121, in which case both may probably be identical with the *C. Lindleyi* of CARRUTHERS†. But if so, the bifid extremity of the fruit in Mr. CARRUTHERS'S plant, and in my fig. 122, has probably been the result of pressure, which has split open the patulous extremity of the micropyle.

Fig. 123 represents a central vertical section of the upper half of a seed made in the plane of fig. 121. We here only see an exotesta, *a*, enclosing a large internal cavity; its upper extremity contracts gradually into a short and narrow micropyle, *d*, but which terminates in a trumpet-shaped mouth or exostoma at d'. We have shrivelled portions of an internal membrane at *g*, but I cannot ascertain what it is. Fig. 124 represents a transverse section of the same seed made a little below the base-line of fig. 123. We here see the lenticular form of the cavity enclosed by the testa, *a*; and though the latter

* 'Notes on some Fossil Plants' &c., fig. 3.

† *Loc. cit.* fig. 182.

is imperfect, enough remains to show that it, too, had a lenticular outline. Within this testa we now find two membranes, of which the inner (*g*) probably represents the perispermic membrane. Fig. 125 is one surface of another transverse section, made parallel to the last, but near the base of the seed. Being the opposite surface of the thick section, fig. 124, its position is reversed—the thick layer of the exotesta, a', being now on the upper instead of the lower side of the figure. The parenchyma of the chalaza is seen at *i*, on each side of which are two basal prolongations of the cavity enclosed within the testa, and which project below the chalaza, indicating the cordate shape of the endotestal cavity at the chalazal extremity of the seed.

Figs. 126, 127, & 128 are three serial longitudinal sections of another specimen made vertically to figs. 121 & 123. The first of these is a central one. Unfortunately the base of the specimen was lost; but we now find that the testa is divisible into two layers. The outer one (*a*) is more or less disorganized, but various indications show that it consisted of a parenchymatous tissue. Thus at a' we have a line of cells which might easily be mistaken for an epidermal layer; but we shall find similar cells in fig. 127 at a', and still more at a'', occupying the innermost portions of the same tissue. Combining these sections we appear to have evidence that the exotesta consisted of a coarse parenchyma, many of the cells of which have a diameter of ·003. Within this is the more dense endotesta, fig. 126 *b*, which is here about ·01 in thickness, and consists of parenchyma, the cells of which are of much smaller size than those of the exotesta. At the apex of the nucleus these united portions of the testa suddenly contracted to form the micropyle, *d*, which was the narrowest at its nucular extremity, and gradually expanded into a trumpet-shaped aperture at its open mouth, corresponding in this respect with fig. 123; but it must be remembered that the latter section is made along a line between the points *y*, *y* of fig. 124, whilst fig. 126 is made across the shorter diameter of the seed from *x* to *x*. At fig. 126, b', b', we see a tendency to the separation of a thin membrane from the interior of the endotesta, which may be the same as fig. 124, *b*. The tissues enclosed within the testa have become much contracted and shrivelled, especially towards the apical half of the seed—a condition which was equally seen in fig. 123. In fig. 126, *f*, we have an outer membrane, and at *g* there appears to be an inner one. The former is shrivelled up, as in fig. 123, to little more than a mere line at the upper half of the nucular cavity, whilst inferiorly the two membranes *f* & *g* unite to invest the perisperm *n*. Thus in both the specimens examined all traces of the nucleus (*n*) seem to have wholly disappeared from the upper half of the interior of the seed, whilst more of it remained at the lower half, where, both in figs. 124–126 & 127, we see clear indications of what may be regarded as a double perispermic membrane, *f*–*g*. Unfortunately none of my sections show whether or not the nucleus, with its investing membrane, originally occupied the interior of the upper part of the membrane f', or whether the latter was largely detached from the perispermic membrane to form a lagenostomal cavity. This point requires further investigation when favourable specimens can be obtained.

Fig. 127, which is a section made along the line fig. 121 *x–x*, shows the endotesta, *b*, extending upwards into the thin lenticular expansion of the testa which borders each side of the micropyle; and the same condition is seen in fig. 128, which is a similar section made through the testa bordering the nucular cavity, *i. e.* along the line *y* in fig. 121. Fig. 128 is enlarged 50 diameters, to show the cells of the endotesta (*b*) arranged in long vertical lines, whilst the exotesta (*a*) exhibits its usual disorganized condition. The line *a'* indicates the former boundary of the latter tissue, much of which has disappeared. The length of the specimen, fig. 126, has been about ·21, and the diameter of fig. 124 about ·25. All the specimens agree in giving to this species much of the general dimensions and contour of the *Cardiocarpum acutum* of LINDLEY and HUTTON, and of the *C. Lindleyi* of Mr. CARRUTHERS, excepting that the latter observer describes his seed as having a central longitudinal ridge, which my specimens certainly have not. Since these differences exist, it may be well to distinguish my type under the name of *Cardiocarpon compressum*.

Since the above descriptions were written, Mr. A. BUTTERWORTH has found, near Oldham, the specimen from which he has prepared the section represented in fig. 128*. It is a transverse one, made immediately above the cordate base of the lenticular seed. In it we have a thick testa, *a*, within which we find the very distinct membrane *f*, which, I presume, is identical with *f* in fig. 124. This, in turn, encloses the shrivelled remains (*g*) of what, I presume, has been a perispermic membrane identical with fig. 124, *g*; but between the two membranes *f* and *g* we have a small number of scattered, free cells, *l*, *l*, which closely resemble the supposed pollen-grains seen in other seeds. Unfortunately the micropylar extremity of Mr. BUTTERWORTH's specimen was lost; hence I cannot determine whether it represents a distinct species or is identical with the *C. compressum*, but if distinct the two types are very closely allied. Supposing the objects *l*, *l* to be pollen-grains, we obtain some light respecting the cavity into which these grains are received in *Cardiocarpon*, and which plays the part of the lagenostome seen in the other seeds. *A priori*, the organization of figs. 116, 117, 118, 119, & 126 would suggest the inference that the pollen-grains would pass down the micropyle through the tubular part of the membrane (*b*) of the first four figures, and into the cavity bounded by the membrane (*b'*) in fig. 126, in each of which cases the grains would be brought into immediate contact with the nucular membrane. If this is a correct explanation, these seeds of *Cardiocarpon* differ little from the simpler types of Coniferous ovules seen in *Juniperus* and *Callitris*. Thus, in each of the figs. 117 & 126, the pollen would reach the triangular cavity (*x*) without the intervention of the more complex arrangements of the lagenostome seen in many of the other seeds which I have described. In their internal organization, and especially in the great length of the micropyle, some of these seeds bear a strong resemblance to the ovules of *Welwitschia*†.

Mr. BUTTERWORTH was also fortunate enough to find in one of the Oldham nodules

† "On *Welwitschia*, a new Genus of Gnetaceæ," by JOSEPH DALTON HOOKER, F.R.S., Transactions of the Linnean Society, vol. xxiv. pl. ix. figs. 11 & 12.

the elegant *Cardiocarpon* represented in figs. 129, 130, & 131. It consists of two parts, the actual seed and a slender peduncle. The former is about ·4 in length and the latter ·25, whilst its diameter at its widest point, *i. e.* near its base, is nearly ·2. Fig. 129 represents the natural size of the specimen; in fig. 130 it is enlarged six diameters. It is lanceolate in form; a prominent ridge which runs up its centre is thick at the base, and almost reduced to a line at the apex. On each side of this ridge is a very regular, parallel groove, external to which again are two broad elevated surfaces, rounded and prominent at the base, but with somewhat flattened surfaces, and which extend to the lateral margins of the seed as well as to its apex. The narrow peduncle is nearly as long as the seed.

Owing to the opposite side of this specimen being crushed, I could not obtain a good section revealing its internal structure; but it clearly shows a double membrane, the outer one of which, I presume, will correspond with the membrane *b* in the sections of the other *Cardiocarpons*, and the inner with the perispermic one. Both these membranes appear to have extended to the apex of the seed. The true testa seems to have been a very thin one.

A second fragment of a slightly larger specimen of the same species, also found by Mr. BUTTERWORTH, is valuable because it exhibits much of the cellular parenchyma of the perisperm. Some of these cells from near the perispermic membrane are represented in fig. 131. In this figure, some of the cells nearest the perispermic membrane, *g*, appear loose and detached; but in a second section which I have obtained they are all compactly united as in ordinary parenchyma, and as seen in the lower part of fig. 131. Many of these cells have a mean diameter of ·006, which is half as large again as those of *C. anomalum*, represented in fig. 120. This *Cardiocarpon* differs from all those of which I can discover any published account. I have therefore given to it the name of *C. Butterworthii*, as a memorial of the valuable aid which its discoverer has rendered me, by supplying me with specimens of the Oldham fossils, as well as by his quickness in detecting new forms and his skill in preparing sections of them.

Figs. 132, 133, & 134 represent three seeds from a slab of shale from Swinehill Colliery, near Stonehouse, Lanarkshire, for which I am indebted to JOHN YOUNG, Esq., of the Glasgow Hunterian Museum*. The seeds are scattered over several large slabs of shale in great numbers, no two of them being exactly alike, save in the fact that they are all compressed, as well as more or less fluted longitudinally. They also exhibit the appearance of a surrounding margin; but I suspect that this may merely have been a result of pressure acting upon a thick testa, which would resist that pressure where it was folded back upon itself. These seeds appear to me to agree with the figure and description given by Dr. DAWSON of his *Cardiocarpum tenellum*†. I scarcely think that

* Mr. YOUNG informs me that these specimens were discovered by Mr. JOHN SMITH, of Stables, Kilwinning, in Ayrshire. The coal from the roof of which they were obtained is the Virtue-Well coal, one of the seams of the upper series of Coal-measures.

† 'Report on the Fossil Plants of the Lower Carboniferous and Millstone-grit Formations of Canada,' pl. vi. fig. 50, p. 28.

they belong to the genus *Cardiocarpon*; but this cannot be determined at present; hence I leave them provisionally with the name which Dr. DAWSON has assigned to them.

The only seeds which remain to be noticed are the two represented by figs. 135, 136, & 137. These are from a bed of fossiliferous red shale which I discovered in 1837 * near the top of the Ardwick beds at Manchester. These deposits correspond to the Limestones of Lebotwood, in Shropshire, and constitute the uppermost of the Carboniferous beds occurring in this country. The shale abounds in plants (including *Neuropteris cordata*, the fern so characteristic of the uppermost of the Carboniferous strata), in *Lepidodendra*, and in *Asterophyllites*.

Fig. 135 represents one of these seeds of its natural size.

Fig. 136 is the same specimen, enlarged four diameters; and fig. 137 is another seed, from the same slab of shale, also enlarged four diameters. Both these specimens are imperfect; but the seed has obviously been a somewhat winged one, thin, compressed, and leaf-like in structure. The rounded leaf-like apex is best seen in fig. 137, whilst the thin membranous base is better seen in fig. 136. The median surface of each seed is characterized by a series of elevated irregularly branched ridges. According to M. GRAND'EURY, these seeds belong to the genus *Polypterocarpus*, and closely resemble the *P. caudatus* found in the French Coal-measures. This latter is a double seed, resembling in its form the samara of an ash. My two portions being found very near to each other upon the same slab of shale, it is quite possible that the base (*i*) of fig. 137 may have been broken off from the part *i* in fig. 136, the two being portions of one seed.

The descriptions and figures which I have here given of such seeds as I have been able to obtain from our British Carboniferous rocks will suffice to show how close is the resemblance of the types which prevail here to those described by M. BRONGNIART from the French rocks of the same formation; but there is one remarkable difference. With us the seeds are all of small size, excepting in the case of *Trigonocarpon* and *Hexapterospermum*, whereas the St.-Étienne specimens are mostly of large dimensions. I am indebted to my friend M. GRAND'EURY for a valuable series of these latter specimens, and am struck with the contrast, in this respect, between his examples and mine.

I will not venture at present upon any speculations respecting the affinities of these seeds, further than to say that they must have belonged to Phanerogamic plants, and that the more they are studied, the more nearly they seem to approach to those of the gymnospermous type of organization; at the same time they show but few exact affinities with any known seeds. How far they may ultimately be found to resemble the fertilized ovules of the Cycads, as M. BRONGNIART'S last communication made to the Academy of Sciences † seems to suggest, time and further study alone can show. Still

* "On the Limestones found in the vicinity of Manchester," Phil. Mag. ser. 3, xi. When this shale was discovered I was under the guidance of Mr. MELLOR, the intelligent superintendent of the "Ardwick Limestone" pits, in the watercourse of one of which the shales were met with.

† Comptes Rendus, tome lxxxi. no. 7.

less can we at present associate them with any of the stems and leaves with which students of Carboniferous vegetation are so familiar. I cannot, for instance, follow Dr. DAWSON and Prof. NEWBERRY in identifying *Trigonocarpon* with *Sigillaria*, merely because the former seeds have sometimes been found accumulated near the bases of the erect stems of the latter. We have numbers of magnificent stems of *Sigillariæ* in Britain, and yet I find no one instance recorded of the two objects being so associated in our British deposits. Evidence of this kind requires to be received with the utmost caution. In time, I doubt not, some of these seeds will be found attached to peduncles from the structure of which much will be learnt; until then we must be content to wait. One lesson we may certainly learn from the numerous species of these seeds with which we are already familiar, viz. that there were, in the Carboniferous forests, many Gymnospermous stems clothed with foliage, of which we have not yet discovered any traces, probably because, as has more than once been suggested, these Gymnosperms did not flourish upon the low swampy grounds which were the homes of the great mass of the coal-producing plants.

M. BRONGNIART'S observations on the fertilized ovules of *Ceratozamia Mexicana* and *C. Ghiesbrechtii*, just referred to (*loc. cit.* p. 305), show that, in them, the apical extremity of the unfertilized nucule projected as a mamilliform prolongation which occupied and filled much of the micropyle. My *Lagenostoma physoides* (figs. 77 & 78) exhibits a similar termination to the nucleus. M. BRONGNIART concluded that the mamilliform projection of the nucleus became absorbed, forming, by the disintegration of its cells, the "cavité pollinique" of his memoir, and which I have termed the lagenostome. If this is the case, the similar mamilla in figs. 77 & 78 cannot be the same structure as is seen in the Cycadean ovules, because the narrow prolongation of its upper part is here retained in its integrity, whilst the lagenostome (figs. 77, *c*, & 78, *c*) is superadded to and not formed out of that structure*. M. BRONGNIART'S idea that all these seeds are Cycadean rather than Coniferous must also await further inquiry before we can either accept or reject it. If the grains discovered in several of the lagenostomes are truly pollen-grains, their presence indicates that the seeds containing them were

* My latest studies seem to favour M. BRONGNIART'S conclusions thus far, viz. that the central organ of each of these seeds which, in the course of the memoir, has been termed "the nucleus," may really be the endosperm found in the interior of the original nucleus, the tissues of the latter structure having been entirely absorbed. In this case the only traces of the original contour of that nucleus are now found in what I have termed "the nucular membrane" and its lagenostomal prolongations. If this be correct, it then becomes probable that the remarkable cluster of parenchymatous cells seen in the interior of the "lagenostome" or "cavité pollinique" of so many of my specimens, and the origin of which is so difficult to explain, is neither more nor less than the remains of the cellular tissue of the uppermost extremity of the original nucleus, which primarily formed its narrowed apical extension occupying the micropyle, and which was not absorbed when the rest of the nucleus disappeared. The acceptance of these conclusions would bring my observations upon the Carboniferous forms into close harmony alike with those of M. MIQUEL ('Archives Néerlandaises,' t. iii., 1868) and of M. BRONGNIART upon the fertilized and unfertilized ovules of living Cycads. Of course the conclusion would follow that the affinities of these fossil forms is Cycadean rather than Coniferous.

young ones. On the other hand, the structure of their testæ shows them to be true seeds and not ovules. Unfortunately the nucleus has almost always disappeared; and where traces do remain we have as yet seen nothing beyond a cellular perisperm. Further research may, however, reveal other examples in which traces of the peculiar and characteristic endosperms of the Conifers and Cycads may be detected. It is very desirable that all who are in a position favourable to the prosecution of such researches should keep this important possibility steadily in view.

Whilst thus avoiding all attempts definitely to associate these seeds with individual plants, we must not overlook the fact that most of them have been obtained either from the thin upper foot coal-seam of the Ganister beds, from which so many of the finest of our Oldham plants have been derived, and that, consequently, we naturally look to those plants to furnish the parent stems on which these seeds grew. But they fail to show any structures with which the seeds can reasonably be associated. The only stems which we yet possess that can with any degree of probability be identified with the seeds are the *Dadoxylons.* BRONGNIART thinks that the *Nœggerrathiæ* may have been the parents of some of them, especially of *Cardiocarpon*; but unless the *Cordaites* were *Nœggerrathiæ* we find no trace of that group in the Oldham nodules; and, as already remarked, our chief specimens of *Dadoxylon* have been derived from the marine beds of the Ganister series and of Coalbrookdale, into which they had obviously been drifted, and in which the seeds are extremely rare.

INDEX TO PLATES 5–16.

Rachiopteris corrugata.

Fig. 1. Small portion of the external surface of the cortex, with its transverse ridges and furrows. Enlarged $7\frac{1}{2}$ diameters.

Fig. 2. Transverse section of the lower extremity of the fragment of a stem. Enlarged $1\frac{1}{2}$ diameter.

Figs. 3 to 12. Series of similar sections to fig. 2, arranged numerically in their ascending order. Fig. 4 is enlarged 3 diameters, the remainder $1\frac{1}{2}$ diameter.

The letters of reference throughout this series indicate the following structures:—

a. Medulla. *b*. Axial vascular cylinder. *c*. Primary vascular bundles given off from the axial cylinder, probably to petioles. *d*. Secondary vascular bundles given off either from the primary bundles (*c*) or from the axial cylinder. *e*. Inner cortical tissue. *f*. Outer cortical tissue. *g*. A branch or petiole separating from the main stem and enclosing a primary vascular bundle. *h.* Smaller divergent petiole, or root, containing one of the secondary vascular bundles.

Fig. 13. Central axial vascular cylinder. Enlarged $18\frac{1}{2}$ diameters.

a. Medulla composed of cells intermingled with small vessels. *b.* Seven clusters of vessels blending peripherally into an almost continuous vascular zone. *g.* Bundle-sheath composed of small vertically elongated cells.

Fig. 14. Longitudinal section of the axial vascular cylinder.

a. Medulla. *b, b.* Vascular cylinder. *e.* Cells of the cortical parenchyma. *g.* Bundle-sheath. Enlarged $18\frac{1}{2}$ diameters.

Fig. 15. Transverse section of vessels (*b*) of the axial cylinder exhibiting the tylose cells (*i*) with which each vessel is filled. Enlarged 100 diameters.

Fig. 16. Longitudinal section of a similar vessel.

i. Tylose cells. Enlarged 100 diameters.

Fig. 17. The primary vascular bundle, fig. 4, *c.*

g. The bundle. *c.* Inner bark. *g''.* The bundle-sheath.

Fig. 18. Transverse section of a detached petiole.

c. Central vascular bundle. *e.* Inner cortex. *f.* Outer cortex. Enlarged $7\frac{1}{2}$ diameters.

Fig. 19. The portion (*b'*, *b'*) of the vascular cylinder of fig. 6.

b', *b'*. A cluster of vessels preparing to separate themselves as a primary vascular bundle. Enlarged $18\frac{1}{2}$ diameters.

Fig. 20. Similarly enlarged representation of the projection *b'* from the central cylinder of fig. 7. Enlarged $18\frac{1}{2}$ diameters.

a. Medullary cells. *b.* Cluster of axial vessels. *b'*, *b''*. Vessels separating from the axial cylinder *b.* *d.* Secondary bundle. *e.* Cells of inner cortex. Enlarged $18\frac{1}{2}$ diameters.

Fig. 21. Oblique longitudinal section of part of a central vascular axis.

b. Vessels of the axial cylinder. *c.* A primary bundle departing from the axial cylinder. *d.* A secondary bundle. *e.* Parenchyma of the inner bark. *f.* Outer bark. *g.* Bundle-sheath. Enlarged 6 diameters.

Fig. 22. Cells and vessels from fig. 19, *b'*. Enlarged 62 diameters.

Fig. 23. Transverse section of the primary petiolar bundle, fig. 5, *c.* Enlarged $18\frac{1}{2}$ diameters.

d. A secondary bundle preparing to branch off from the primary one.

Fig. 24. Transverse section of the secondary bundle, fig. 6, *d'*, now becoming detached as a small petiole or root and invested by its cortical tissues. Enlarged $18\frac{1}{2}$ diameters.

Fig. 25. Section of a sporangium of a Fern. Enlarged 75 diameters.

a. Annulus. *b.* Peduncle. *c.* Spores.

Fig. 26. Single spore of fig. 25, enlarged 320 diameters.

Fig. 27. Lateral view of the base of a sporangium of a Fern allied to the Gleicheneaceæ or Schizeaceæ. Enlarged 75 diameters.
a. Base of attachment.

Fig. 28. Inferior surface of a similar sporangium to fig. 27. Enlarged 75 diameters.
a. Base of attachment.

Fig. 29. Transverse section of a similar sporangium, intersecting the annulus and filled with sporangia.

Fig. 30. Transverse section of a similar sporangium made near its apex at the upper margin of the annulus. Enlarged 75 diameters.

Figs. 31 & 32. Sections of two of the spores of fig. 29. Enlarged 320 diameters.
a. Spore-wall. *b.* Primordial utricle.

Gymnospermæ.

Fig. 33. Transverse section of the ligneous zone (*b*) and the outermost part of the medulla (*a*) of a young twig of a *Dadoxylon* from Coalbrookdale. Enlarged 50 diameters.

Fig. 34. Transverse section of the bark of the same specimen.
b. Outermost fibres of ligneous zone. *d.* Inner bark. *e.* Outer bark.

Fig. 35. Vertical section of the structures seen in fig. 33. Enlarged 50 diameters.
a. Medulla. *b.* Ligneous zone. *b′.* Medullary sheath.

Fig. 36. Vertical section of fig. 34. Enlarged 50 diameters.
b. Outermost fibres of ligneous zone. *d.* Inner bark. *e.* Outer bark.

Fig. 37. Barred vessels of the medullary sheath of fig. 35. Enlarged 270 diameters.

Fig. 38. Radial section of portions of two fibres of the ligneous zone of fig. 35.
f. Cells of a medullary ray. Enlarged 270 diameters.

Fig. 39. Similar representation to fig. 38, but without any medullary ray.

Fig. 40. Tangential section of parts of four fibres with four medullary rays (*f*) and interfibrous beaded lines (*g*), which are sections of the margined disks seen on the surfaces of figs. 38 & 39.

Fig. 41. Vertical section of the Sternbergian pith of a *Dadoxylon* from near Oldham. Natural size.

Fig. 42. Transverse section of the pith and ligneous zone of a large branch of a *Dadoxylon* from South Owram, near Halifax. Natural size.

Fig. 43. Vertical section of the stem fig. 42. *a.* Medulla. *b.* Ligneous zone.

Fig. 44. Transverse section of a small branch of a *Dadoxylon* from near Oldham. Enlarged 6 diameters.
a. Medulla. *b.* Woody cylinder. *d.* Inner bark. *g, g.* Pair of bundles going off to leaves?

Fig. 45. Vertical section of fig. 44. Enlarged 6 diameters.
a. Sternbergian pith. *b.* Ligneous cylinder. *d.* Inner bark disorganized.

Fig. 46. Transverse section of a small branch of a *Dadoxylon*, exhibiting concentric lines of growth. Enlarged $4\frac{1}{2}$ diameters.

g, *g*. Pairs of leaf-bundles.

Fig. 47. Portion of a radial section of the specimen fig. 44, exhibiting a foliar bundle (b') departing from the innermost layer of the woody zone. Enlarged 15 diameters.

a, *a*. Thickened outermost margins of the Sternbergian medullary disks.

Fig. 48. Tangential section of a portion of the ligneous zone of fig. 44, exhibiting two of the foliar bundles (*g*, *g*) intersected transversely. *b*. Vessels of the ligneous zone. Enlarged 15 diameters.

Fig. 49. Tangential section of a portion of the ligneous zone of the Coalbrookdale twig (figs. 33–40), exhibiting some of the fibres undergoing deflection to form a foliar (?) bundle. Enlarged $62\frac{1}{2}$ diameters.

f, *f*. Medullary rays.

Fig. 50. Part of the radial section of a *Dadoxylon* from Binns Cliff, Burntisland. Enlarged $62\frac{1}{2}$ diameters.

Fig. 51. Part of a wood-fibre of fig. 50, showing the surface parallel to the medullary rays. Enlarged 270 diameters.

Fig. 52. Part of a fibre, showing the surface parallel to the medullary rays, from Oldham. Enlarged 270 diameters.

Seeds of Gymnospermæ.

Fig. 53. *Lagenostoma ovoides*. Obliquely transverse section through the upper extremity of the micropyle of Mr. BUTTERWORTH's specimen.

a. Exotesta. *d*. Orifice of lagenostome. *e*. Part of the "canopy" of the lagenostome.

Fig. 54. Second section of the same specimen made a little below the apex of the seed.

a. Exotesta. *c*. Lagenostome. *e*. Folds of canopy.

Figs. 55 & 56. Third and fourth sections of the same, made yet lower down.

Fig. 57. Portion of the testa (*a*) and canopy (*e*), from a section intermediate between figs. 55 & 56.

Fig. 58. Tangential section of a second seed of *Lagenostoma ovoides*, made midway between its centre and its lateral surface.

a. Testa. *f*. Nucular membrane. *g*. Perispermic membrane. Enlarged 15 diameters.

Fig. 59. Second tangential section of fig. 58, made nearer to its centre.

a. Testa. *c*. Lagenostome. *e*, *e*. Canopy. *f*. Nucular membrane. *g*. Peri spermic membrane. *h*. Parenchyma of the interior of the lagenostome. Enlarged 15 diameters.

Fig. 60. Vertical section made through the centre of fig. 58.

a. Testa. *c*. Lagenostome. *d*. Micropyle. *e*, *e*. Canopy. *f*. Nucular membrane. *g*. Perispermic membrane. *h*. Parenchyma of the lagenostome. Enlarged 15 diameters.

Fig. 61. Tangential section of the same made nearly in the plane of fig. 59, but on the opposite side of the seed.

a. Testa. *c*. Lagenostome. *e*, *e*. Canopy. *f*. Nucular membrane. *g*. Perispermic membrane. *h*. Parenchyma of lagenostome. Enlarged 15 diameters.

Fig. 62. Upper part of the section, fig. 61. Enlarged 80 diameters.

Figs. 63 to 68. Series of longitudinal sections of a third specimen of *Lagenostoma ovoides*, of which fig. 67 is the central one, whilst fig. 68 exhibits the chalaza (*i*) and what appears to have been a funiculus, *k*. Enlarged 15 diameters.

Fig. 69. Upper part of fig. 67, enlarged 80 diameters.

a. Exotesta. *b*. Three folds of the canopy. *c*. Lagenostome. *f*,*f*. Nucular membrane probably united to the perispermic one.

Fig. 70. Imperfect upper or apical portion of a fourth seed of *Lagenostoma ovoides*, with pollen-grains (*l*) lodged in the interior of the lagenostome, between its outer wall and the lagenostomal parenchyma.

Fig. 71. Transverse section near the apex of Mr. NIELD's specimen of *Lagenostoma ovoides*. Enlarged 15 diameters.

a. Exotesta. *d*. Lagenostome. *e*. Canopy.

Fig. 72. Transverse section of the seed, fig. 71, made across the centre of the lagenostome.

a. Testa. *c*. Membranous wall of the lagenostome. *e*. Canopy. *h*. Parenchyma of lagenostome. *l*. Pollen-grains. *n*. Vertical columns of a peculiar cellular tissue. Enlarged 30 diameters.

Fig. 73. Parallel section to fig. 72, made inferiorly to that figure. Enlarged 30 diameters.

g. Apex of the perispermic membrane.

Fig. 74. Prosenchymatous cells from the membranous wall of the lagenostome in fig. 70. Enlarged 175 diameters.

Fig. 75. Portion of the perispermic membrane of fig. 73. Enlarged 175 diameters.

Fig. 76. Vertical section through the dried endotesta and nucleus of the seed of a *Salisburia Adiantifolia*.

a. Endotesta. *f*. Nucular membrane. *c*. Cavity between the divided layers of the nucular membrane.

Fig. 77. Vertical section through the centre of a seed of *Lagenostoma physoides*.

b. Prosenchymatous endotesta (?). *c*. Lagenostome. *d*. Micropyle. *e*. Folds of canopy. *n*. Perisperm. Enlarged 15 diameters.

Fig. 78. Tangential longitudinal section of fig. 77.

Fig. 79. Enlarged representation of part of a section made near to fig. 77.

b. Testa? *c*. Lagenostome. *e*. Parts of the canopy. *g*. Probably the united nucular and perispermic membranes. *h*. Parenchyma of interior of lagenostome. *n*. Nucleus.

Fig. 80. *Conostoma oblonga.* Vertical section.

a. Testa. *c.* Cavity, probably occupied by a prolongation of the nucleus. *f.* Nucular membrane. *g.* Perispermic membrane. *h.* Parenchyma of the lagenostome? Enlarged 15 diameters.

Fig. 80*a.* Vertical section of the detached apex of the testa of fig. 80. Enlarged 35 diameters.

Fig 80*. Tangential section of fig. 79 passing outside the parenchyma of the lagenostome.

Fig. 81. Tangential section of fig. 80 made yet more peripherally than fig. 80*.

Fig. 82. *Conostoma ovalis.* Longitudinal section.

a. Testa. *b.* Endotesta. *f.* Nucular membrane. *g.* Perispermic membrane. *h.* Parenchyma of the lagenostome? *n.* Perisperm. Enlarged 22 diameters.

Fig. 83. Upper part of fig. 82.

a. Testa. *b.* Endotesta. *c.* Lagenostome? *c'.* Prosenchymatous wall of the lagenostome, with its inverted funnel-shaped entrance. *f.* Nucular membrane. *f, g.* Nucular and perispermic membranes united. *h.* Parenchyma of the lagenostome? *n.* Nucleus. Enlarged 60 diameters.

Fig. 84. Oblique section of a second specimen made in the direction of the line, fig. 82, *xx.*

a. Testa. *c.* Lagenostome? *c'.* Walls of the funnel-shaped lagenostome. *f.* Divisions of the nucular membrane. *h.* Parenchyma of lagenostome. Enlarged 22 diameters.

Fig. 85. Small seed allied to *Conostoma.* From Mr. AITKEN's Cabinet. Nat. size.

Fig. 86. Vertical section through the centre of Mr. BUTTERWORTH's specimen of *Conostoma oblonga.*

a. Testa. *c.* Cavity, corresponding to *c* in fig. 79. *d.* Micropyle. *f.* Subdivisions of the nucular membrane enclosing the lagenostomal cavity with its parenchyma, *p.* *f, g.* Nucular and perispermic membranes united?

Fig. 87. *Conostoma intermedia.* Longitudinal section, probably not quite central. Enlarged 15 diameters.

a. Testa. *b.* Endotesta? *f.* Nucular membrane. *h.* Parenchyma; probably a remnant of the perisperm.

Figs. 88–93. *Malacotesta oblonga.* Five longitudinal and tangential sections, of which fig. 93 is the most central at the chalazal end of the seed, and fig. 92 at its apex. Fig. 88 is the upper extremity of fig. 92, enlarged 50 diameters. The others are enlarged 15 diameters.

a. Sarcotesta. *b.* Hard endotesta. *c.* Lagenostome. *d.* Micropyle. *f.* Nucular membrane. *g.* Perispermic membrane. *h.* Parenchymatous tube of the micropyle. *i.* Chalaza. *k.* Funiculus.

Fig. 94. Sandstone cast of the interior of the testa of *Trigonocarpon olivæforme,* showing the rounded exterior of the nucleus with two of the narrow radial extensions of the endotestal cavity and the prolonged triangular terminal microplye.

Figs. 95–99. *Trigonocarpon olivæforme.* Five consecutive longitudinal sections, of which fig. 95 is the most peripheral, and fig. 97 the most central one.

a. Exotesta or sarcotesta. *b.* Hard endotesta. *c.* Lagenostomal cavity. *d.* Micropyle. *f.* Nucular membrane. *g.* Perispermic membrane often collapsed. All these figures are of the natural size.

Figs. 100–108. Series of transverse sections, of which fig. 100 is made through the lower part of the triangular micropyle, and fig. 108 near the chalazal base of the seed. The others are intermediate in the order of their numbers. The letters of reference are the same as in the longitudinal series.

Fig. 109. Transverse section of the cells of the endotesta in the neighbourhood of the chalaza. Enlarged 108 diameters.

Fig. 110. Transverse section of the sarcotesta immediately below the chalaza; enlarged 108 diameters. The central aperture is doubtless that through which a vascular bundle entered the seed.

Fig. 111. Vertical section of a portion of the testa. Enlarged 62 diameters.

a. Cells of sarcotesta. *b.* Endotesta.

Fig. 112. Transverse section of the same, from part of fig. 106.

Fig. 113. Upper extremity of the nucular membrane of fig. 96. Enlarged 15 diameters.

c. Lagenostome. *f.* Nucular membrane. *g.* Perispermic membrane.

Fig. 114. Similarly enlarged portion of fig. 97.

Fig. 115. Similarly enlarged portion of fig. 98.

Fig. 115 *a.* *Hexapterospermum Nöggerathi*, nat. size.

Fig. 115 *b.* *H. Nöggerathi*, enlarged 3 diameters.

Fig. 116. *Cardiocarpon anomalum*? Superficial aspect. Enlarged 11 diameters.

a. Exotesta. *b.* Endotesta or nucular membrane? *d.* Micropyle. *n.* Nucleus.

Fig. 117. Slightly oblique longitudinal section of fig. 116. Enlarged 15 diameters.

a. Exotesta. *b.* Endotesta or nucular membrane. *g.* Perispermic membrane. *i.* Chalaza. *k.* Funiculus. *n.* Nucleus.

Fig. 118. Vertical section of another example of *Cardiocarpon anomalum.* Enlarged 22 diameters.

a. Exotesta. *b.* Endotesta. *d.* Micropyle. *i.* Chalaza.

Fig. 119. Vertical section of another specimen of the same. Enlarged 22 diameters.

a. Exotesta. *b.* Endotesta. *d.* Micropyle. *i.* Chalaza.

Fig. 120. Parenchymatous cells of the perisperm of fig. 116. Enlarged 50 diameters.

Fig. 121. *Cardiocarpon compressum.* Approximate external form.

Fig. 122. *Cardiocarpon acutum* of LINDLEY and HUTTON.

Fig. 123. Vertical section of the upper half of a seed of *Cardiocarpon compressum*, made on the plane of its greatest diameter. Enlarged 11 diameters.

Fig. 124. Transverse section of the same seed from the lower end of fig. 123.

Fig. 125. Transverse section of the base of the same seed passing through the chalaza.

Fig. 126. Longitudinal section of another specimen of *Cardiocarpon compressum* made vertically to the broad surface of fig. 121, and nearly at its centre.

a. Exotesta. *b*. Endotesta. *d*. Micropyle. *f*. Nucular membrane. *g*. Perispermic membrane. *n*. Nucleus.

Fig. 127. A vertical section of the same specimen made on one side of its centre along the line fig. 121, *x*.

Fig. 128. A vertical section made through the line of fig. 121 *y*.

Fig. 128*. Transverse section of *Cardiocarpon compressum* near its base.

Fig. 129. *Cardiocarpon Butterworthii*. External aspect. Natural size.

Fig. 130. *Cardiocarpon Butterworthii*. Enlarged 6 diameters.

Fig. 131. *Cardiocarpon Butterworthii*. Cells of the perisperm of a second and somewhat larger specimen. Enlarged 50 diameters.

Figs. 132, 133, 134. Three seeds from the Upper Coal-measures near Stonehouse, Lanarkshire. Enlarged 7 diameters. Apparently the *Cardiocarpum tenellum* of Dr. DAWSON.

Fig. 135. Half of a seed of *Polypterospermum* from the uppermost Coal-measures of Ardwick. Natural size.

Figs. 136 & 137. The two halves, apparently, of the same seed, enlarged 4 diameters.

Fig. 1.

Fig. 4.

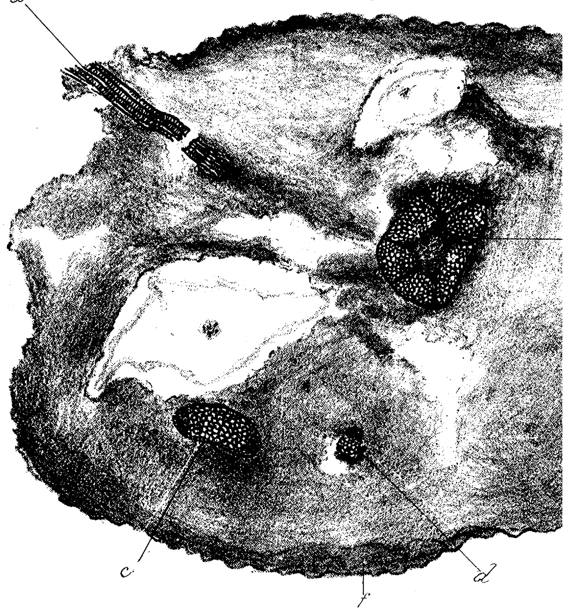


Fig. 2.

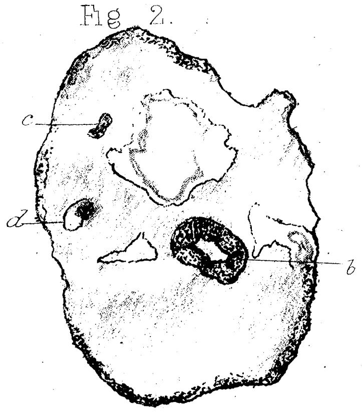
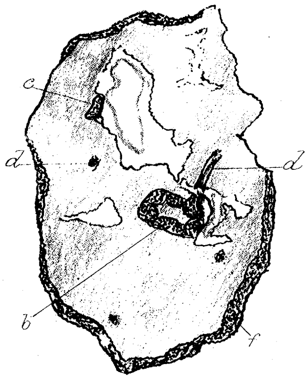


Fig. 3.



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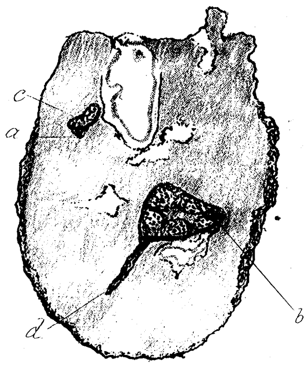

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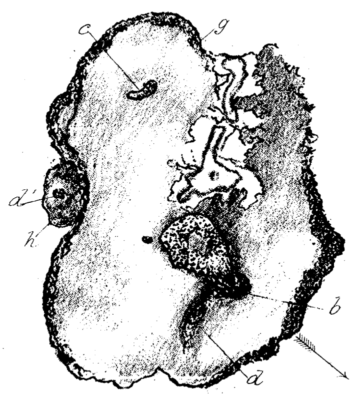

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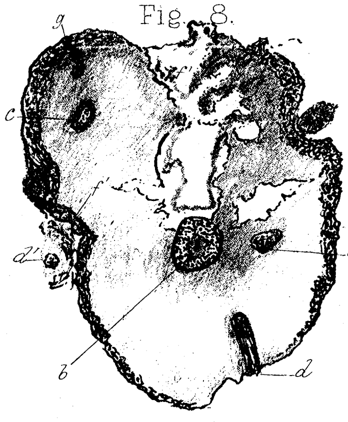

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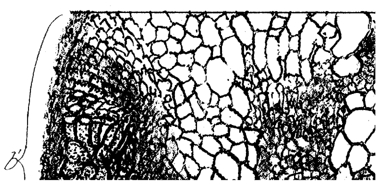

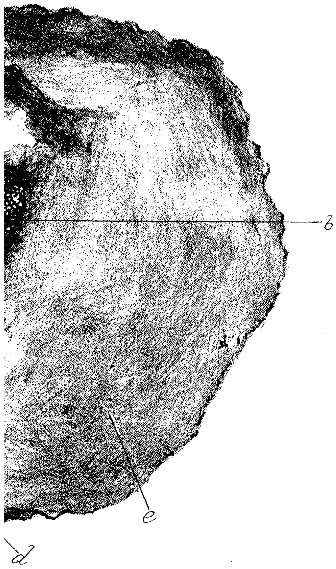

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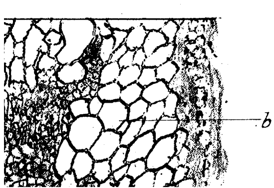

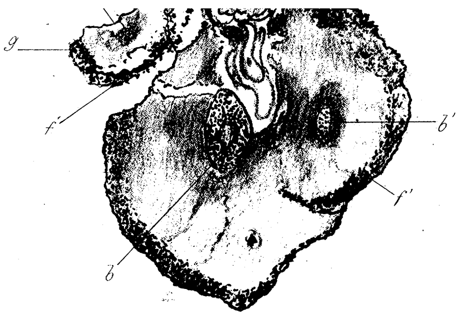

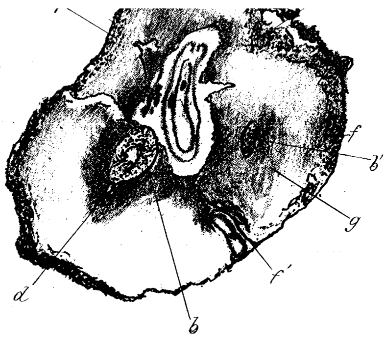

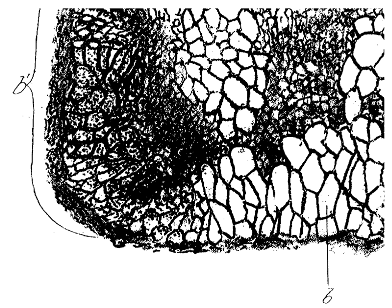

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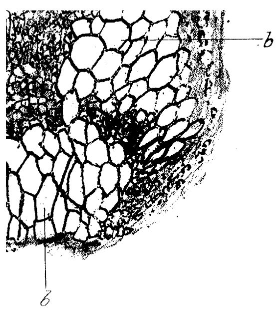

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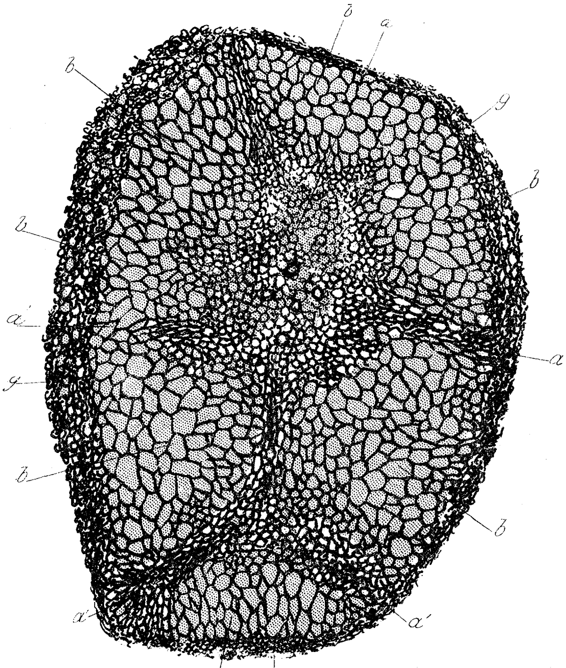

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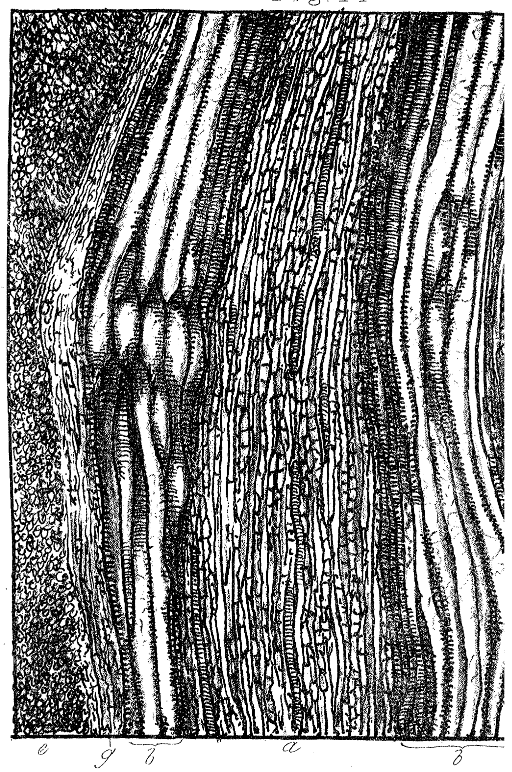

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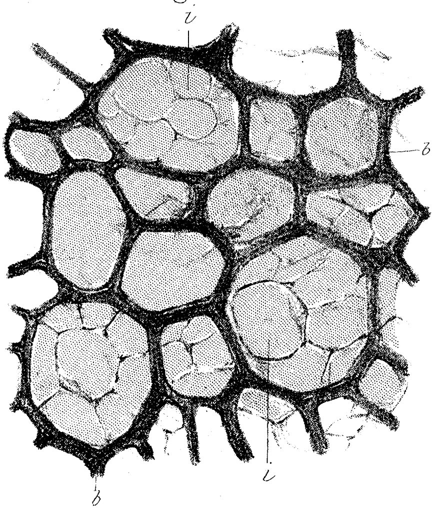

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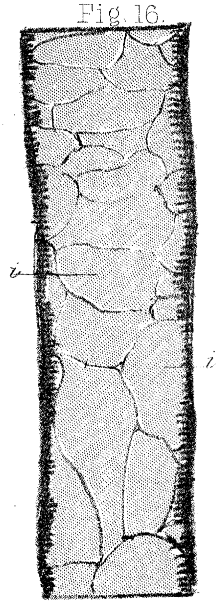

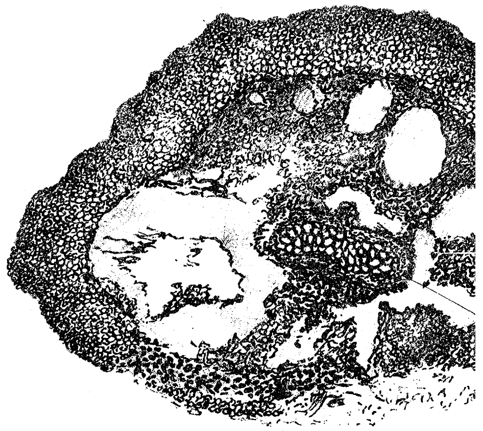

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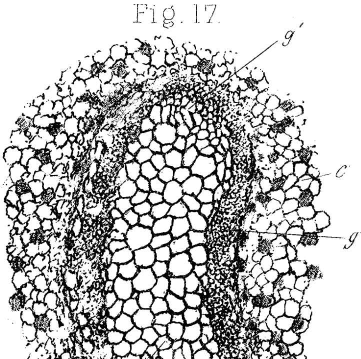

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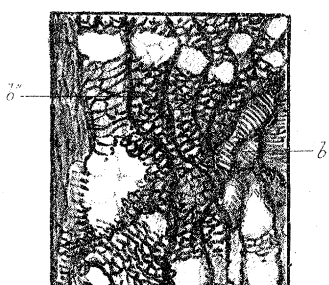

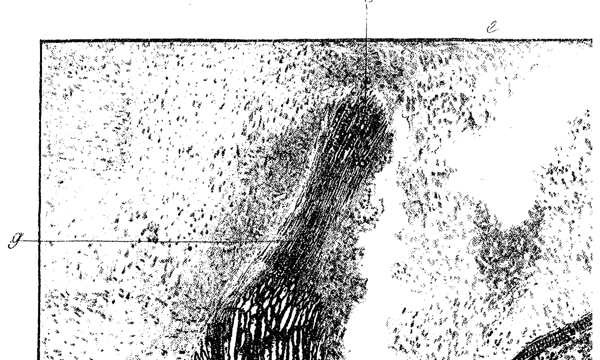

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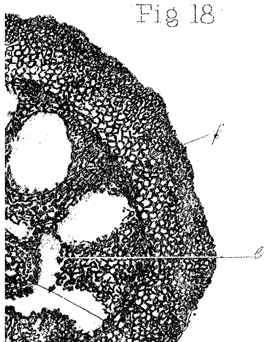

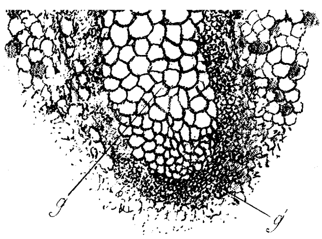

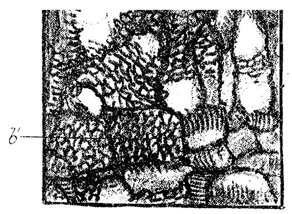

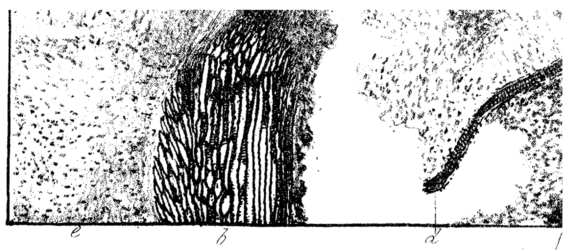

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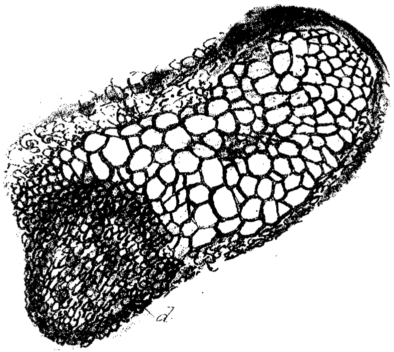
Macdonald, Lith. London.

Fig. 23.



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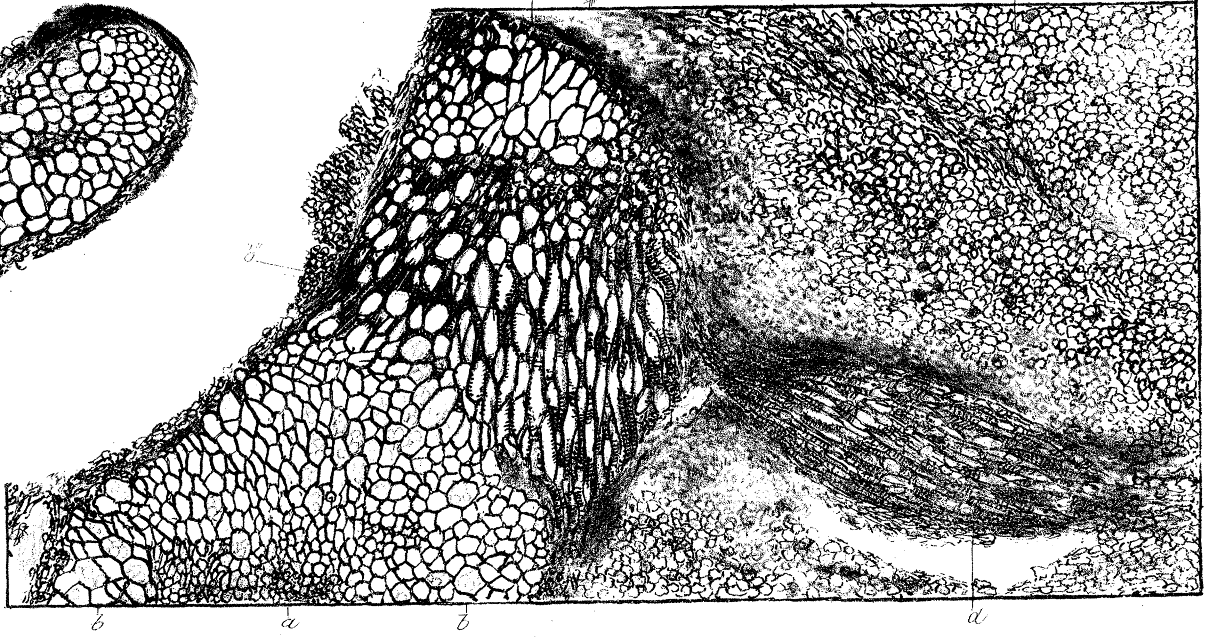

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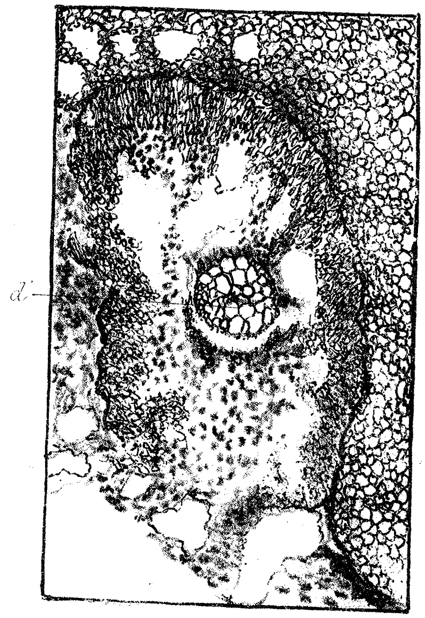

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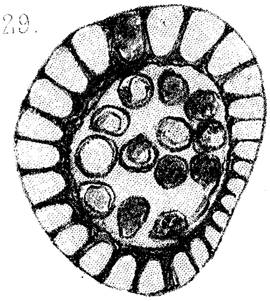

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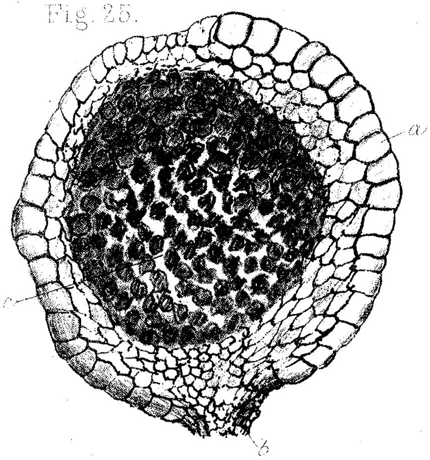

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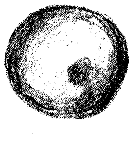

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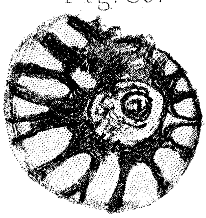

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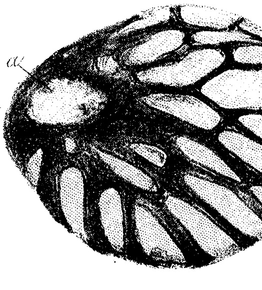

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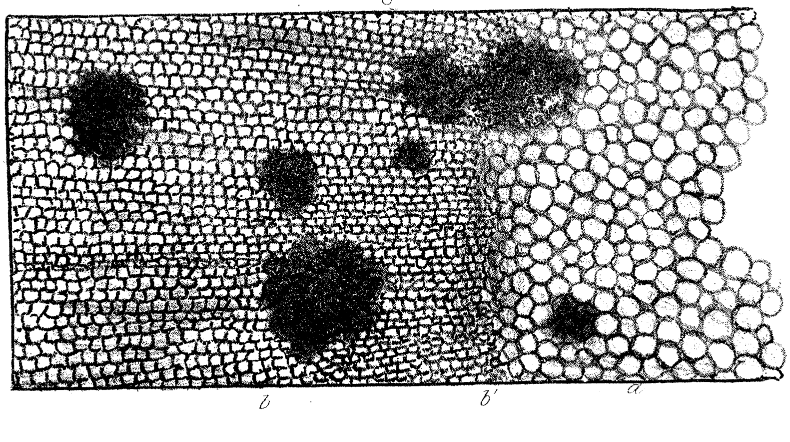

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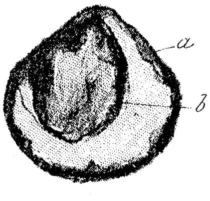

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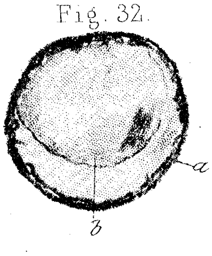

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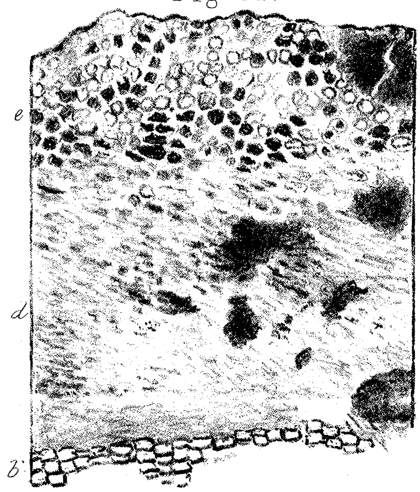

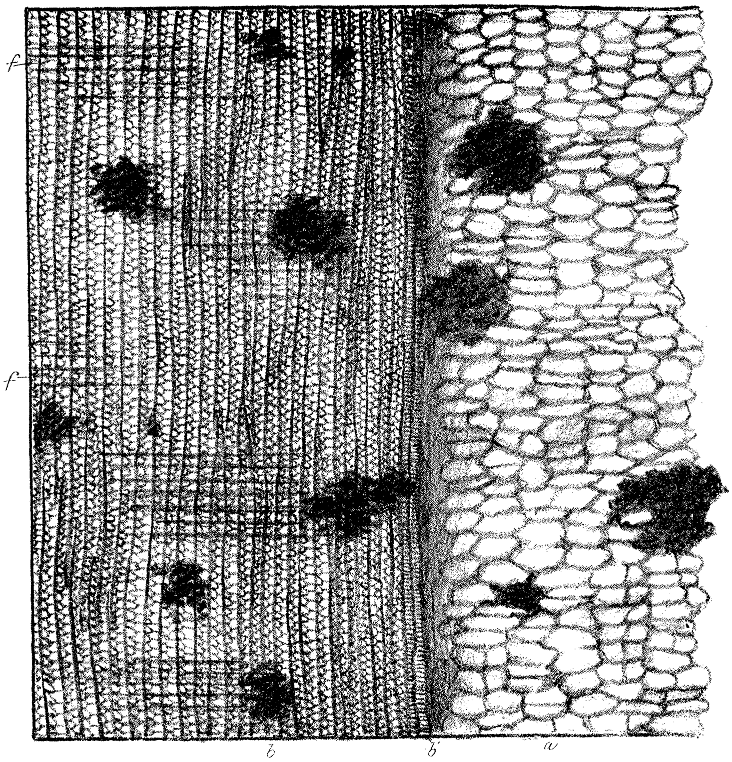

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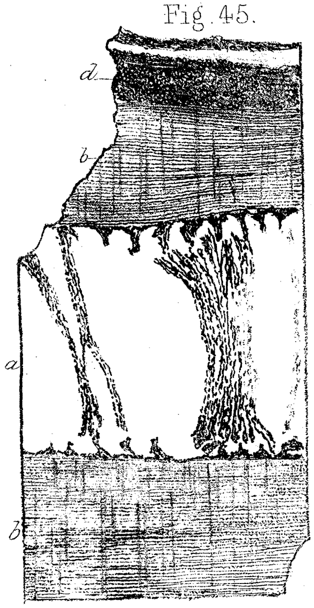

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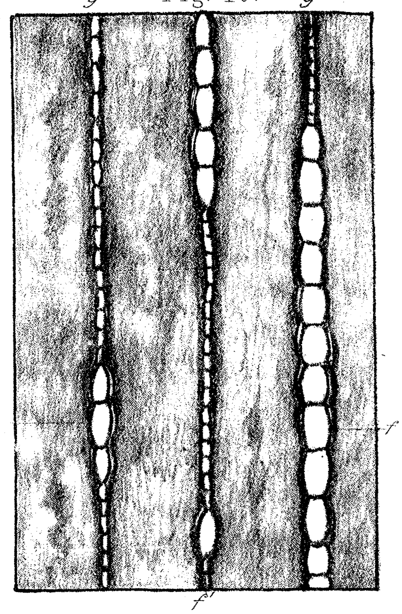

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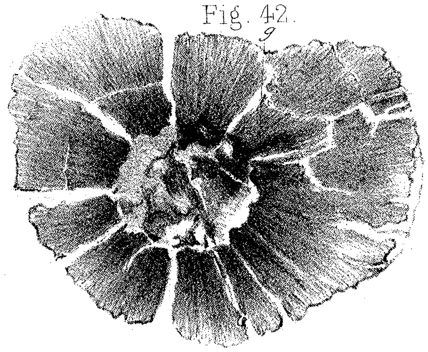

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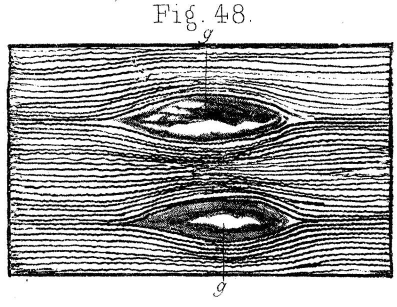

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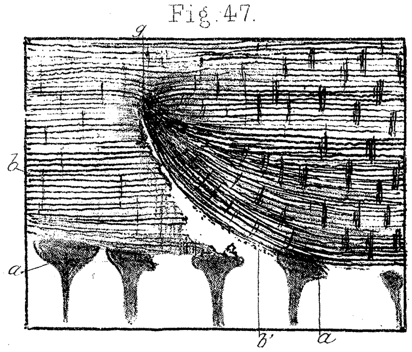

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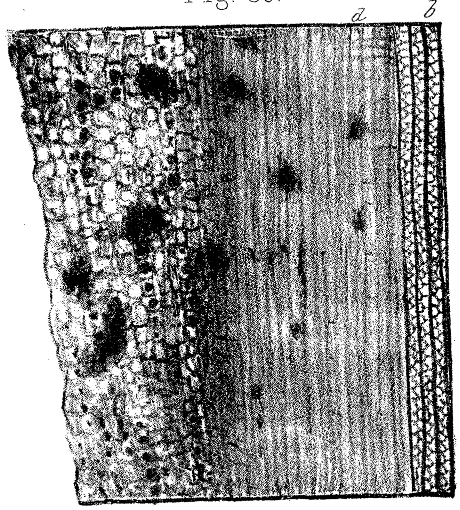

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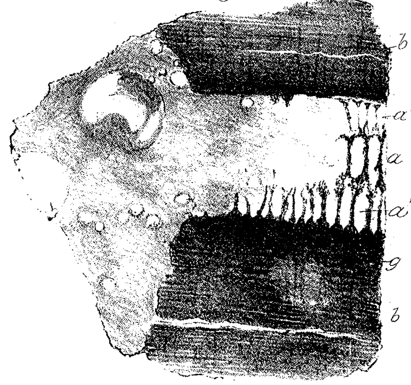

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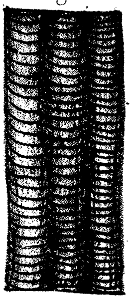

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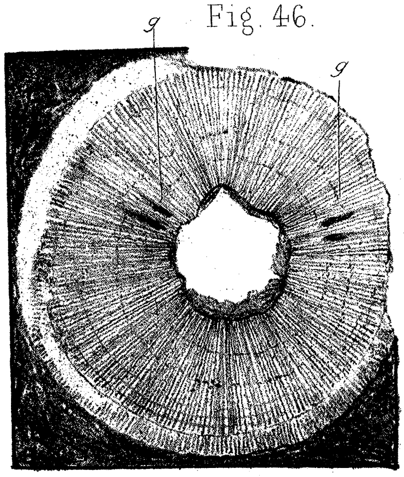

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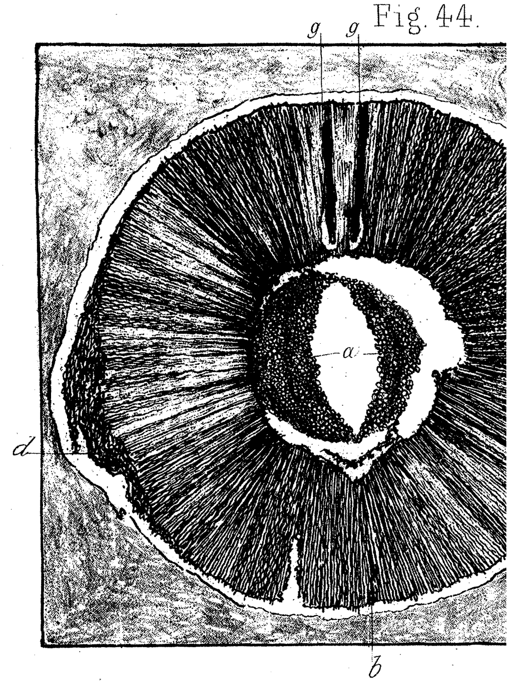

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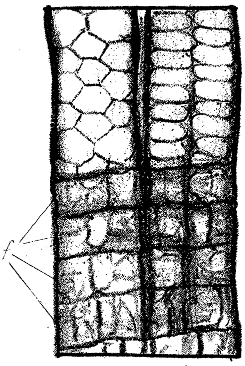

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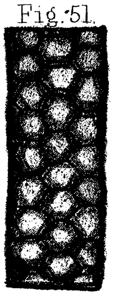

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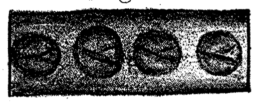

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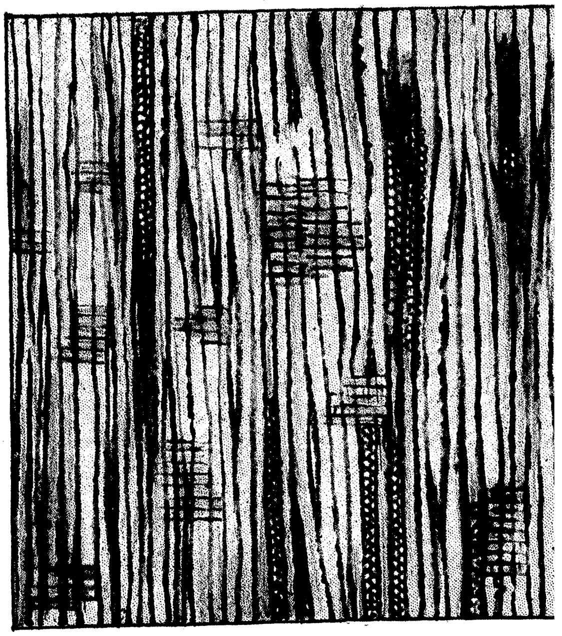

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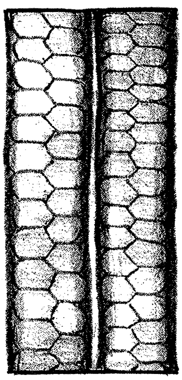

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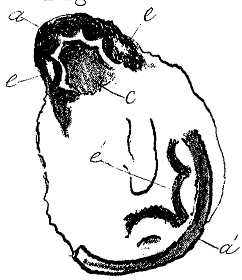

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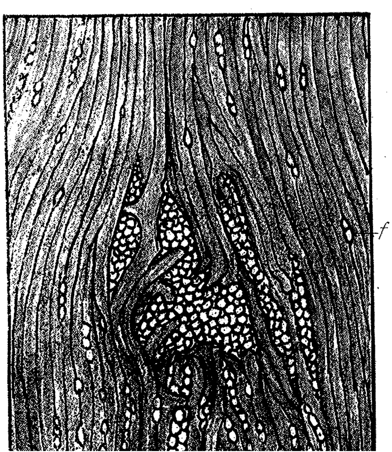

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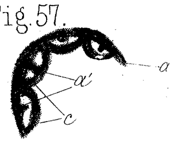

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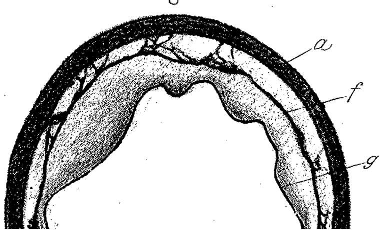

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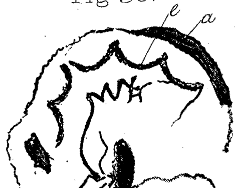

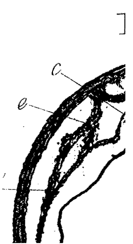

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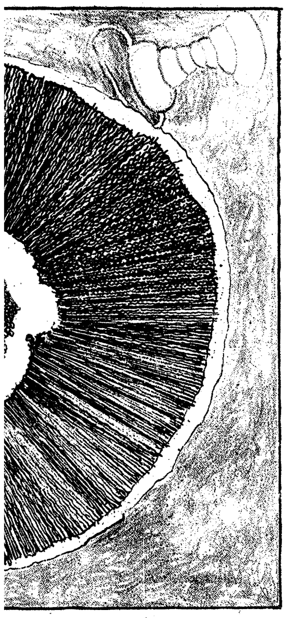

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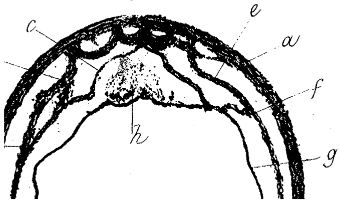

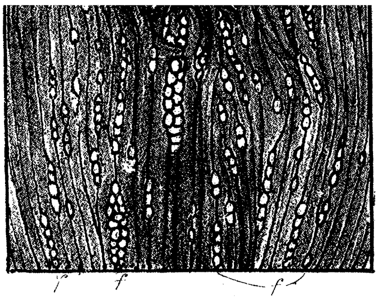

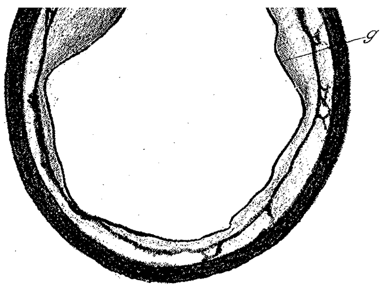

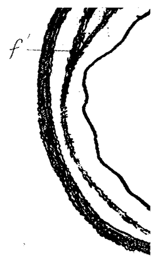

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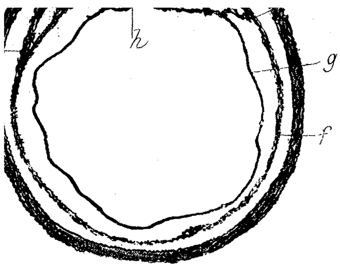

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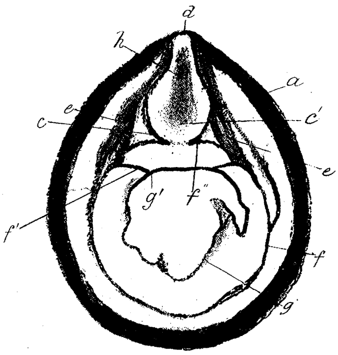

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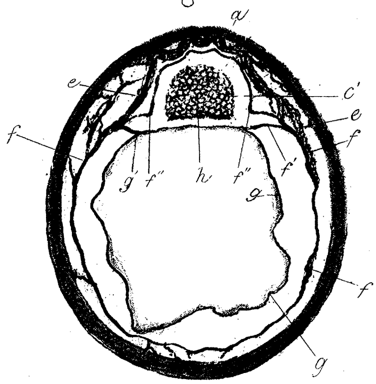

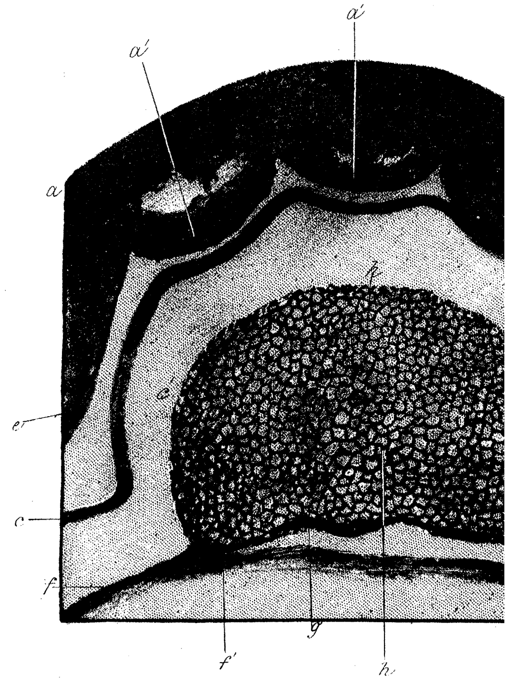

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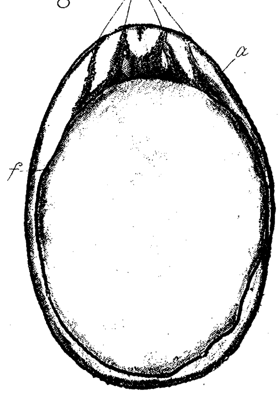

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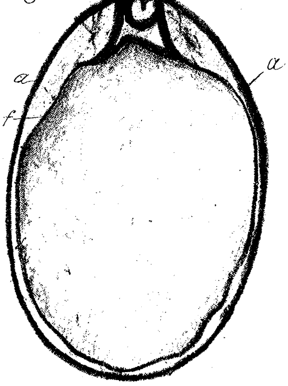

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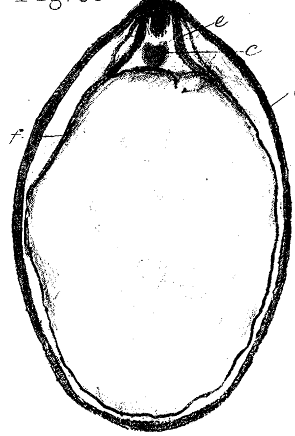

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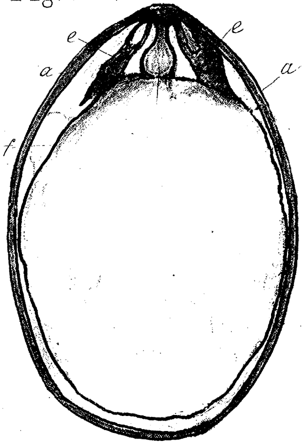
Fig. 67.



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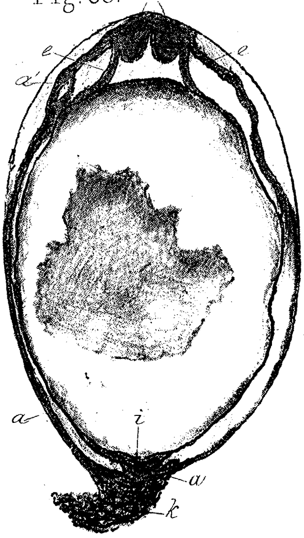

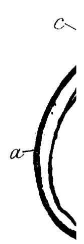

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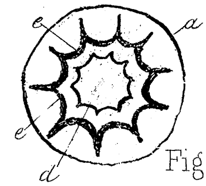
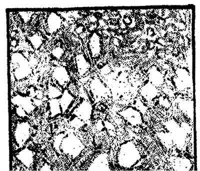


Fig. 69.

Fig. 74.

Fig. 75.



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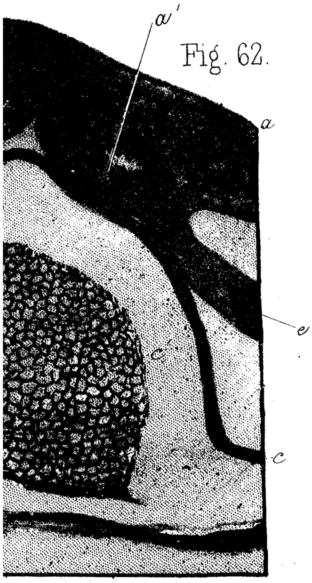

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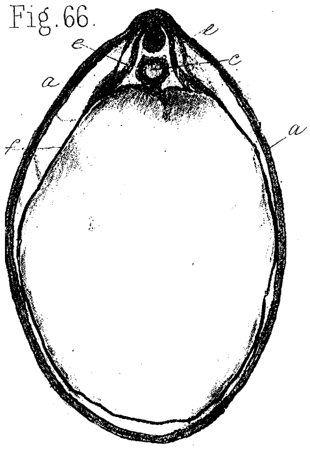

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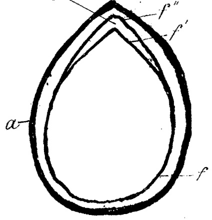
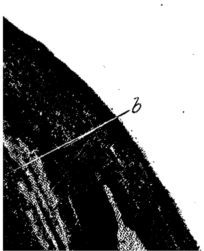
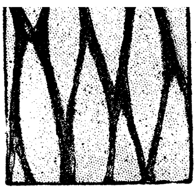
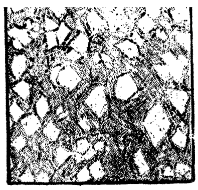
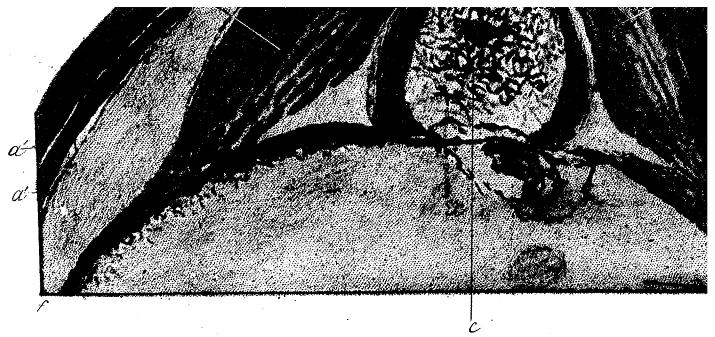








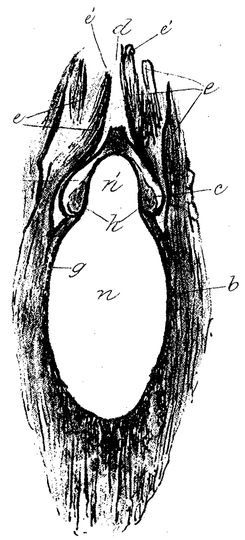


W.C. Williamson, Auto. Lith.

Maclure &

Maclure & Macdonald, Lith. London.

Fig 77.



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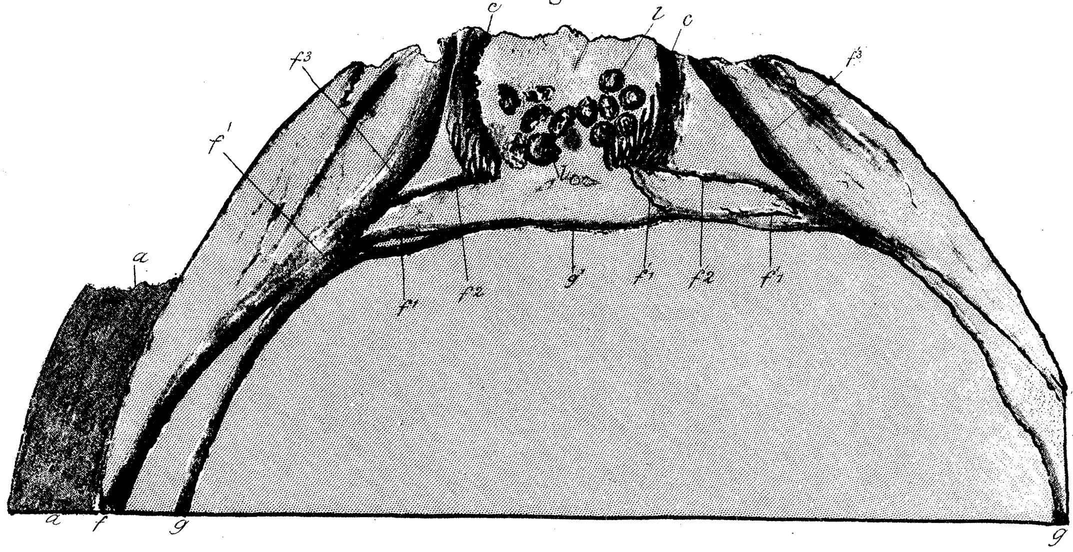

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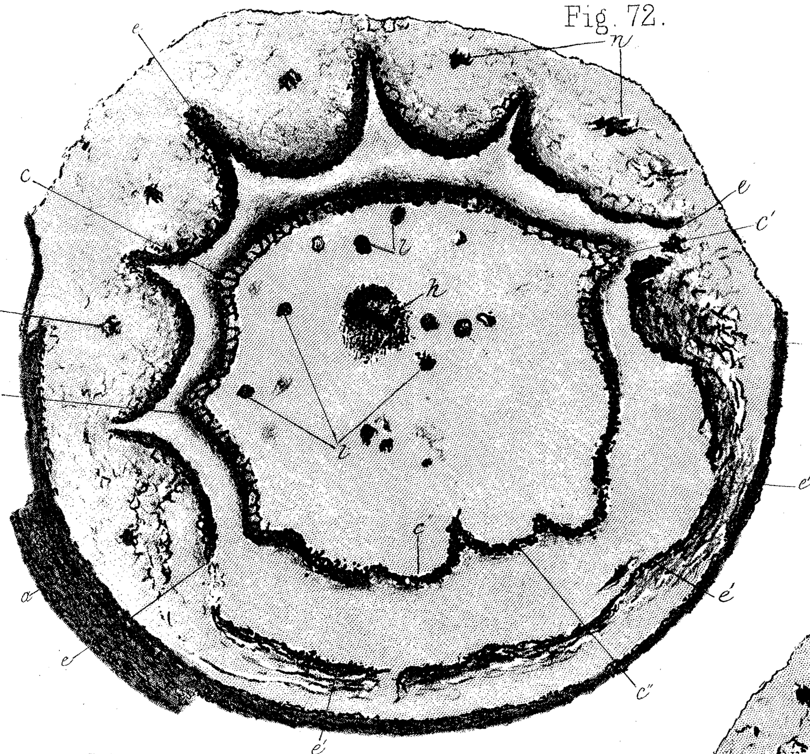
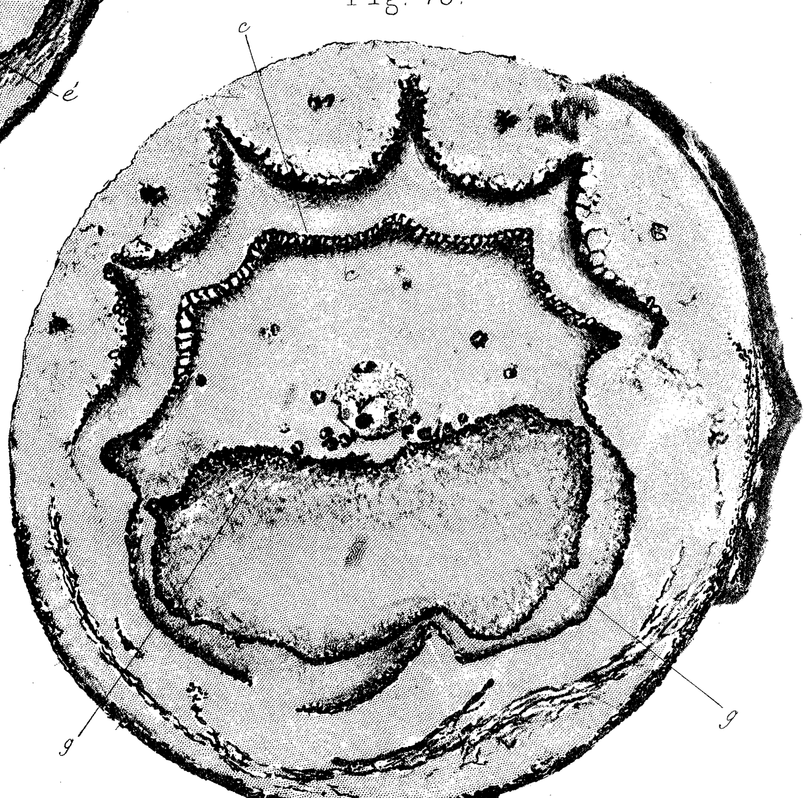


Fig. 80*.

Fig. 73.



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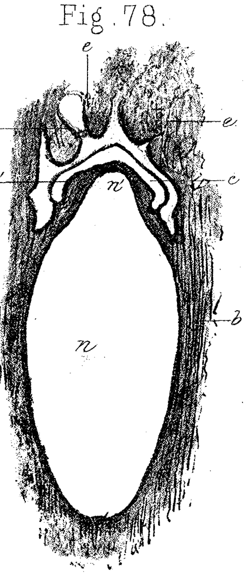
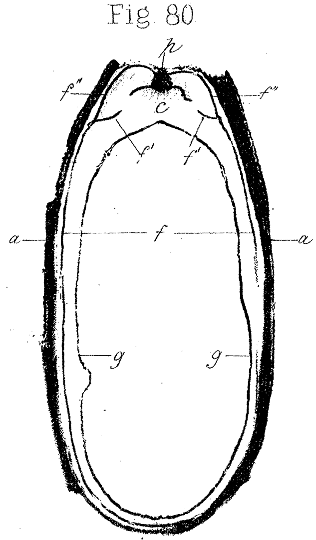


Fig 80



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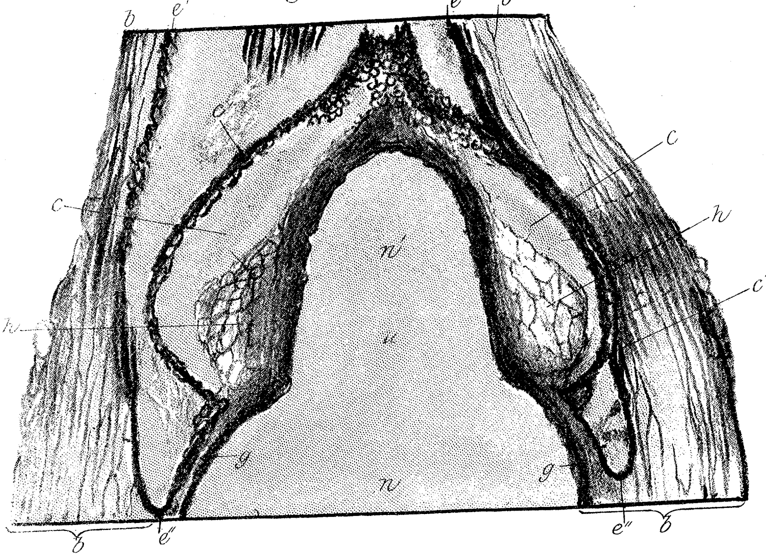

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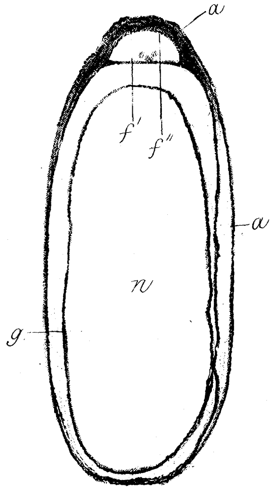

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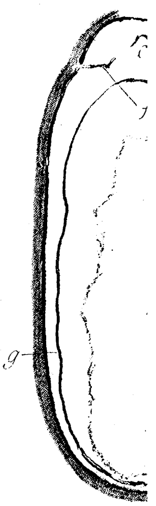

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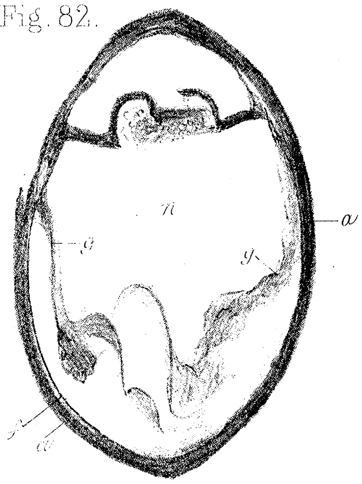
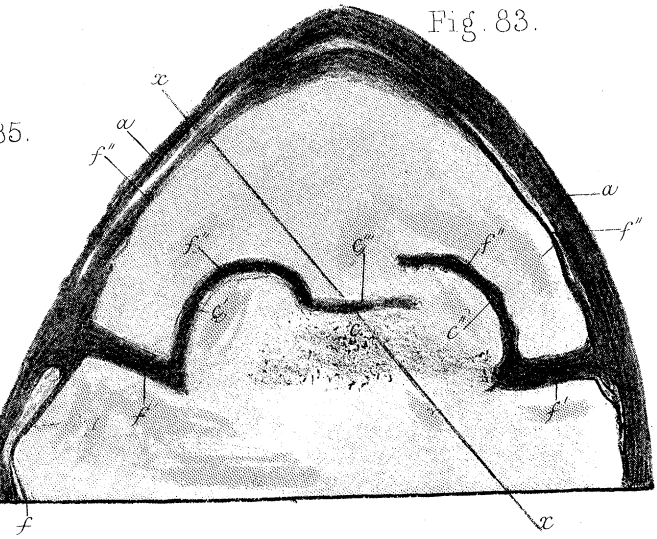
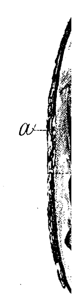
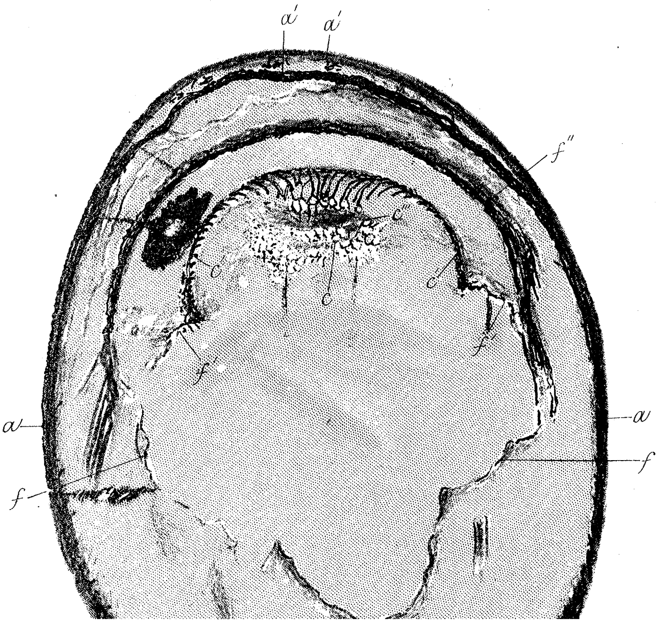


Fig. 85.

Fig. 83.







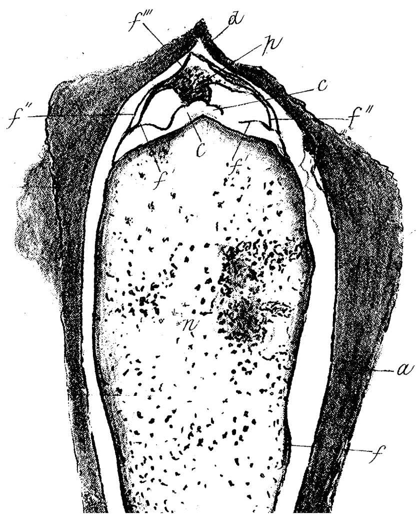


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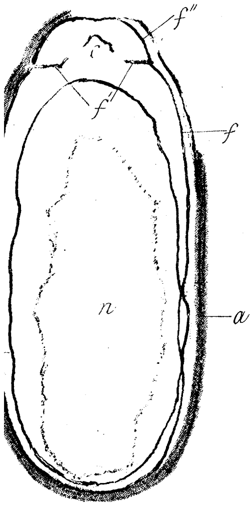
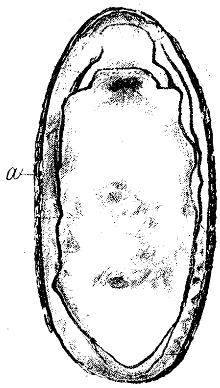
Fig. 80*.





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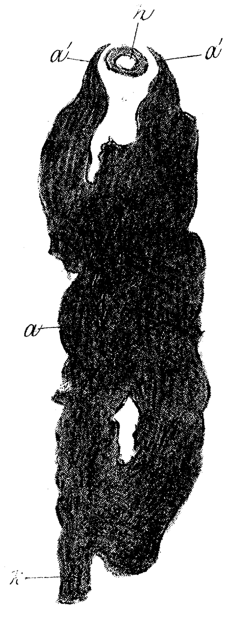

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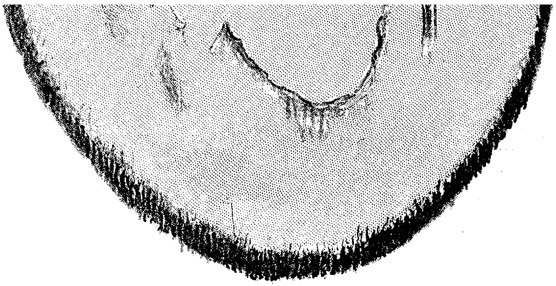

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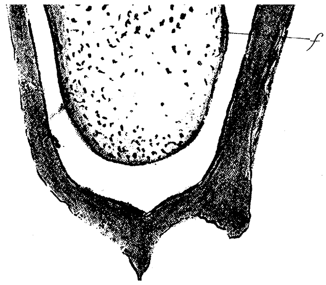

Fig. 86.

W.C. Williamson, Auto Lith.

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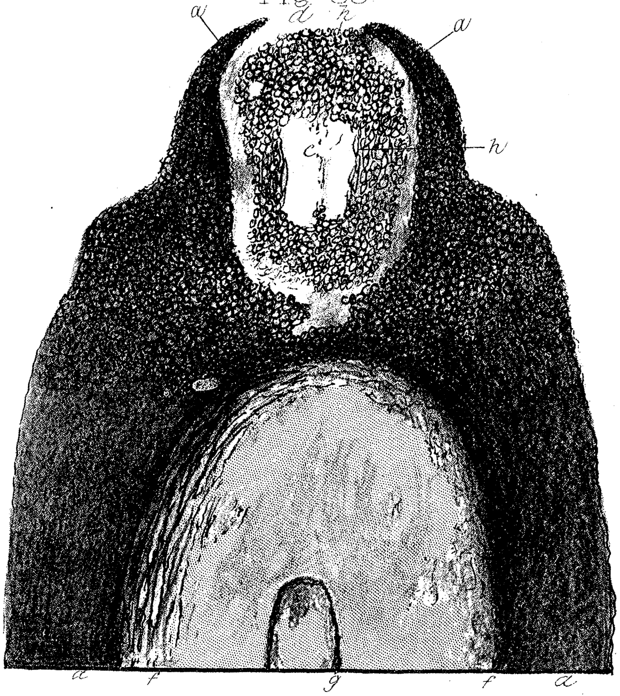
Maclure & Macdonald, Lith. London.

Fig. 88



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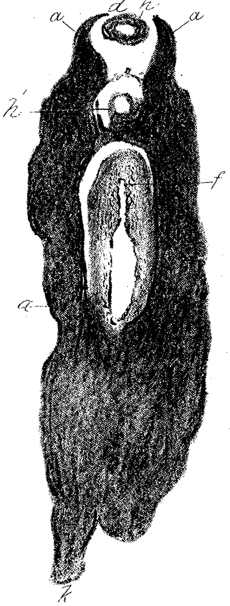

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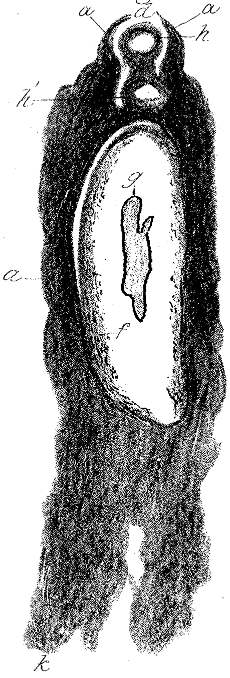

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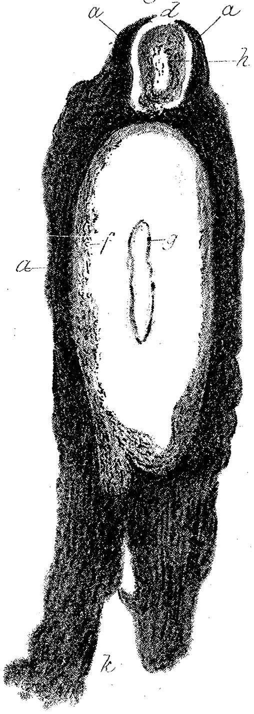

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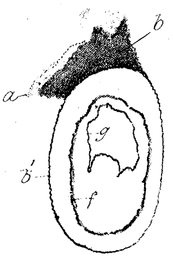

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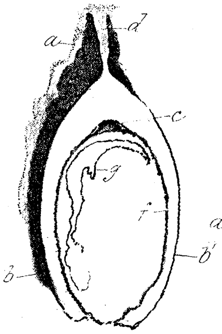

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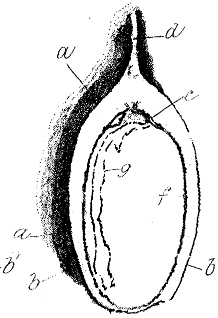

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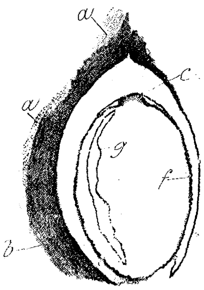

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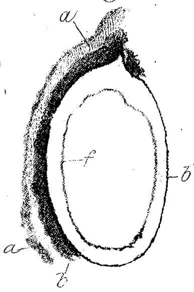

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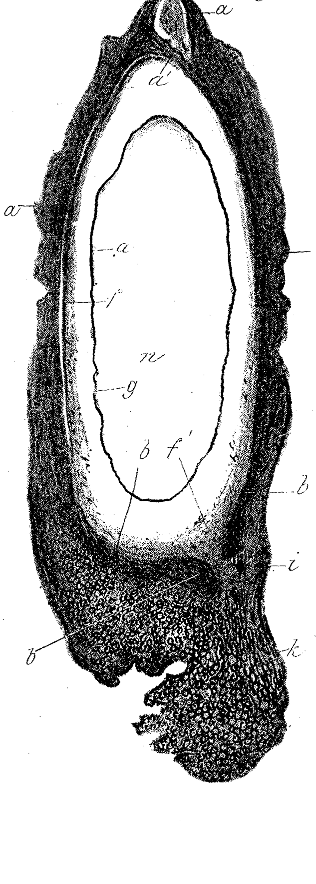
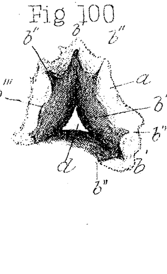


Fig. 100



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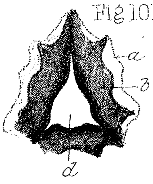

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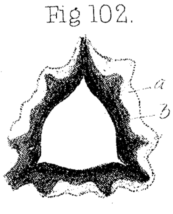

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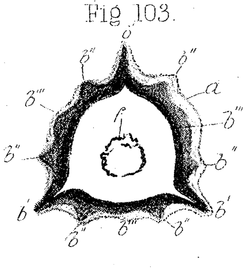
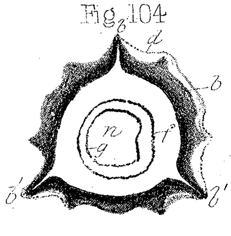


Fig. 104



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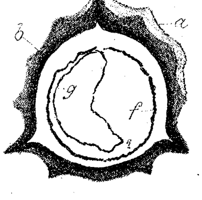
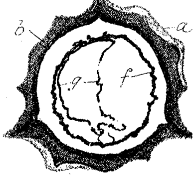


Fig. 106



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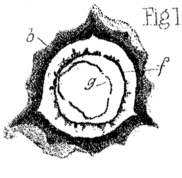
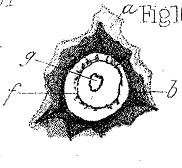


Fig. 108



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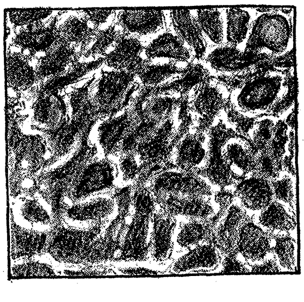

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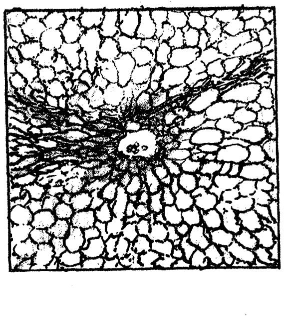

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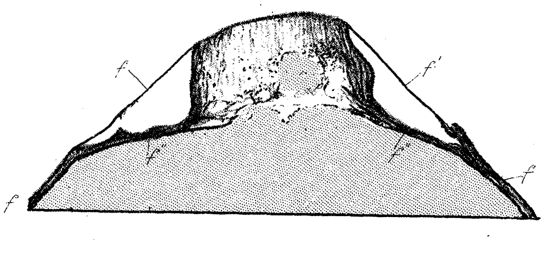

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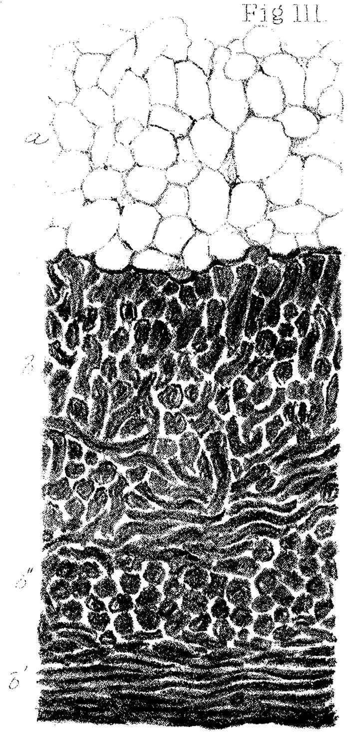

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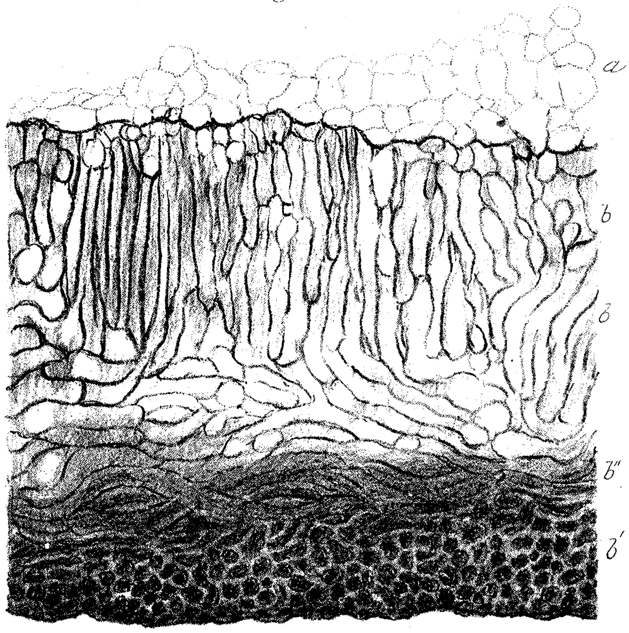

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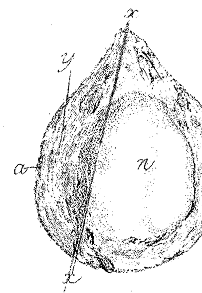

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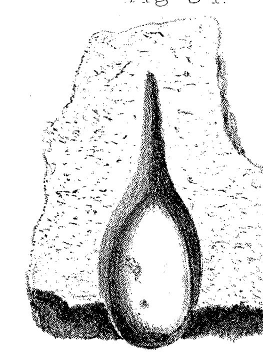

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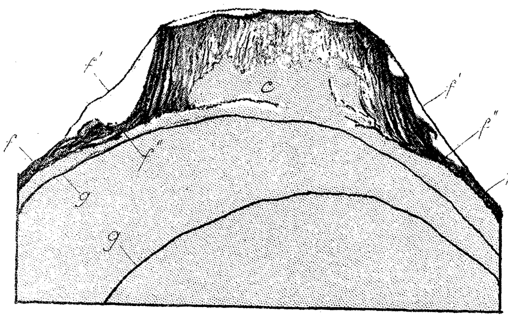

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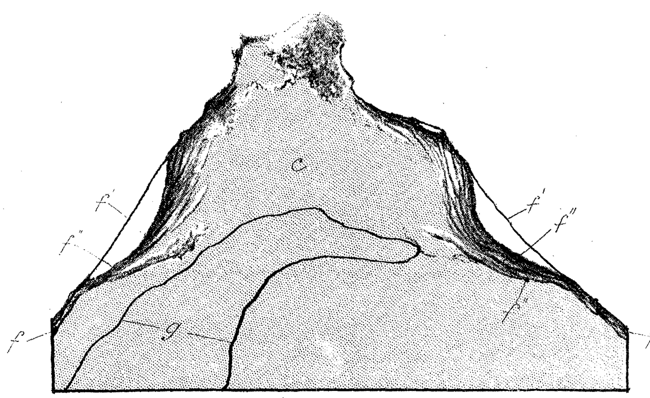
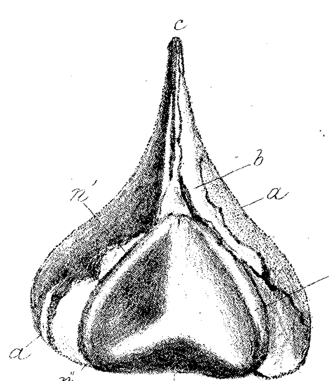


Fig 116



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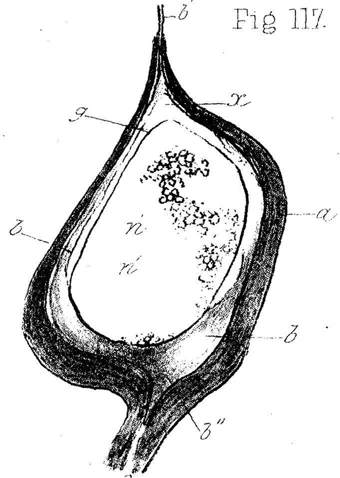

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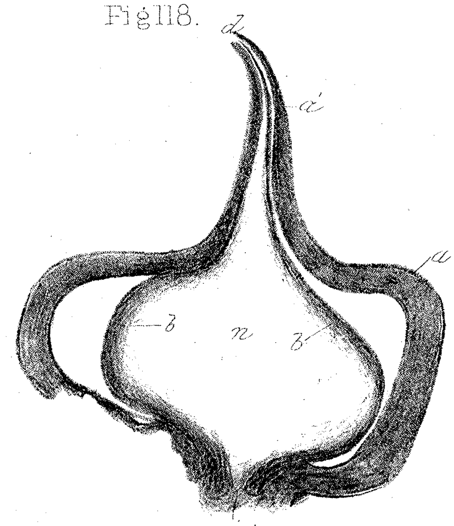

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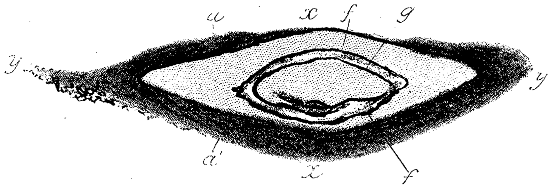

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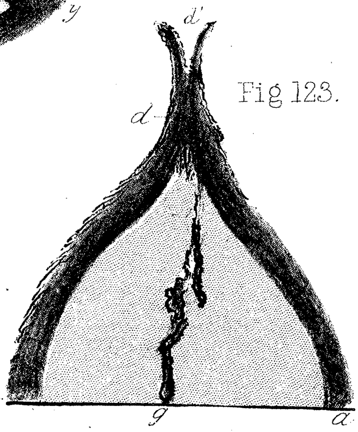

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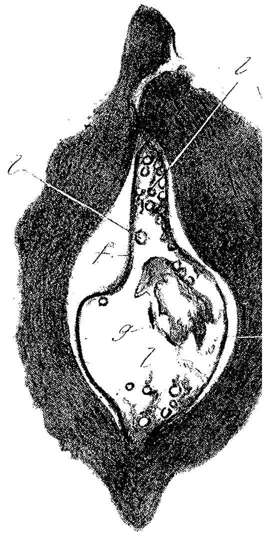

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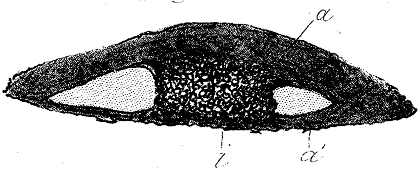

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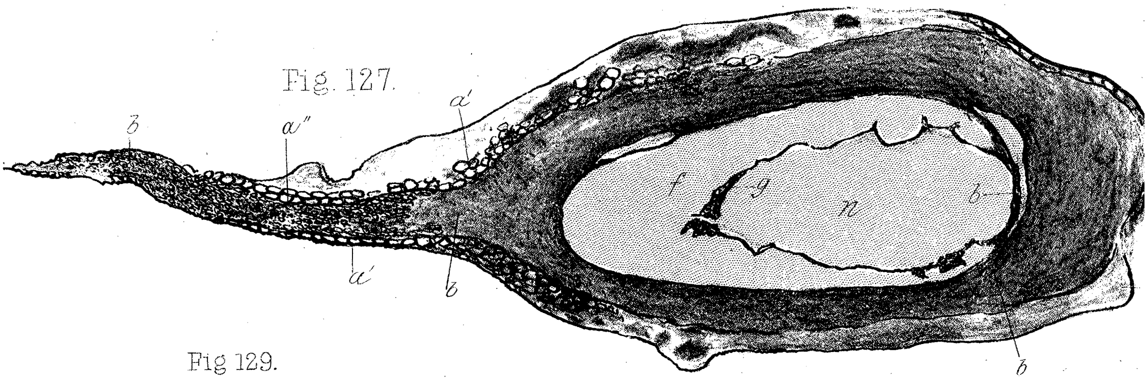
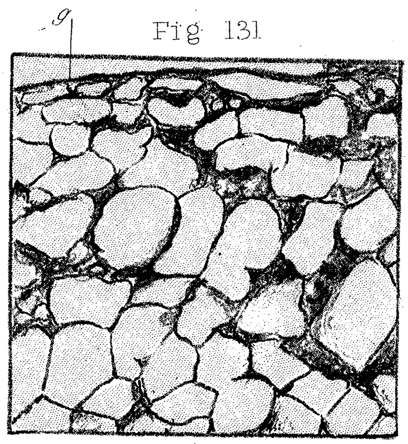


Fig 129.

Fig. 122.

Fig 131



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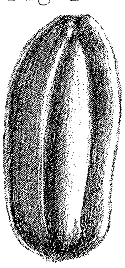

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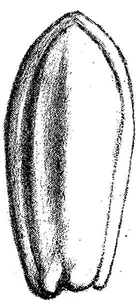

Fig 134

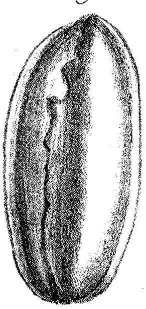

Fig 128.

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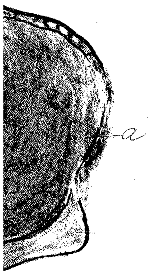

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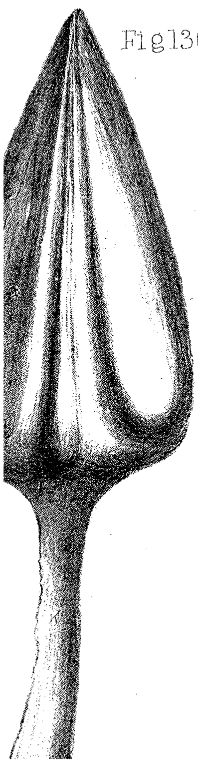

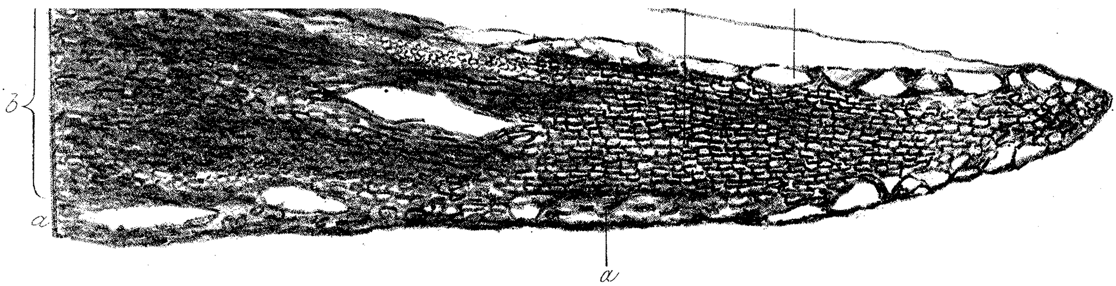

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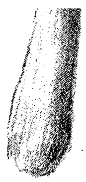

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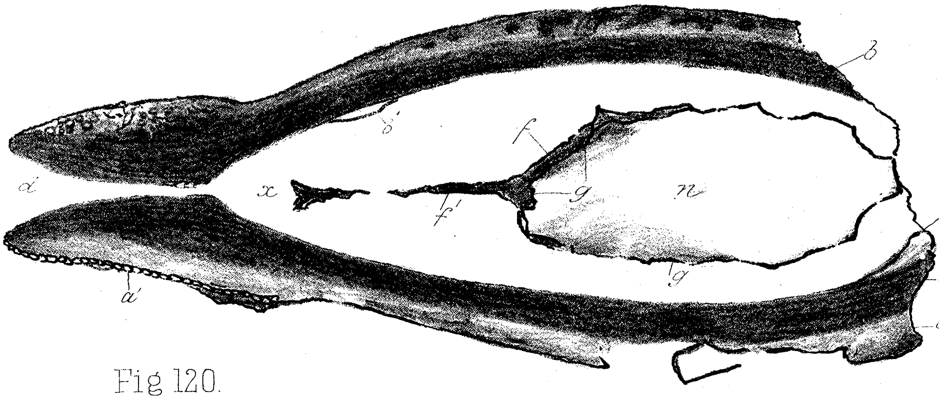
Fig 126.



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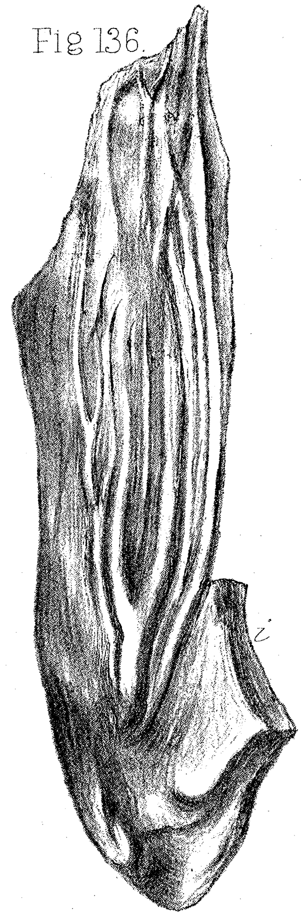
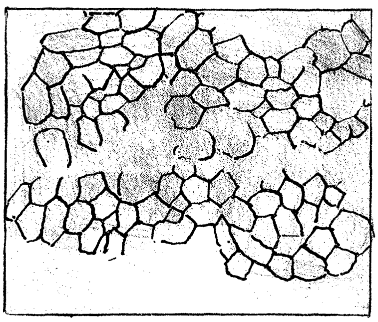


Fig 120.



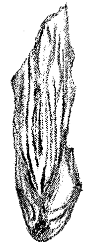


Fig 135

Fig. 119.

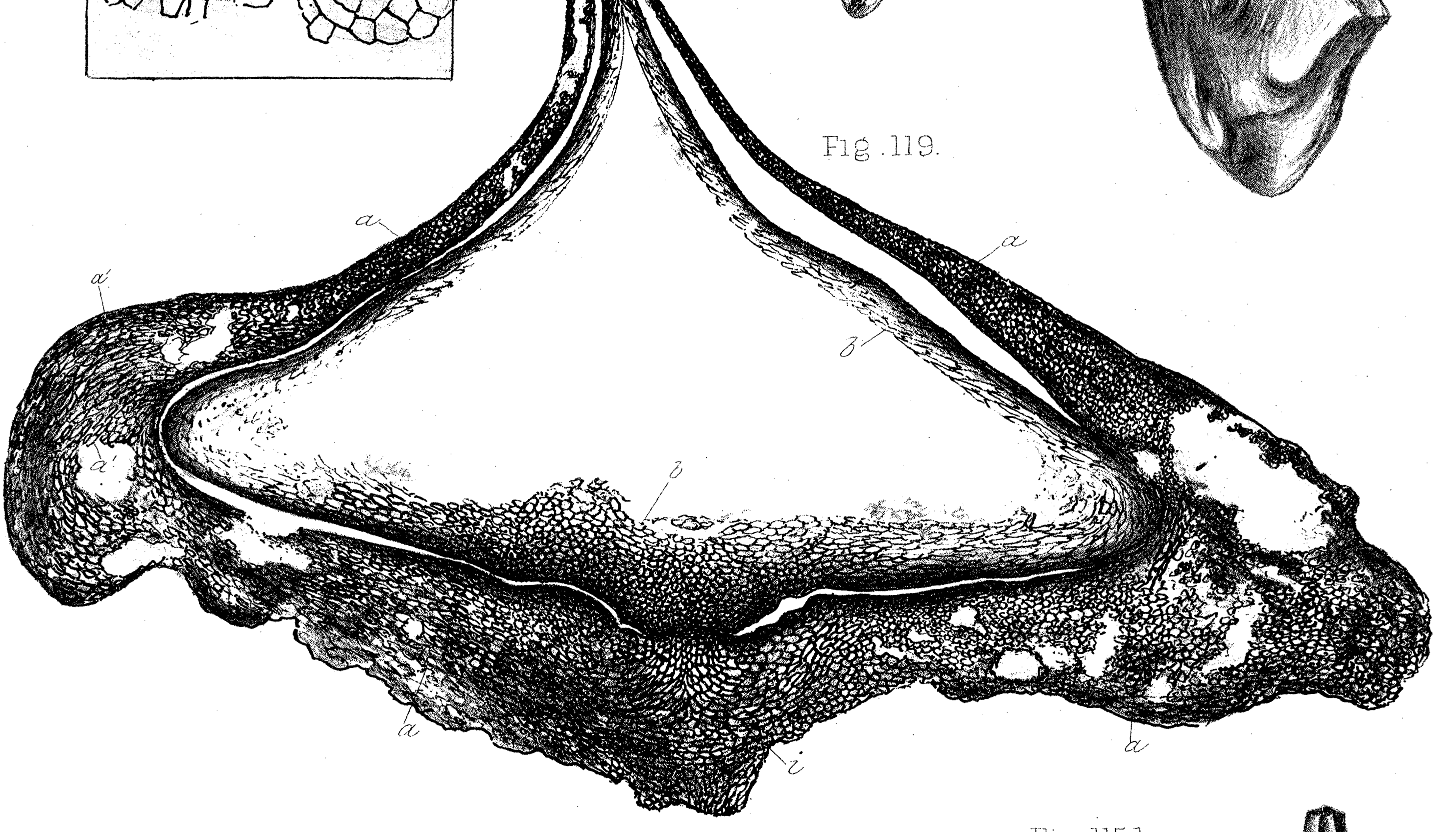


Fig 137

Fig 115 b

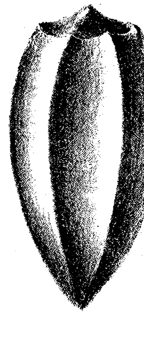
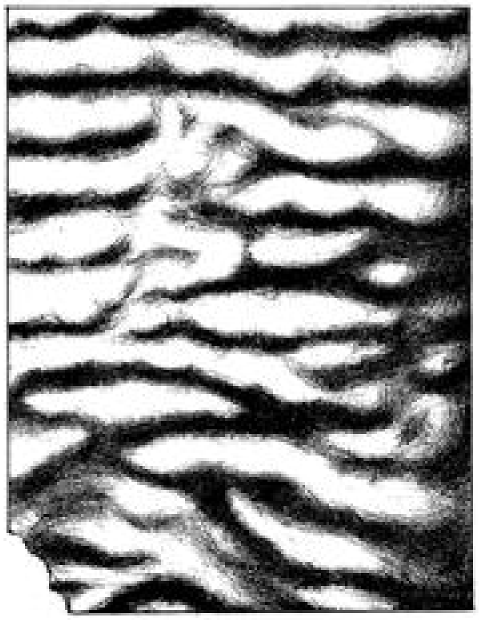


Fig 115 a

W. C. Williamson, Auto Lith.

Maclure & Macdonald, Lith. London.

Fig. 1.



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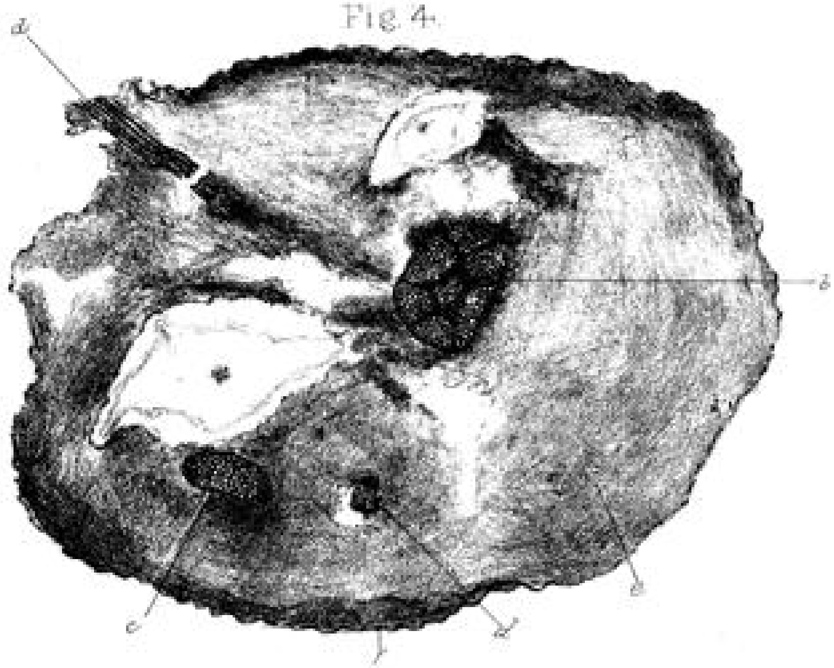

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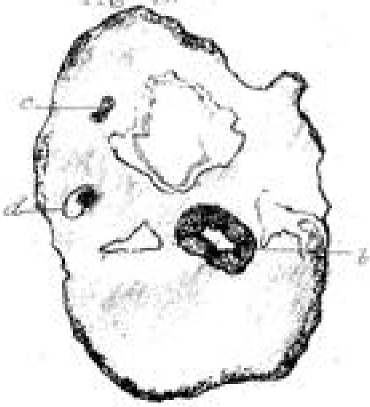

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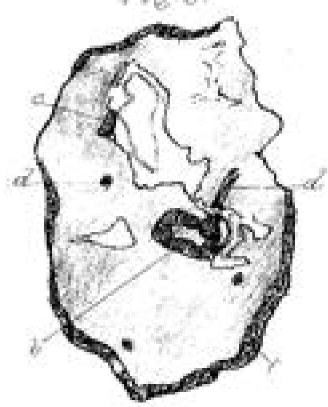

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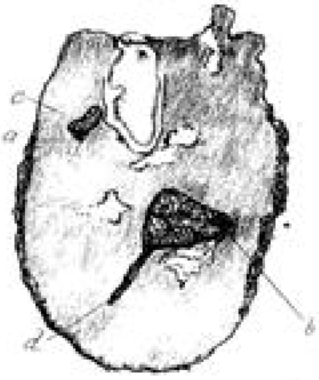

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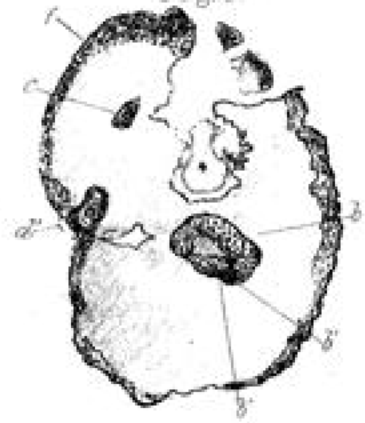

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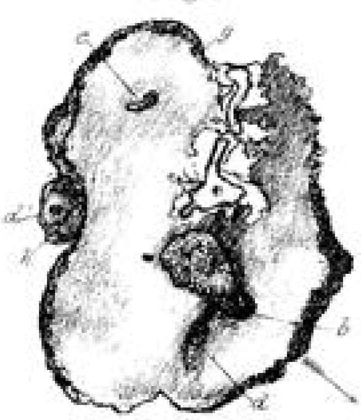

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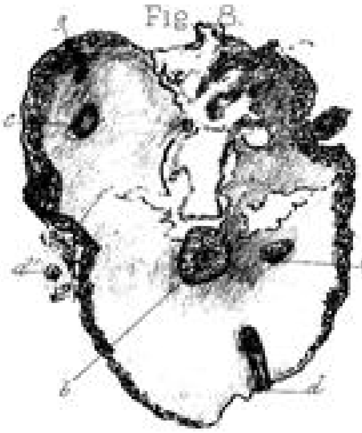

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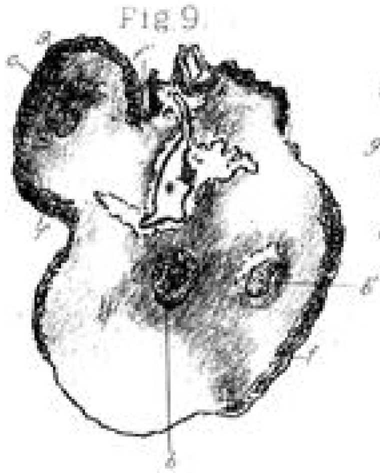

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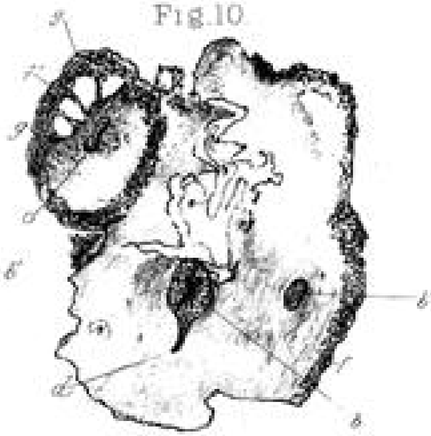

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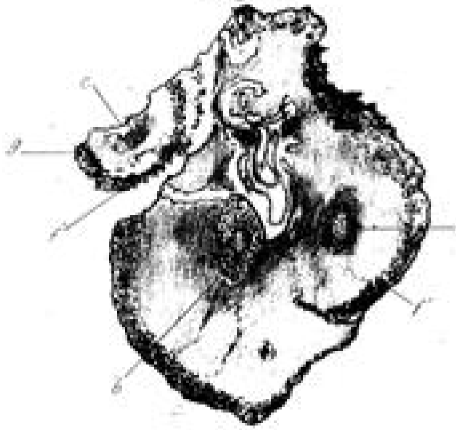

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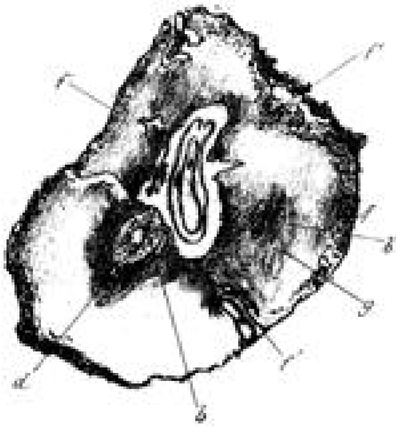

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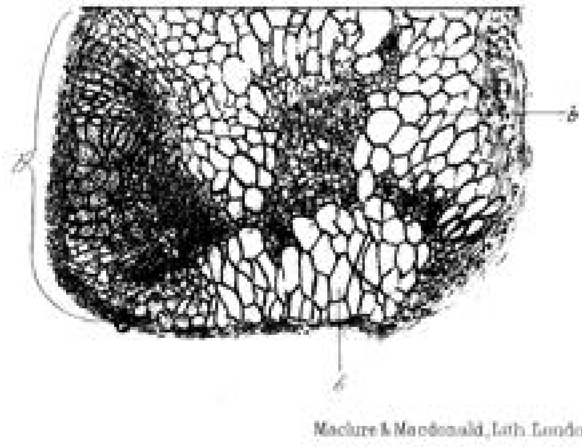
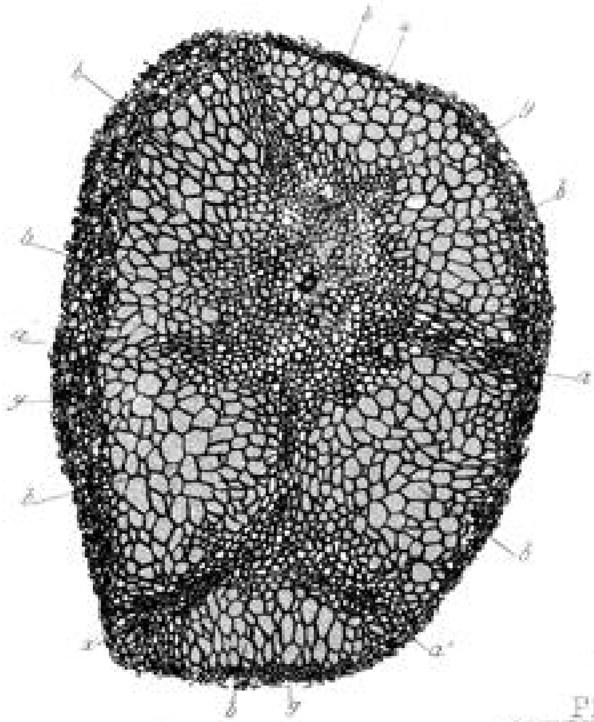


W. C. Williamson, Auto. Lith.

Maclure & Macdonald, Lith. London.

Fig. 13.



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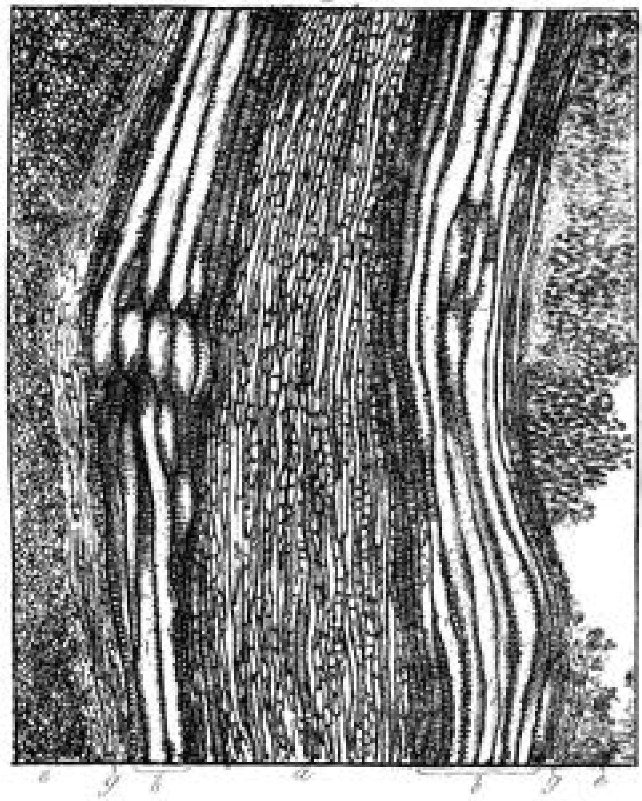

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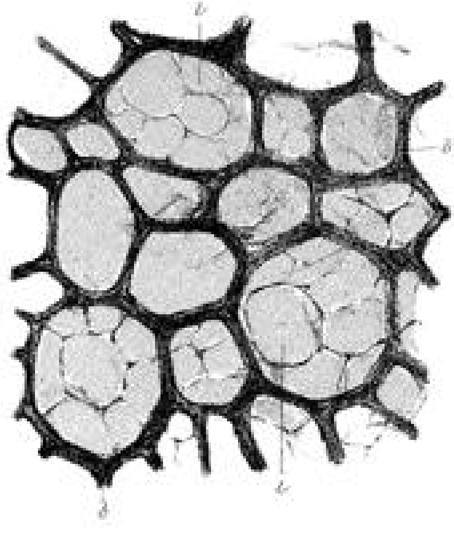

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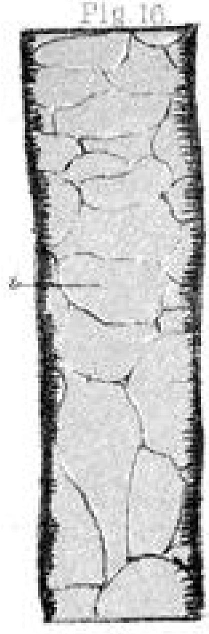

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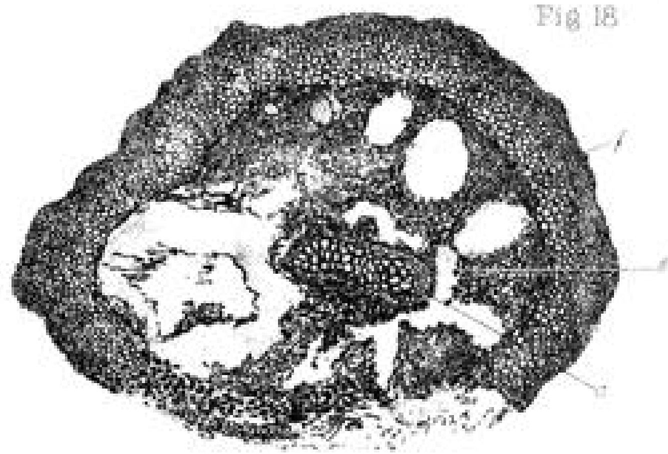

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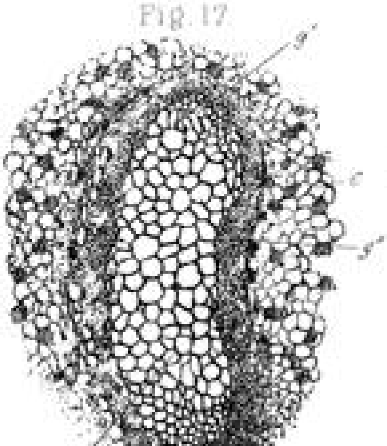

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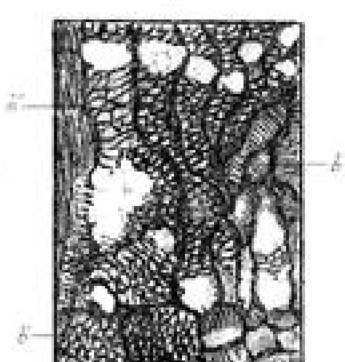
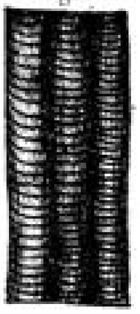


Fig. 21.

W. C. Williamson, Auto Lith. Maclure & Macdonald, Lith. London.

Fig. 37.



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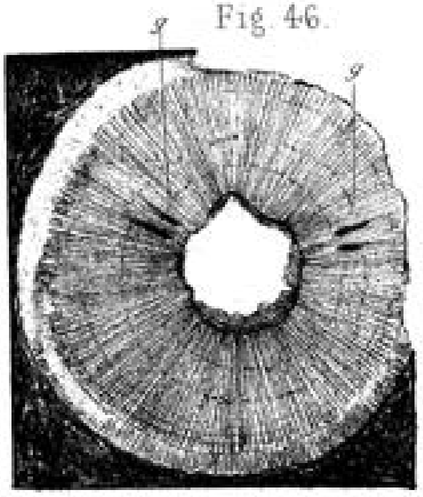

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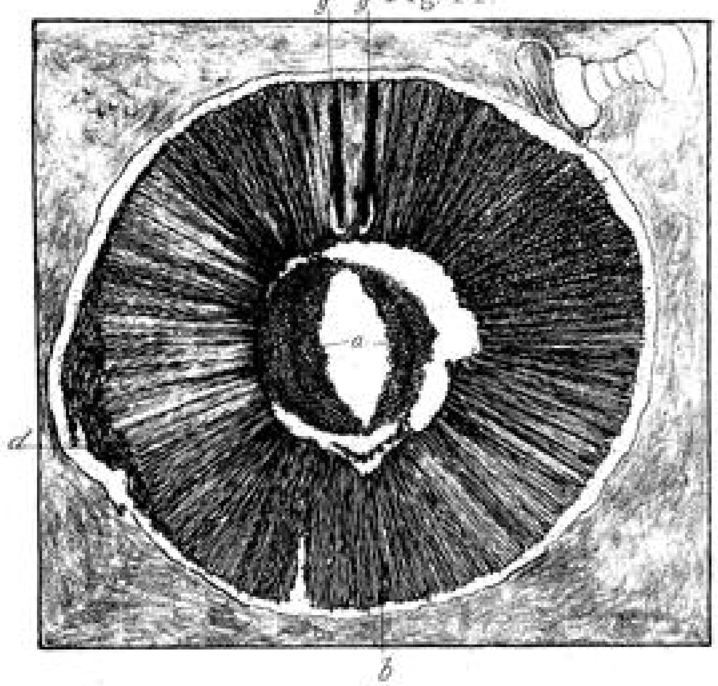

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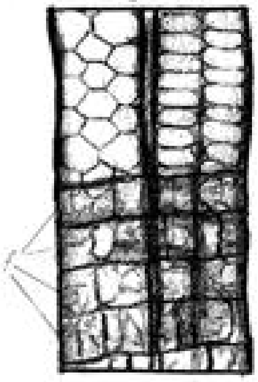

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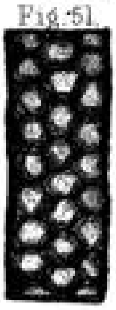

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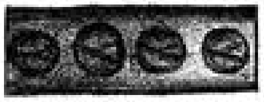

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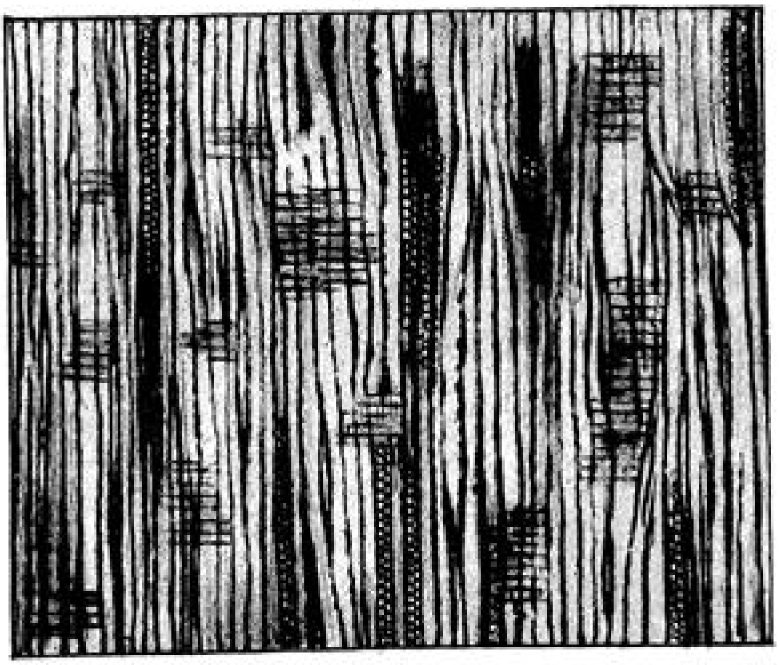

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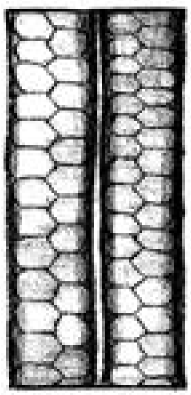


Fig. 54

Fig. 53.

Fig. 55.

Fig. 49

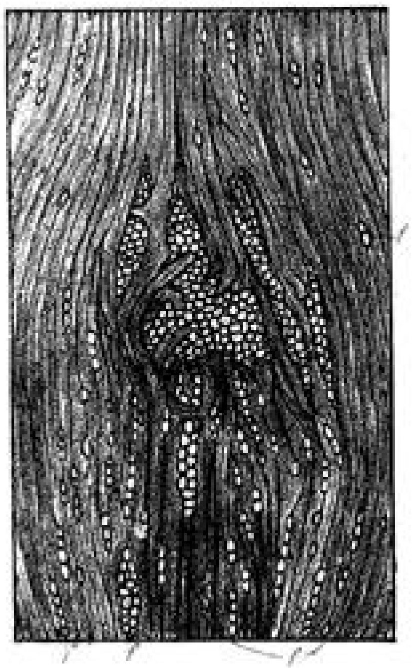
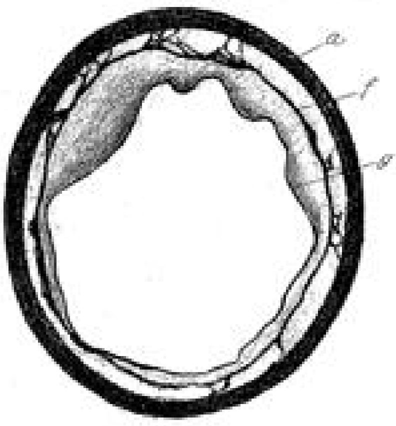


Fig. 57.

Fig. 56.

Fig. 58.



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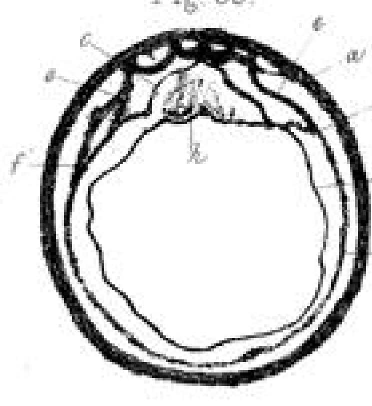

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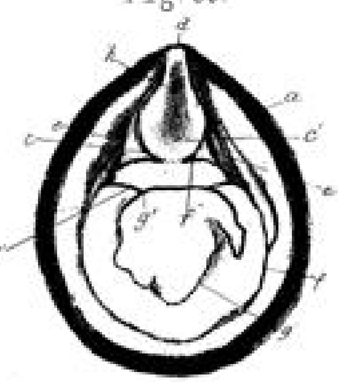

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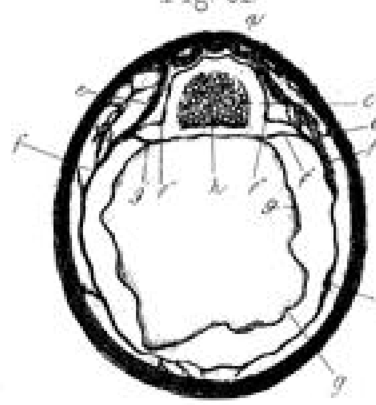

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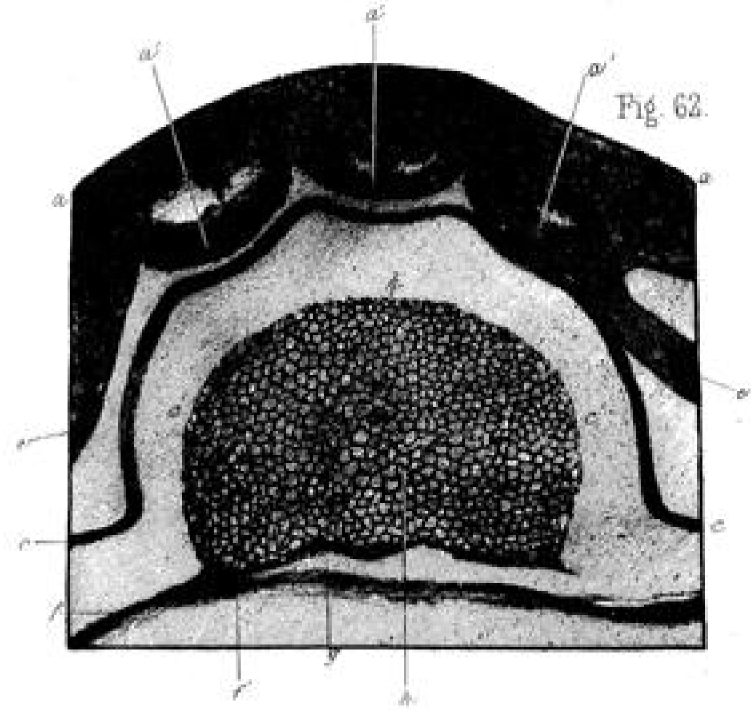

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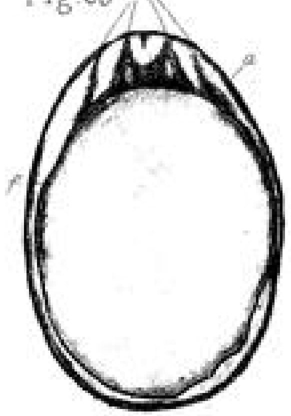

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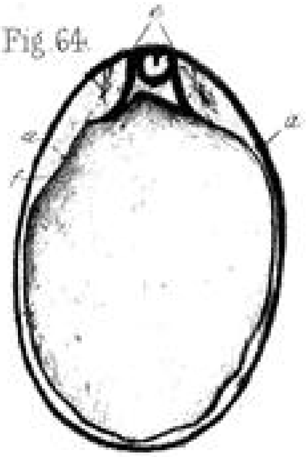

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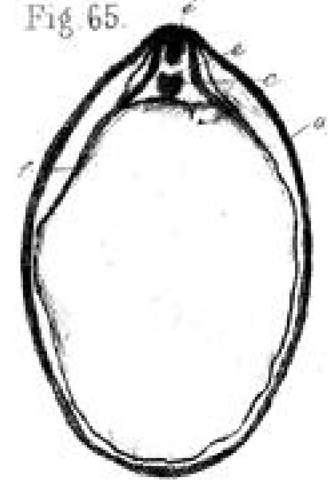

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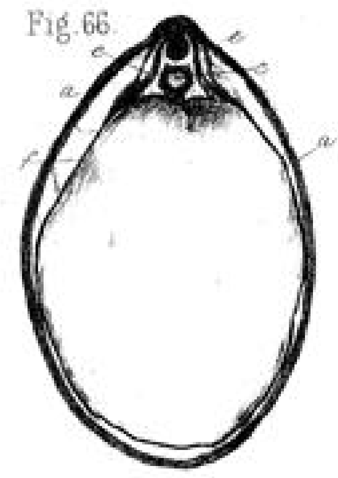

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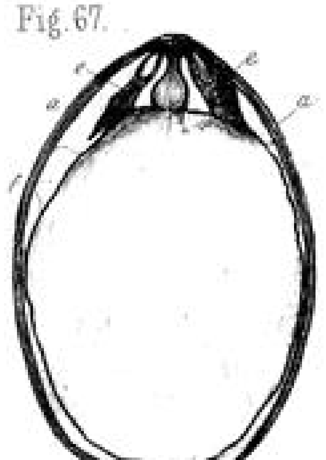

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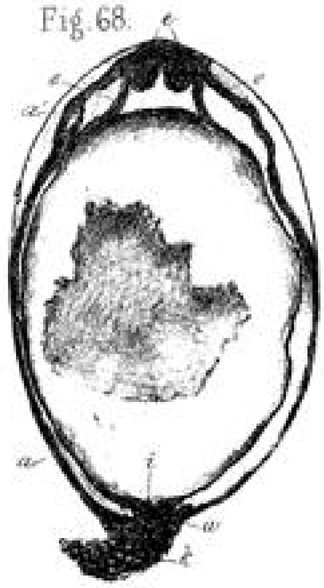

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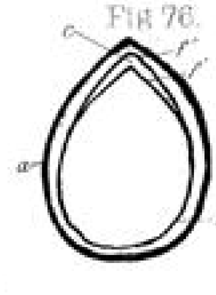
Fig. 76.



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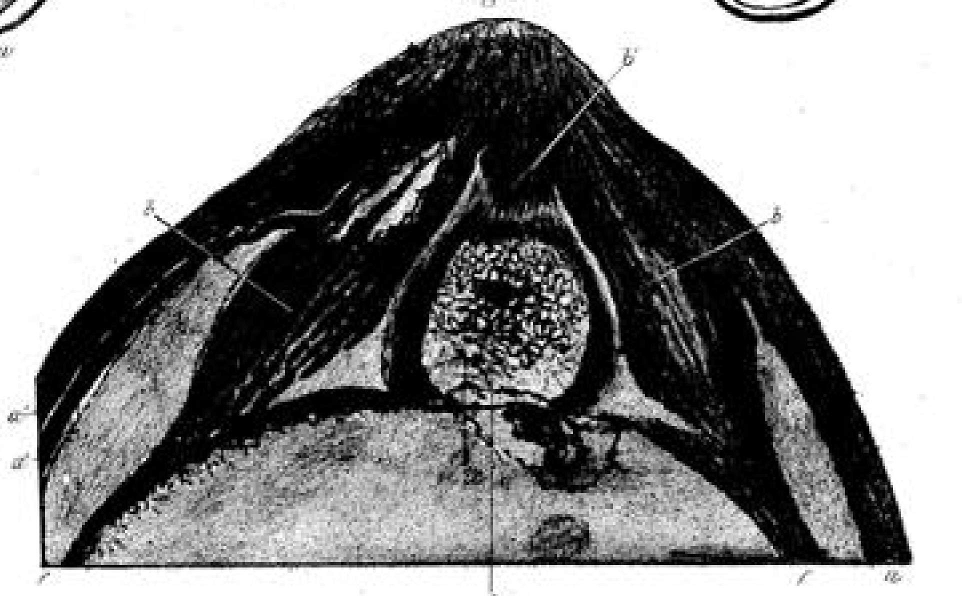

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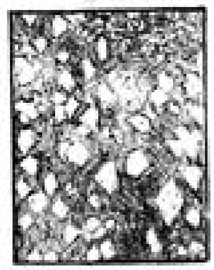

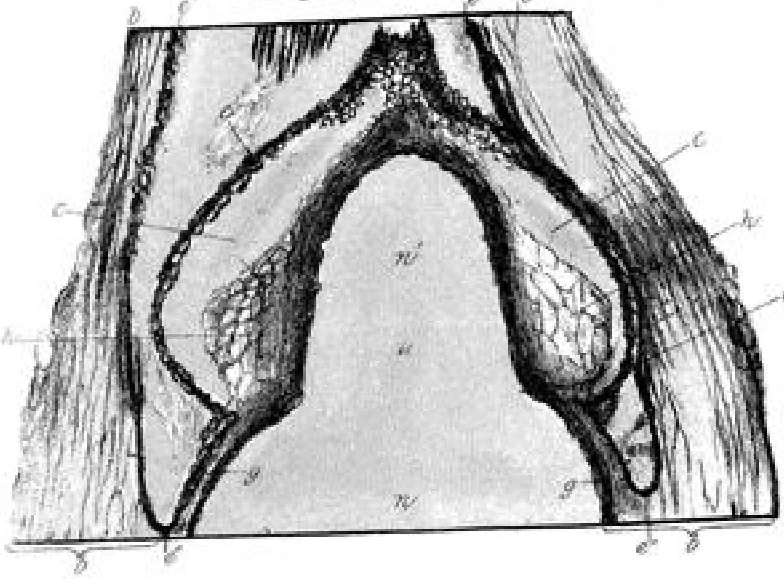
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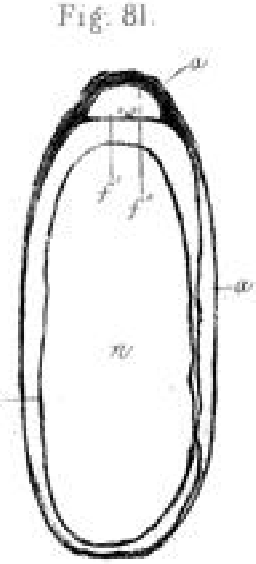
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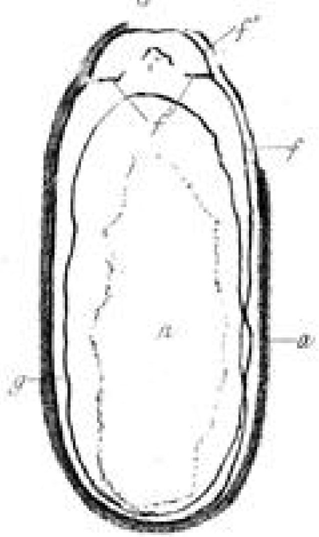
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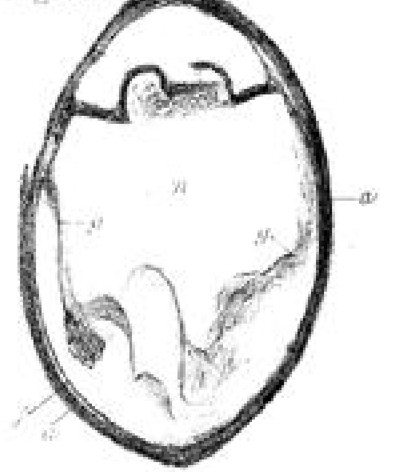
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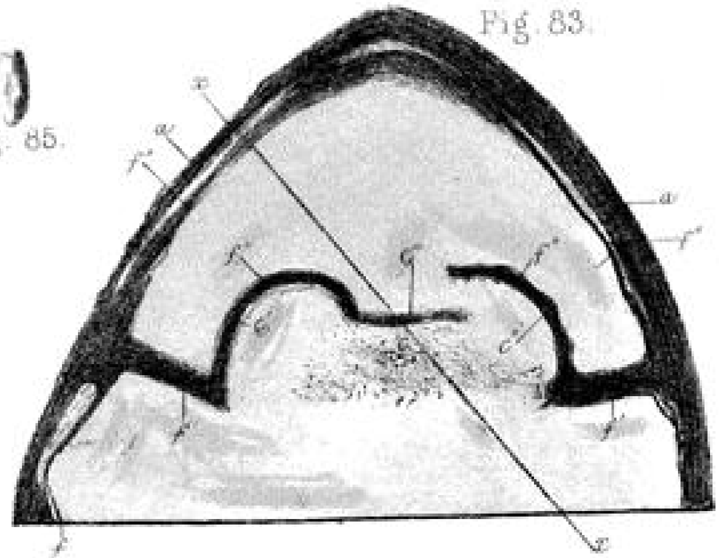
Fig. 85.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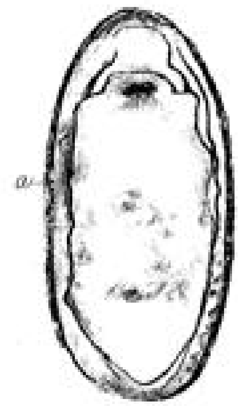
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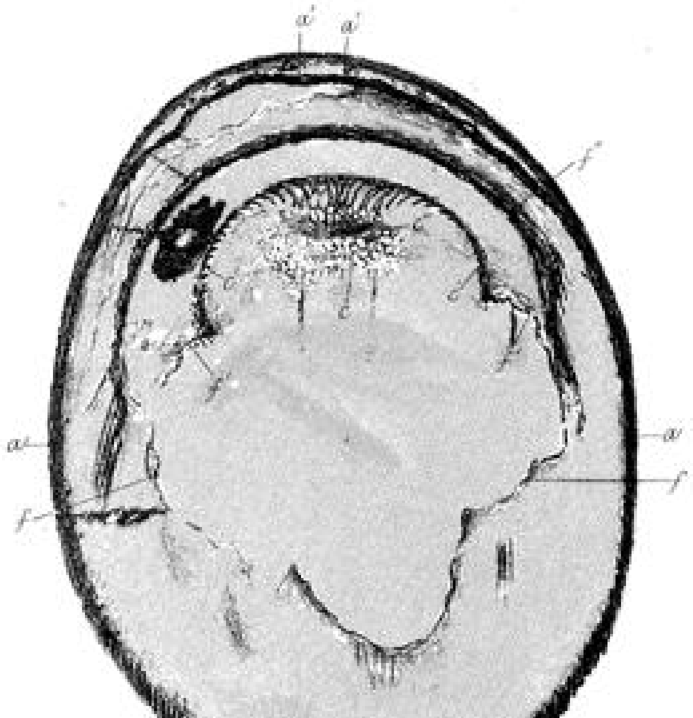
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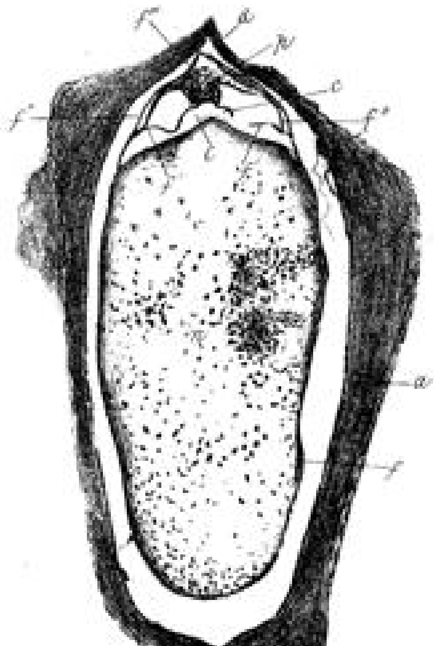
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Fig. 89.

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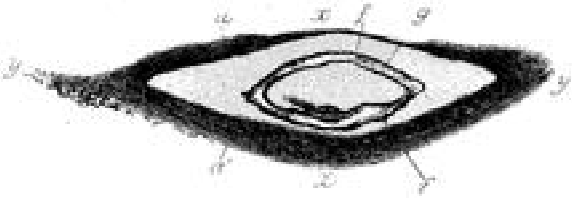
Maclure & Macdonald, Lith. London.

Fig 124.



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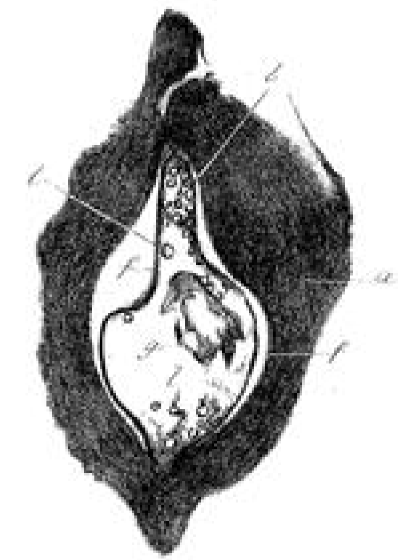

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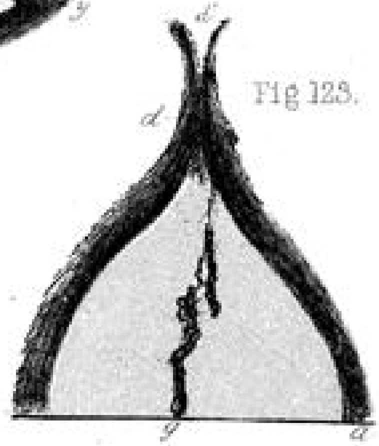

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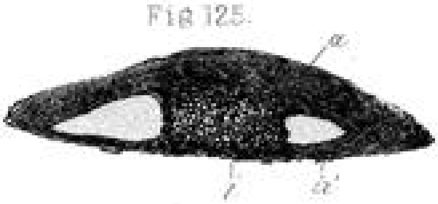

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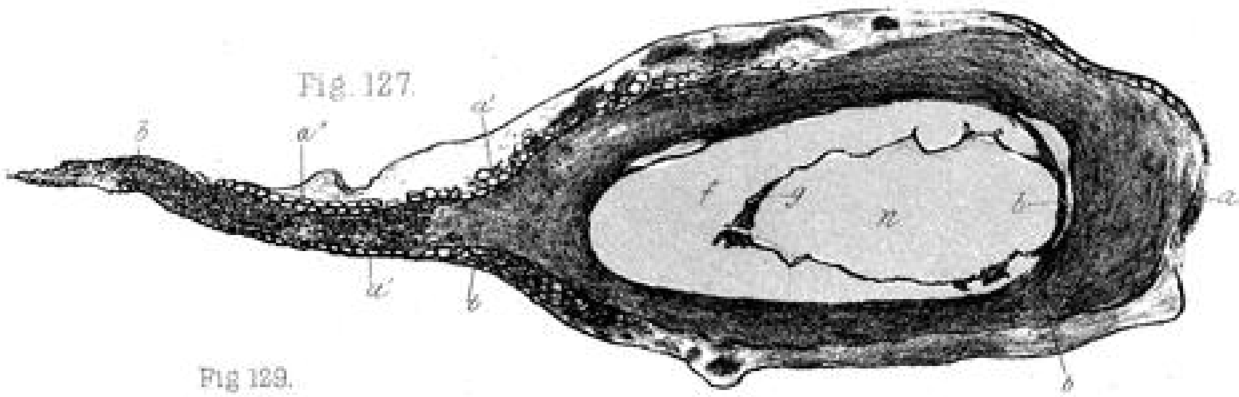

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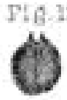

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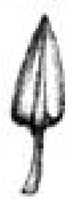

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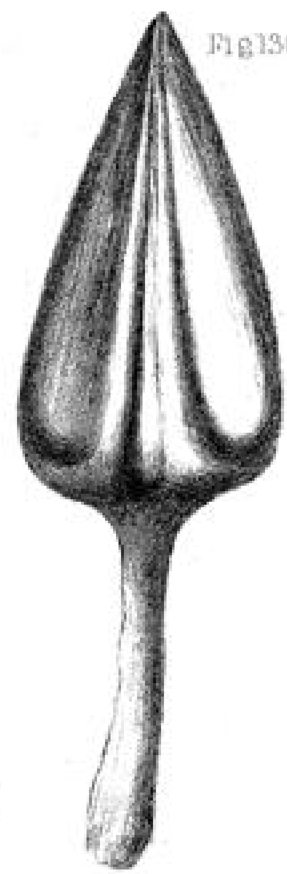

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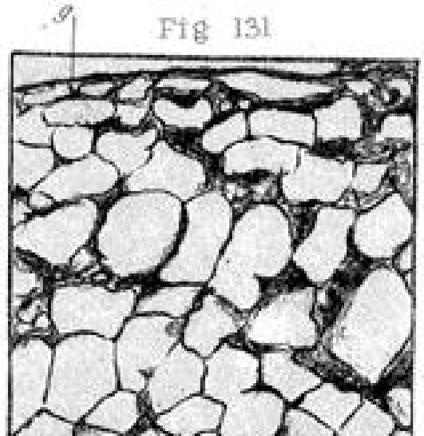

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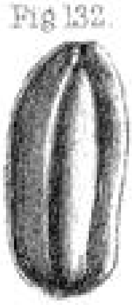

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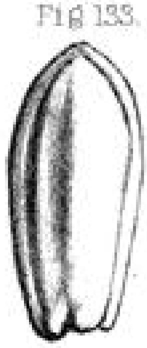

Fig 134.

Fig 128.