XIX. *On the Organization of the Fossil Plants of the Coal-measures.*—Part VI. Ferns.

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In no part of the investigation upon which I have been so long engaged have I encountered so many real difficulties as in that of which I am about to lay the results before the Society. Amongst the earliest sections which I made I found anomalous structures, generally consisting of a single bundle of vessels, such bundles varying much in size and form, enclosed in a parenchymatous or prosenchymatous bark. Few of these examples exhibited any clear indication of the group of plants to which they had respectively belonged. Many of them might have been either Lycopods or Ferns, so far as structure was concerned. But in addition to the difficulty of assigning them to their respective groups, was the further one of determining which were independent plants or which merely varying portions of the same plant. This latter difficulty is more real in the case of Ferns than of Lycopods, because nothing is more common amongst the recent examples of the ferns than to find a rhizome possessing one structure, its primary petiole another, and its secondary and tertiary petioles yet different structures*; consequently it became exceedingly probable that similar variations would be found in fossil types. This possibility was converted into a certainty by the researches of Cotta, Corda, and Renault, all of whom obtained stems with petioles attached, and which exhibited differences such as I have referred to. But supposing all these difficulties to have been overcome, supposing the *disjecta membra* of each plant to have been properly collocated, and each species to have been correctly referred to its natural order, a new difficulty arose from the plans of procedure adopted by previous writers on this subject. In 1832 C. Bernard Cotta published his 'Dendrolithen,' giving descriptions and somewhat defective figures of a number of specimens to which he assigned new generic and specific names. He threw these forms into the three families of Rhizomata, Stipites, and Radiati, the latter family being defined as "Caules ad tertiam familiam pertinentes strias radiales continent, quæ horizontaliter perscissæ vel inter se separatos concentricos annulos formant, vel inde ab axe incipientes usque ad peripheriam exeunt"

* I may observe that, before completing this portion of my inquiries, I made an extensive series of observations upon the structure of the rhizomes and petioles of all the recent ferns which I could obtain, especially in reference to the way in which the bundles supplying the secondary petioles and nervures originated in the primary one. Having thus made myself practically master of a mass of detailed information on these subjects, I was enabled to study with the greatest advantage the admirable memoir of M. Trécul ("Remarques sur la position des Trachées dans les Fougères," Annales des Sciences Naturelles, tom. xii., 5ème série) and to enter upon the present inquiry.

(*loc. cit.* p. 58). The plants thus defined are obviously such as I should have considered to possess some modification of exogenous growth, though COTTA points out certain features in which he considers that they differ from the stems of true Dicotyledons.

The above publication was followed in 1845 by CORDA'S noble work entitled "Beiträge zur Flora der Vorwelt." In this admirably illustrated volume he described and figured a large number of hitherto unknown forms, and included in his respective genera all those previously described by COTTA, the whole being thrown into two primary groups. One of these groups was composed of what he regarded as Monocotyledonous and Dicotyledonous plants, the other of Ferns. These groups he further divided into secondary natural families. The only one of these latter belonging to his first division which concerns me now is that of the Palmæ. The Ferns he divided into seven families and more than forty genera, the latter being too often based upon the most insufficient characters. The undue multiplication of genera by this distinguished botanist was very properly objected to by M. BRONGNIART, who says, "M. CORDA, dans son essai sur la flore de l'ancien monde, me paraît avoir trop multiplié, pour l'état actuel de nos connaissances, les genres fondés sur les tiges des Fougères, dont nous ne connaissons généralement la structure que d'une manière trop imparfaite pour établir des divisions bien définies" ('Tableau des genres de Végétaux Fossiles,' p. 34, 1849). He then proceeds to throw many of CORDA'S genera into more comprehensive generic groups, still retaining sixteen genera, nine of which, however, he regards as merely provisional ones.

The second great difficulty with which I have had to contend springs out of CORDA'S multiplied genera even as reduced in number by BRONGNIART. They are all based chiefly upon variations in the form of the vascular bundles, a character which a study of living forms demonstrates to have no generic value whatever; and his definitions further take no cognizance of the immense differences which generally subsist between the form of those bundles in the primary and in the secondary petioles. Thus, on the one hand, there is a close resemblance between the transverse sections of the bundles in the petioles of *Dicksonia rubiginosa*, *Pteris umbrosa*, *Adiantum trapeziforme* and *macrophyllum*, and *Aspidium molle*, whilst, on the other, nothing can be more distinct than the vascular arrangements in *Pteris umbrosa* and *P. aquilina*, in *Adiantum trapeziforme* and *A. cuneatum*, and in numerous other examples of a similar kind which might be quoted. Such being the case, it is obvious that no guides can well be less trustworthy than transverse sections of these vascular bundles in establishing generic distinction amongst the fossil ferns.

These difficulties are not diminished by the fact that in the fossil petioles the tissues forming the sheath of each bundle, and the elongated cells which are enclosed along with the vessels, are rarely, if ever, so distinctly marked as in the living one. Indeed in many of them the cortical cells graduate uninterruptedly up to the scalariform vessels, which latter constitute the only tissue that is sharply differentiated from the cortical ones; in other words, such bundles appear to be *vascular* rather than *fibro-vascular.*

Under these circumstances the question which is forced upon our consideration is a practical one. I find amongst my sections several well-marked structures which cannot be located in any of CORDA's genera. Hence, if I act upon CORDA'S method, I must not only adopt all his generic distinctions, but even add to the evil by creating several new genera.

I was at first disposed to adopt the latter plan, and had proposed the names of *Edraxylon* and *Arpexylon** for two undescribed types, and also intended adopting Mr. BINNEY's name of *Stauropteris*† for a third one. The reasons already assigned make the absurdity of this plan obvious. I have therefore determined to reduce the number of these genera, and to adopt one common term for the entire series of what appear to be fern-petioles, trusting to time and diligent research to enable us to identify them with the several fronds and stems to which they belong, all of which have doubtless already received generic names. Of course I exclude from my common genus such names as *Caulopteris* and *Psaronius*, which represent arborescent stems whose external aspects are more or less known, and which consequently are not genera exclusively based upon the form of the vascular bundle of the petiole. Nothing better indicates the necessity for some such course as that which I propose to adopt than the way in which even BRONGNIART has classed these petioles or isolated rachis. He divides them into two groups:—"*Pétioles a faisceau vasculaire unique" and "**Pétioles a faisceaux vasculaires multiples." I shall have to describe examples in which the primary petiole would have to be located in one of these divisions and its secondary branches in the other—a condition sufficiently common amongst living ferns.

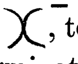
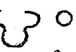
CORDA has embraced a number of these petioles in one family under the name of Rachiopterideæ. In order to avoid the introduction of new names, I propose to adopt the term *Rachiopteris*, and to include in that genus all the several condensed genera adopted by M. BRONGNIART from CORDA, under the names of *Zygopteris*, *Selenochlæna*, *Selenopteris*, *Gyropteris*, *Anachoropteris*, *Ptilorachis*, *Diplophacelus*, *Calopteris*, and *Tempskia*, as well as my own proposed genera of *Edraxylon* and *Arpexylon* and Mr. BINNEY's *Stauropteris*. I am fully alive to the inconveniences to which this plan exposes us; but it will be easy to indicate the several forms by provisional specific names. It appears almost certain that the stems and petioles which are now represented by the names just quoted will be ultimately found to belong to various species of *Pecopteris*, *Neuropteris*, *Sphenopteris*, and their allies. Consequently all other names can but be provisional and temporary ones. By adopting the plan proposed we avoid burdening science with a number of meaningless genera, based upon characters which have little, if any, generic value, and which only possess even specific ones under peculiar limitations, such limitations arising from the variations which a single petiole exhibits according to the portion of it from which a section is made.

Transverse sections of the petioles of recent ferns exhibit four common types of fibro-vascular bundles:—(1) that in which the transverse section of the bundle represents

* See Proc. Roy. Soc., No. 136. † Proceedings of the Lit. and Phil. Soc. of Manchester, vol. xi. p. 69.

various modifications of the letter H; (2) similar modifications of T; (3) modifications of U; and (4) of X. In many instances these primary bundles have secondary ones superadded. The arrangement of the fibro-vascular bundles in the *stem* or *rhizome* is that of a network constituting a hollow cylinder, prolonged through the entire stem. From each mesh of this cylinder there arise one, two, or more fibro vascular bundles, which pass outwards to form the petiolar bundles; but, as M. Trécul has pointed out, many of these are abortive, because, generally speaking, some or even many of the meshes, especially in creeping rhizomatous stems, fail to develop corresponding leaves. Where leaves are developed we find great variations in the arrangements of the petiolar and radicular bundles. Sometimes both these are given off from the primary cylinder of the stem; at others one or more bundles are thus given off to the petiole, and the radicular bundles spring from them as they pass through the cortical parenchyma of the stem or rhizome. Even where a single fibro-vascular bundle passes outwards to the petiole it frequently subdivides into a number of others, variously distributed over the transverse section of the petiole; but even in this case we always find on the upper portion of the section two dominant ones, from which the secondary bundles going to the secondary petioles are almost exclusively given off.

The bundles, however subdivided throughout the greater part of the length of the petiole, sooner or later reunite as they approach its upper extremity, where, generally speaking, they constitute a single bundle, grooved or indented on its upper surface, and which M. Trécul has designated gutter-shaped ("gouttière vasculaire"). It is, of course, important to bear in mind the occurrence of these morphological variations within the limits of the same frond in attempting to correlate differing sections of fossil forms.

The structure and composition of the fibro-vascular bundle and the mode of orientation of the secondary fibro-vascular bundles require to be attended to. I can confirm, from personal investigation, many of M. Trécul's observations on both these points. Each bundle almost invariably consists of a combination of scalariform or reticulated, annular and spiral vessels, the two latter being located in varying special positions in the bundle in different genera and species of ferns. The vascular portion of the bundle is very distinct from the investing fibrous one, and its section describes very definite figures. The secondary petiolar bundles spring from these primary ones in various ways in the different types. In many cases (e. g. *Pteris hastata*) the upper extremity of each lateral arm of the vascular figure X becomes elongated in alternating order, , and the enlarged portion becomes detached, , to form the secondary bundle. In other cases each of these upper vascular arms terminates in a loop, the concavity of which is directed inwards, . When a secondary branch is about to be given off, this loop ("*crochet*" of Trécul) becomes elongated,  (*e. g.* in *Adiantum macrophyllum*). Then a double vascular partition forms, cutting off its outer extremity, , which now separates as a distinct vascular ring, , supplying the secondary pinnule or leaflet. This ring soon opens out at its upper surface, , forming a gutter-shaped bundle; and in a few cases it again divides inferiorly, and forms two distinct fibro-vascular bundles, but which reunite as they approach the end of the pinnule or base of the leaflet. In some species, *e. g.* in *Pteris umbrosa*, the entire loop is detached to form the secondary bundle.

In the larger number of ferns the secondary pinnules are not given off in pairs, hence the orientation of these secondary bundles alternates on opposite sides of the petiole; in other cases, where the leaflets or pinnules are opposite, we have the same process of orientation occurring simultaneously on the two sides of the primary bundle. In dealing with fossil forms, we have to guard against confounding the *two secondary bundles* thus formed *on opposite sides of the primary one* with the subdivision of a *single primary one into secondary ones* as it emerges from the parent stem or rhizome to enter the petiole. This distinction is not always easy of recognition.

There appears to be no doubt that the small outermost vessels of each arm of each bundle, whatever its form, are those first developed, and that the further growth is centripetal, the larger central vessels of the bundle being produced as the growth advances. Though these plants differ very widely in many respects from the Calamitean and Lycopodiaceous plants described in my previous memoirs, I believe that certain homologous relationships can be demonstrated to exist, enabling me to employ the same letters of reference to indicate corresponding organs and tissues, except that *a* has now been accidentally employed instead of *c* to represent the central vascular axis.

The first of these plants which I have to describe is that to which formerly I proposed to assign the name of *Edraxylon.* I have at length succeeded in connecting this petiole with its leaflets, which are either those of a *Pecopteris* or of a *Sphenopteris.* It has had the surface of its petioles covered with small warty projections, such as BRONGNIART has represented in several species of *Pecopteris*, especially in his *P. platyrachis**, in *Sphenopteris Hoeninghausi* †, and which appear in many recent ferns.

Plate LI. fig. 1 represents a transverse section of the matured petiole, to which I originally gave the name of *Edraxylon* ‡. It consists of a mass of parenchyma containing a bundle of barred vessels, and invested by a layer of sclerenchyma, which is not continuous, but disposed in interrupted longitudinal bands. Each of these matured petioles is about a quarter of an inch in diameter.

The central vascular bundle (*a*) is somewhat of the form of the letter H, with its upper and lower vertical arms diverging outwards from their central connecting band, and its lower ones much shortened. It consists, in fact, of a horizontal bar and two vertical ones, each bar having a variable mean thickness of from ·016 to about ·12 §. It consists of transverse sections of numerous vessels arranged without any definite order, and varying in size, but rarely exceeding ·0031 of an inch. I can discover no trace of a special

* Végétaux Fossiles, pl. 103. figs. 5–5 A.

† *Idem*, pl. 52. This plant is also exceedingly well figured in the 'Vorweltliche Pflanzen aus dem Steinkohlengebirge der preussischen Rheinlande und Westphalens' of Dr. CARL JUSTUS ANDRÄ, tab. iv. & v.

‡ Proceedings of the Royal Society, No. 136.

§ As in the previous memoirs, all these measurements are in decimal parts of an inch.

sheath, or of any fibrous elements surrounding this vascular bundle. As is so frequently the case amongst the half-dried petioles of recent ferns, the surrounding parenchymatous cells have slightly shrunk away from the bundle in several parts; but in others they extend up to it. The vertical and horizontal portions are all slightly curved; the concavities of the former being directed outwards, and that of the latter to the lower or dorsal surface of the petiole. Those who are familiar with the aspects of recent petioles of ferns will have no difficulty in identifying the superior and dorsal surfaces in this example. Much of the inner and middle portions of the cortical parenchyma (*g* and *h*) has been destroyed in the specimen; but what remains suffices to show that it was of the ordinary type, and composed of cells whose diameters ranged about ·0025 to ·003, and, so far as this individual section indicates, of nearly uniform character throughout its entire extent. Other sections will show that such was not always the case. The exterior of the petiole consists of a denser layer (*k*), having a thickness of from ·012 to ·016. This is composed of alternating wedges of sclerenchyma (k') and parenchyma (h'), the broader parts of the former of which and the narrower ones of the latter reach the peripheral margin of the section; but the forms as well as the sizes of both are irregular and unequal. The sclerenchyma (k') consists of narrow prosenchymatous cells, of from ·0012 to ·0016 in diameter. Their internal cavities are generally filled with carbonaceous matter, making them black and opaque. The intervening angles between the wedges (k') are occupied by an outward extension of the middle parenchyma (h'), which here reaches the surface of the petiole. These cells are smaller and more uniform in size than in the interior of the section. The peripheral outline projects at numerous points (k'', k'') into little swellings. These we shall afterwards find are the little warty projections from the surface of the petiole, apparently abortive hairs, to which I have already alluded. Transverse sections, like that just described, sometimes intersect dark-coloured intercellular lacunæ; but these are much better seen in the vertical sections.

Plate LI. fig. 2 is a vertical section made a little obliquely through a section like the last. *a* represents the central vascular bundle, *g* the innermost parenchyma of the cortex, *h* its median portion, and *k* its prosenchymatous investment. The vessels composing the central bundle in this and all similar specimens are either reticulate (Plate LI. fig. 3 A), barred (fig. 3 B), or spiral (fig. 3 C). The greater portion of them belong to the first of these forms. This is especially the case with those occupying the central parts of all longitudinal sections. Towards the outer margins of the bundle in such sections we find some that are barred and a small number that are unmistakably spiral vessels. The larger ones are invariably reticulated, and in passing along the series we find connecting links between them and the smaller barred ones. On turning to transverse sections of similar bundles, we find that the central line of each bundle is occupied by vessels of larger size than its more peripheral ones. These facts accord substantially with the observations of M. TRÉCUL upon recent Ferns, and which accord with my own. The spiral and annular vessels are both of earlier growth, and occupy a more peripheral position, as well as being of smaller size than the larger scalariform or reticulated ones, which a centripetal mode of growth produces subsequently and in more central portions of the bundle. The special positions of these spiral vessels vary in the different species of recent ferns, but their general arrangement is that just described.

Immediately surrounding the vascular bundle we have the innermost of the cortical tissues (*g*), which varies much in thickness in different specimens. This is a delicate parenchyma (*g*), the cells of which are from ·002 to ·0025 in diameter, and which are disposed in interrupted vertical lines running parallel with the periphery of the bundle. These cells are nearly square, and must not be confounded with the prosenchymatous fibres which invest the vascular portions of each fibro-vascular bundle in living ferns. In the plant before us this fibrous sheath is wholly wanting. The line of demarcation between the innermost parenchyma and the middle one (*h*) is not very sharply defined, and yet we discern that we have passed from the one to the other from the rapid increase in the size of the cells, and in their diminished tendency to arrange themselves in vertical lines. This central parenchyma constitutes the greater portion of the bark. A large number of its component cells are fully ·005 in diameter. The striking feature of this tissue consists in its containing a large number of oblong intercellular lacunæ (*i*) of a dark colour, having their longer axes arranged radially in the horizontal direction. In Plate LI. fig. 3, two of these lacunæ (*i*) are seen enlarged and, with the cells of the surrounding parenchyma (*h*), drawn with all possible accuracy. It will be observed that whilst most of the cells of the central parenchyma assume an ordinary arrangement, such of them, in the specimen figured, as immediately surround each lacuna display a tendency to radiate from the lacuna as a centre; but this, though a frequent arrangement, is not invariably the case. These lacunæ vary in length from ·002 to ·008, the latter dimensions being the more frequent ones.

The outermost bark (*k*) is seen, in longitudinal sections, to contain a large quantity of prosenchymatous tissue, intermingled with various modifications of parenchyma. The former is arranged in longitudinal bands more or less interrupted, and which correspond with the peripheral wedges (*k*) seen in fig. 1. Plate LI. fig. 5 represents an enlarged tangential section of this part of the plant. The narrow fibres of prosenchyma (*k*) are of great and variable length, and have a diameter of about ·0028. The vertical intermediate bands of long, narrow, square-ended cells (*h*) are extreme modifications of parenchymatous forms, which gradually become shorter as we proceed towards the interior of the plant, and ultimately merge with those of the middle bark, of which they are merely prolongations separating the fibrous wedges as seen in fig. 1, h'. The fibrous bands are obviously modifications of the *sclerenchyma* of authors, but which, instead of forming a continuous investing layer, as is so commonly the case in recent ferns, is here arranged in a network of longitudinally disposed bands with very long and narrow meshes.

Though not appearing very prominently in the section represented by fig. 1, the outermost bark projects at innumerable points (fig. 1, k'') into small rounded or conical protuberances. These are generally extensions of the middle parenchyma rather than of the prosenchymatous cells, and obviously correspond with similar projections seen on the petioles of many recent ferns, as in *Alsophila excelsa* and other arborescent forms. BRONGNIART has also figured several fossil species of *Pecopteris* in which the rachis is covered with similar protuberances. I presume they are to be regarded as undeveloped hairs, or as the remnants of abraded ones.

Having thus ascertained the structure of the matured petiole, we may now examine the modifications which that structure undergoes as we proceed from the base towards the tip of the rachis. As we do so we find that the horizontal bar of the vascular bundle, seen in transverse sections like fig. 1, gradually diminishes in size and alters its form until we obtain the condition represented in Plate LII. fig. 6, *a*, where we have two bundles. These are widely divergent superiorly, but almost meet dorsally. In Plate LII. fig. 7, these two bundles have reunited to form the gutter-shaped bundle of TRÉCUL. In Plate LII. fig. 8, this bundle is but slightly cordate, whilst in figs. 9 & 10 (which latter represents the extremity of the rachis) we have only a very small cylindrical bundle remaining. In all these sections we see in the bark the same features noticed as existing in fig. 1, but in a more prominent form. In the upper part of fig. 6 the cells of the middle parenchyma (*h*) are somewhat drawn out radially, whilst the prosenchymatous fibres (*k*) are very clearly shown, their cavities being filled with coally matter. In the smaller sections 7, 8, 9 & 10, the abortive hairs (k'') become conspicuously large in proportion to the size of the petiole. This feature reappears in all the smaller sections*. All these sections are drawn to one scale.

Some longitudinal sections which I have made of these smaller parts of the petiole reveal some important features. Plate LII. fig. 11 represents one of these, and fig. 12 a second one still more enlarged. The vascular bundle reduced in size appears at *a*. In fig. 12, *b*, we find traces of the innermost cortical parenchyma, which here appears to consist of a few layers of narrow, vertically elongated, square-ended cells, suggestive of a rapid vertical growth. The middle parenchyma (*h*) resembles that seen in sections made near the thicker base of the petiole, but in these terminal portions a remarkable difference presents itself: we find bands of small, compactly grouped cells (*i*) extending from the inner to the outermost bark; and at i', i', where the section has passed somewhat tangentially between the inner and outermost bark, we see that these cells are frequently arranged in quoit-shaped disks, exactly resembling, save in their greater irregularity of position, the similar disks in the young petioles of *Heterangium Grievii*, described in my fourth memoir (Phil. Trans. 1873, Pl. XXXI. figs. 45 & 47). I think there can be no doubt whatever that these are the structures which, breaking up at a later period of growth into detached masses, and having their special cells subsequently absorbed, produce the intercellular lacunæ (*i*) seen in Plate LI. figs. 2 & 4; at least I have failed to find any other explanation of the existence of these two singular arrangements in the young and the more matured parts of the petiole.

* BRONGNIART applies to these organs the name of "écailles sétacées" (Vég. Fossiles, p. 200).

Even had I no further evidence to offer as to the fern-like character of these petioles, it would be impossible to overlook their very close resemblances to those of many recent ferns. The form of their vascular bundles is not widely dissimilar from that of *Asplenium nidus*, whilst their bands of subepidermal fibres represent the continuous layer of the sclerenchyma of METTENIUS and other authors, so common in many ferns. The epidermal surface of *Pteris umbrosa* is covered with small rounded protuberances like those shown in the transverse sections of our fossil. But fortunately we are provided with further testimony. Many of my sections display evidence of the association of leaves with these petioles; but the two represented in Plate LII. fig. 13, and Plate LIII. fig. 14, from sections made by Mr. BUTTERWORTH, are the finest of this class that I have hitherto met with.

Plate LII. fig. 13 is evidently part of the upper extremity of a frond giving off lateral pinnules. In the large central rachis we have at *a* the vascular bundle, and on each side of this we have the bark with its characteristic masses of dark-coloured cells (*i*) and its epidermal tubercles (k''). Two lateral pinnules are given off at *x*, *x*, and fragments of similar pinnules are scattered throughout the entire section. Each pinnule divides into groups of terminal leaflets (*l*), each of which leaflets is supplied with a central vascular bundle (*m*) prolonged from the central vascular axis (*a*). Numerous similar but detached leaflets (l') are scattered over the section.

Plate LIII. fig. 14 represents either one of these lateral pinnules or that constituting the terminal portion of a rachis in a still more perfect state. The central vascular bundle of the rachis (*a*) sends branches into each of the lateral pinnules (*x*), and which again subdivide to reach the several terminal leaflets (*l*). The general aspect of these sections suggests the idea of a young half-developed frond in a semicircinate state. It is very difficult, if not impossible, to determine with absolute certainty the exact type of fern to which this specimen belongs. The mode of subdivision of the lateral pinnules is more suggestive of a *Sphenopteris* than of a *Pecopteris* or a *Neuropteris*. The leaflets seem to have been grouped in small radiating clusters rather than on the regular bilateral plan of an ordinary *Pecopteris*; at the same time this apparent irregularity may but be the result of a section passing through a plant distorted through pressure. The rounded form of the numerous transverse sections of leaflets (fig. 13, l'') seen in the specimens suggests the idea of the latter being very succulent, with a vascular bundle penetrating the centre of the parenchymatous mass.

Another circumstance connected with these objects originally suggested the possibility that the plant might have been a bipinnate frond of the type of *Pecopteris*. At an early period of my researches my attention was arrested by the frequent occurrence, in the nodules from which these specimens were obtained, of objects like Plate LII. figs. 15 & 16, associated almost invariably with long narrow lines of beaded structures like the upper parts of Plate LIII. fig. 17 and the left-hand side of fig. 18. The former of these structures (fig. 16) consisted of a doubly curved object like a section of a young leaf having a revolute vernation. These objects were generally about ·1 measured from side to side; when unrolled they would be much more. The other beaded structures (fig. 17) were fragments of various lengths, from a quarter of an inch downwards, often arranged in pairs, or even in more or less parallel sets of four, as in the upper part of fig. 17, *l'*. By making sections of these two forms at right angles to each other, as in fig. 17, I succeeded in obtaining proofs that the revolute objects (fig. 15) were merely transverse sections of structures, of which the beaded lines (fig. 17, *l'*) were longitudinal ones. After months of research, involving labour apparently very disproportionate to the end attained, I obtained further proof that these were sections of leaflets of *Pecopteris*, a nearly perfect one of which is represented in Plate LIII. fig. 19. It appears that even in their mature form these leaves were apt to assume a remarkably revolute form. Hence the great number of sections obtained like Plate LII. fig. 15. Specimens like figures 17 & 18 of Plate LIII. showed that the white bead-like spaces represented the intervals between the nervures, and the dark dividing lines were the nervures themselves. In the double-beaded line at the lower part of fig. 17 the section has only passed through one lateral half of the revolute leaf; in the upper part of the same figure, owing to the twisted position of the leaf, it has passed similarly through both halves, hence the four beaded lines *l'*, *l'*. The mid rib of the leaf appears at the points indicated by *l''*, *l''*, *l''*. In the central part of the figure the dark lines of the nervures are seen proceeding upwards and outwards from the mid rib towards the left-hand margin of the leaf, the section being here made in the plane of that half of the leaf without passing entirely through it as at *l*. The right-hand margin of fig. 18 is in the same condition as is the centre of fig. 17.

The exceeding abundance with which fragments like those just described are associated with the specimens represented by all the figures from 1 to 14, early suggested to me the possibility that they all belonged to the same plant. On this supposition figs. 13 & 14 would belong to young and half-developed fronds, whilst figs. 15, 17, 18, & 19 were parts of matured leaflets. Plate LII. fig. 16 represents one of several specimens which seemed to sustain this idea. It looks like a section of a revolute leaflet resembling fig. 15, yet it undoubtedly belongs to the leaflet series of figs. 13 & 14; as is the case with all the leaflets of the latter specimens, its obtuse margins indicate a more succulent state than do the sharply defined incurved edges of Plate LII. fig. 15. If fig. 16 is really a *transverse* section of *one* leaflet, and not a combination of *two* leaflets intersected *longitudinally*, the identity of the two forms would be almost certain; but I have not been able to link the two forms in a perfectly satisfactory manner. There is also the further difficulty, that the objects represented in figs. 15, 17, 18, & 19 are leaflets of a *Pecopteris* of the type of *P. Serlii*, none of the pinnules of fronds of which type are constructed on the plan of figs. 13 & 14. I am therefore now inclined to conclude that *Rachiopteris aspera* (as I propose provisionally to designate the petioles just described) is a *Sphenopteris*. It is an important fact in reference to this question, that we have in the Coal-measures a *Sphenopteris* with a tuberculated rachis, and which has a wide geographical range. This is the *S. Hoeninghausi* already referred to. The pinnules of this plant exhibit aspects which resemble those of figs. 13 & 14 in the closest manner, rendering the conclusion that our Oldham fossil is generically, if not specifically, identical with the above plant, an exceedingly probable one.

The acceptance of this conclusion demonstrates two facts connected with the Carboniferous ferns :—first, that their vascular bundles are not necessarily, like those of living ferns, surrounded by a definite investing cylinder of prosenchyma; and, secondly, that the prosenchymatous fibres of their subepidermal tissues (the sclerenchyma of authors) do not, as in recent ferns, constitute an uninterrupted investing layer, but that it is broken up into a network of fibrous bands arranged longitudinally, and through the long narrow meshes of which some of the parenchymatous cells of the middle bark reach the epidermal surface. We shall find these two facts of importance, throwing light upon some other examples awaiting examination.

One of the earliest discovered of the plants from the rich storehouse of the upper foot coal-seam near Oldham was one of which Mr. BINNEY exhibited a section at the meeting of the Manchester Literary and Philosophical Society held on January 9th, 1872, when he proposed to give to the plant the name of *Stauropteris Oldhamia*. As in the preceding instance, I have obtained specimens of this petiole in every stage of growth, from the largest examples down to the smallest twigs. One of the most beautiful, it is also one of the most perplexing of the plants of the Coal-measures—not as regards the details of its structure, since these are clearer than in most of these objects, but the interpretation of them presents several difficulties. The largest of the transverse sections (Plate LIII. fig. 20) are usually about ·125 in diameter. The vascular bundle (*a*) consists of four clusters of vessels arranged in a crucial manner, and is imbedded in a mass of exceedingly delicate cellular tissue (*g*), which not only surrounds, but fills in all the intervals between the bundles. In the specimen fig. 20 this tissue is destroyed, but it is preserved in Plate LIII. figs. 21, 22, 23, & 24; it is invested with a broad prosenchymatous layer (*k*). Plate LIV. fig. 25 is part of a longitudinal section of a matured stem. Each of the four vascular clusters consists of a central group of barred vessels (*a*) of large size, and a more peripheral series (*a*′) of very much smaller ones. The largest of the inner series have a diameter of ·005, and the smallest of the outer ones of ·001. Both the former and the latter are barred. I am unable to detect any true spirals amongst the smaller series. They all pass through the stem with remarkable straightness and freedom from irregularity of arrangement. The cellular tissue which immediately surrounds the vessels (fig. 25, *g*) exhibits the same features as it does in the centre of the stem, where it partially separates the four vascular clusters. It consists of very delicate cells, elongated longitudinally, and having a mean diameter of ·00083. Their ends are often square, but sometimes oblique. A casual glance at many of the specimens would almost make it appear that we have here a true representative of the fibrous sheath of living ferns; but such is not the case. As we proceed from within outwards we perceive that this tissue passes gradually, though rapidly, into a coarse prosenchyma (*h*); in Plate LIII. fig. 20 this prosenchyma appears as if it terminated abruptly at its inner margin; but this appearance is only due to the destruction of the more delicate central tissue. In Plate LIII. figs. 21 & 22, the two tissues are seen to graduate into each other. At the extreme periphery of the sections the cells become smaller; some of the larger ones have a diameter of as much as ·0025, whilst the lesser ones are not more than ·0012. This thick prosenchymatous cortical layer has every appearance of having been hard and woody, as is the case with the corresponding tissue in many of the living Adiantums. In the transverse section of a smaller stem (Plate LIII. fig. 21), the only change observable is the consolidation of the four vascular bundles into a common bundle, and in the much smaller size of its component vessels. Its transverse section still retains its crucial form. In Plate LIII. fig. 22, representing a yet smaller stem, the transverse section of the bundle has become distinctly trifid. In some specimens this tripartite feature is yet more striking than in that figured, owing to the greater length and slenderness often attained by the three divergent arms. The individual vessels of fig. 21 are now reduced to a very small size. In fig. 23 this reduction has gone further still, and the entire bundle is but a slender, cylindrical, vascular thread; whilst in Plate LIII. fig. 24 the whole stem is reduced to a small cylindrical body, looking more like the ultimate fibre of a root than a stem, and with two or three very small vessels in its centre, scarcely discernible amidst the cellular tissues that invest them. These smallest and ultimate fibres are not more than ·006 in their entire diameter.

Unlike the greater number of the non-Lepidodendroid stems of the Coal-measures, that under consideration branches freely, and we are able to trace the process in the various sections represented by Plate LIII. figs. 25 A & B and Plate LIV. figs. 26 & 27. Fig. 25 A exhibits at a' some of the small peripheral vascular tissues already seen in fig. 20, a'; but on the upper side of the section the corresponding vessels have become detached as well as increased in numbers, forming the two triangular bundles (a'', a''), the inner bark (g) still connecting them with the two uppermost of the primary bundles (a, a). In fig. 25 B we have a similar condition of things, but in a somewhat earlier stage of progress. The diverging tissues (a'') are here less completely detached from the central bundles (a, a), and they have not yet in this instance undergone the division into two separate bundles which invariably takes place before these tissues emerge from the bark. Plate LIV. fig. 26 exhibits a smaller stem in which these trifid bundles (a'') are completely detached from the central one (a). In all the above three cases the transverse sections have been made at points intermediate between those at which the central bundle first separates into three and those at which the branches dichotomize externally. This will be made sufficiently intelligible on referring to Plate LIV. fig. 27, which is a similar branching stem intersected longitudinally. In the latter section the common vascular bundle (a, a) is but slightly divided at its lower part into two bundles by some cellular tissue (g). Superiorly these two bundles (a', a') diverge—that on the right hand proceeding into the branch of its own side, whilst that on the left, and which is a somewhat smaller bundle, proceeds to the left-hand smaller branch. In the bark investing these bundles we can still trace the various elements seen in the larger stems; but the individual layers of cells are comparatively few in number. The transverse sections of these branching examples thus exhibit some important features. Before a stem is about to branch, there is obviously a decided increase in the number of smaller vessels at the ends and corresponding side of the two arms of the crucial bundle from which the branches are about to proceed. Then these additional vessels, along with others not additional, become detached in two distinct bundles. Sometimes transverse sections of these detached bundles exhibit the same crucial form as that seen in the parent stem; but they much more frequently assume the trifid form seen in fig. 22. Though in making a longitudinal section like fig. 27 we can only pass in the same plane through the main stem and one of its branches, it is obvious that two branches of equal size are given off at each of these ramifications. Hence it would appear as if these branches had been given off in pairs, as in many species of *Pteris*.

The question remains to be asked whether or not this is a fern. In favour of this conclusion we have its general aspect, the arrangement of its vessels in each bundle, the fern-like mode of increase in the dimensions of the vascular bundles on the side from which branches are about to be given off, and the detachment of those bundles in *two* coequal groups, indicating a different mode of branching to what is common amongst the Lycopods. I have seen no Lycopod, transverse sections of which exhibit this mode of orientation of the secondary bundles from the primary ones. The single bundle given off in the Lycopods separates into two parts in the young shoot; but these two bundles always go into the same branch, continue closely parallel to each other, and are but the common points of departure for new vessels, which continue to develop centripetally until the two temporarily separated vascular foci are again united into one elliptical bundle. This is very different from what occurs in the plant just described. But in the latter case, on the other hand, we have the remarkable succession of divisions and subdivisions continued until we obtain clusters of minute twigs like fig. 24, and which look much more like cylindrical rootlets than twigs or ultimate branches of a rachis. It seems strange, supposing them to be the ultimate subdivisions of the petioles of ferns, that we should reach these ultimate divisions without discovering any trace of a leaf or of a leaf-attachment. If they bore leaves they must have been very small terminal ones, resembling in their positions those of some of the Adiantums. But notwithstanding the difficulty just stated, the arguments in favour of the affinity of this plant with ferns appear to me to preponderate over the opposite ones. I would therefore retain it in my genus *Rachiopteris*, associating with it Mr. BINNEY'S specific name of *Oldhamia*.

Amongst the specimens sent to me from Burntisland by Mr. GRIEVE, I found one or two full of branching fragments of a plant apparently undistinguishable from this Oldham one. Both in size and organization the two appear to be identical.

The next plant to be described is also one which I discovered amongst the Burntisland specimens, but which I have not yet found at any other locality. It is beyond all question one of the most beautiful structures that I have hitherto obtained from the Carboniferous beds. Plate LV. fig. 28 is a transverse section of this petiole, and Plate LIV. fig. 29 a vertical one taken through its centre and along its longer axis. Its form, as seen in transverse sections, has been oval, with a major diameter of rather more than ·5, and a minor one of about ·37. It possesses, in its matured form, a double vascular bundle, a larger one (a) filling one focal portion of the ellipse, and a smaller one (a') occupying the other. Transverse sections of the former exhibit an hourglass-shape, and similar sections of the other display a crescentic one. The vessels composing the larger bundle (a) are remarkable for the regularity of their arrangement, comparative uniformity of size, and exquisite definiteness of outline. They are generally about ·005 in diameter. At the peripheral extremity of this bundle (a'') there is a deep longitudinal groove running down the side of the bundle, so deep that it is as nearly as possible enclosed by the vessels and converted into a canal*. The vessels in its immediate neighbourhood, and especially those forming the two crescentic horns embracing the groove, are much smaller than the more central ones of the bundle, being about ·0016, and a few of them are even smaller still. These conditions are better shown in Plate LIV. fig. 30, which is a more enlarged representation of a vascular axis of this plant, the general form of which has been disturbed by pressure, but without any corresponding disturbance taking place in its individual vessels. The vessels composing the two horns enclosing the canal (a'') are again seen to be of smaller size than those constituting the rest of the bundle, and a few similar ones exist on the opposite or central side of the groove.

These distinctions are important, since on turning to longitudinal sections of these parts (Plate LIV. fig. 29) we find that these very small vessels are barred ones, whilst all the larger ones are reticulated. At the same time, as is shown by Plate LIV. figs. 31–34, there is a gradual transition from the one modification to the other. Figs. 31 & 32 represent two reticulated forms, the latter being the more common one; fig. 33 is semireticulated, and fig. 34 simply barred. All the four figures are drawn to the same scale. At the opposite or more central end of the hour-glass bundle there is a second longitudinal groove (Plate LV. fig. 28, a'''); but this is less deep, barely amounting to half a circle. A very small number of barred vessels occur in its vicinity, even the more minute ones being generally more or less reticulated. On turning to the crescentic bundle (a'), we find these conditions reversed. Generally speaking its vessels are smaller than those of the hour-glass bundle. A few of the largest are seen to be reticulated, especially as in fig. 33; but most of them are merely barred. I have been unable to detect any true spirals amongst them. In the longitudinal section (Plate LIV. fig. 29), a represents the central part of the hour-glass bundle; a' the crescentic one; a'' is the canal-like groove at the cortical end of the former bundle, with a few barred vessels on the right of it at the lower half of the figure; whilst at the upper half, where the section has just missed the groove, we find

* I have obtained one specimen (Plate LV. fig. 35) in which the incurved crescentic margins absolutely meet, virtually converting this groove into the canal a''.

its place occupied by a number of the small barred vessels which so nearly surround it. In Plate LIV. fig. 30, a', the crescentic vessel is rather different in form from what it generally appears to be. It is brought into close contact with the very slightly convex adjoining face of the hour-glass bundle, its own inner surface for nearly the central half of its length being also flattened, whilst its two extremities are incurved. These arrangements appear to me to be too symmetrical to be merely the accidental results of pressure. In Plate LV. fig. 35 this crescentic bundle is broken up into two (a', a'); and that this subdivision also is not the result of violence, but is a normal organic state, is shown by the circumstance that each half has its ends curled inwards in the same crescentic manner as characterized the two ends of the bundle a' of fig. 30—a fact which, as we shall see immediately, has a physiological significance.

The cortical investment of these bundles closely resembles that of the *Rachiopteris Oldhamia*. We have in both a delicate inner parenchyma (fig. 28, g), usually more or less destroyed, a thick middle portion consisting of a coarse parenchyma (h), and an outer dense prosenchymatous layer (k). In the plant under consideration very little of the innermost tissue (g) remains. In one example it is preserved in the canal-like groove (a''), and in several I find small portions of it in contact with the bundle. All these indications tell the same tale, viz. that it exhibits the common aspect of parenchyma, but with smaller and somewhat more delicate cells than those which constitute the middle portion of the cortex. This latter structure (h) is exquisitely preserved. It consists of a vast multitude of cells arranged, as is so commonly the case amongst recent ferns, in interrupted columns running parallel with the vascular axis. These cells, which in the perpendicular sections appear to be nearly cubical, are about ·0025 in diameter. Plate LIV. fig. 36 is an enlarged representation of three columns of them as they appear in vertical sections. Plate LIV. fig. 29, h, shows how large a portion of the bark is occupied by this tissue; but as we approach the periphery we find that its cells gradually become more elongated vertically, as shown in the enlarged figure 37, and gradually pass into the outer prosenchymatous layer (k), a few of the cells of which are seen in the longitudinal section fig. 38, which is drawn to the same scale as figs. 36 & 37. At the outer surface the prosenchymatous cells have only a diameter of from ·00083 to ·0012. Closely associated with the stems just described are considerable numbers of smaller ones of various dimensions, including mere twigs, like that represented in Plate LV. fig. 40. The structure in all these smaller stems is so exactly identical with the large ones in every respect, save in the more cylindrical form and in the shape of the vascular bundle, that, even had we no direct proof of the fact, there could be no doubt as to their being portions of the same plant. Plate LVI. fig. 39 represents one of the larger examples of this form.

The central vascular bundle (a) exhibits a crescentic section with incurved angles and with three slight tooth-like projections in the interior of the concave margin. When I first called attention to these stems, I had not ascertained the relation of the form just described to that with the hour-glass bundle (Plate LV. fig. 28). Hence I proposed for it the separate specific name of *Arpexylon simplex.* I have now, however, indisputable evidence that the two are parts of the same plant, and that fig. 39 is but a secondary petiolar branch of fig. 28. I have traced these branches downwards, exhibiting every degree of size from fig. 39 to fig. 40, and even further, since I find abundance of yet smaller twigs in some of my slides, which I have no doubt are the terminal portions of the same structures. The latter have but a very few vessels forming a small central bundle, which loses its special crescentic shape. These conditions remind us of those already represented in figs. 22, 23, & 24, belonging to *Rachiopteris Oldhamia.*

The last described sections make it quite clear that the two halves of the subdivided crescentic bundle seen in Plate LV. fig. 35, a', a', have been so subdivided preparatory to passing outwards through the bark to supply secondary branches like fig. 39. A very slight modification of each of these two clusters of vessels in the former figure would give to it the characteristic form of fig. 39, and the entire process would be in close accordance with what takes place amongst recent ferns.

The difficulties attending the interpretation of this petiole are very great, and would have been much more so, but for a series of sections for the loan of which I am indebted to my friend Mr. CARRUTHERS. The obvious question suggested by the specimens which I have already described is this—have the secondary rachides been invariably given off from one side of the central *hour-glass* bundle? or has the primary crescentic bundle (a') been formed and disappeared in the shape of pairs of secondary bundles, alternately given off from its opposite sides? The specimens now to be described demonstrate the truth of the last of these suggestions.

Plate LV. fig. 35 A is part of an imperfect transverse section of a matured petiole. At *a* we have the two extremities of the hour-glass bundle, whilst at *aa*, *aa* we have, passing through the cortical layer, two crescentic secondary bundles, each of which have been exactly like that of fig. 39; on the concave side of the perfect crescentic bundle (*aa*), on the right of the figure, we have a yet smaller one (x), which has evidently been detached from that with which it is so closely associated. In fig. 35 B, which represents a second section of the same petiole, taken a little higher up, we obtain a clue to the relations of these several parts. At *a* we have the hour-glass bundle accidentally ruptured across its central portion; at a' we find the large primary crescentic bundle in its normal position as a single unbroken band. Longitudinal sections in my cabinet clearly demonstrate that the vessels of this primary crescentic bundle leave those of the hour-glass one very gradually, since the two sets run for considerable distances in perfect parallelism with each other. At *aa*, *aa* we find the two secondary crescentic bundles going off to some secondary lateral appendages, clearly demonstrating the fact that those appendages, whatever they have been, were alternately given off from the opposite convexities of the hour-glass bundle. The groove at a''' is nearly obliterated, in consequence of the recent detachment of the primary crescentic bundle a'; but the opposite side has so far recovered from the effects of the detachment of the secondary bundles *aa*, *aa*, that, instead of being truncated, it has regained its convex form, and its canal (a'') has, in like manner, ceased to be a mere superficial groove. But we further observe that the small bundle (x) also seen in fig. 35 A has now moved away from the larger secondary bundle (aa) with which it was so closely associated in the last figure. I think I discover a similar bundle at x' in corresponding association with the twin secondary bundle (aa), to the left of the figure. The several vacant spaces (g) in this figure indicate areas from which extensions of the innermost cortical parenchyma investing the vascular bundles of the larger petioles have disappeared. The masses of the parenchyma of the middle bark (h) are continuous with the common investing cortex of the petiole.

In fig. 35 C, which is a third section of the same specimen, but made at a point yet a little higher up in the petiole, we find all the cellular tissues of the bark much more homogeneous than in fig. 35 B. The central bundle (a) and its two branches (aa, aa) retain nearly the same relative positions as before. The small bundle (x') is not very clearly seen, but its fellow on the opposite side (x'') is now very conspicuous. In a section made a little above the last, but which I have not deemed it necessary to figure, the bundle x' is seen moved still nearer to the periphery.

Plate LVI. fig. 35 D represents the next section in the ascending order, and is important to us. The various structures of this section correspond closely with those of fig. 35 C; but it will be observed that at k, k, k, k we have a broad trifid line of condensed prosenchyma enclosing the two areas of the middle cortex, within which are the two secondary bundles (aa, aa), and the left-hand one of these three divergent lines again subdivides in like manner to enclose the small ternary bundle (x''). It is sufficiently obvious that these dark bands consist of similar tissues to those constituting the periphery of the sections fig. 35 A, B, and C, and indicate that along these lines we are approaching the peripheral surface, or that, in other words, the rachis is here about to subdivide into two secondary rachides (aa, aa) and one ternary one (x''). Still further light is thrown upon this matter by another section made still higher up in the petiole, and represented in Plate LVI. fig. 35 E. We now find the two secondary bundles (aa, aa) not only moved much further away from the central hour-glass, from which they are separated by an enlarged mass of the middle cortical parenchyma, but they appear as if they were entering two secondary petioles which project from the primary one like two horns (y, y). But since these horns are chiefly composed of the prosenchyma of the outermost bark, we have no absolute proof whether they actually represent *two* separate secondary petioles, or mere longitudinal ridges of *one* secondary one. But that the former is the case is almost certain, because we see at k' the triangular line of small prosenchymatous cells, such as we find near the surface of the outermost bark, and which, I think, clearly indicates the approaching division of the stem into three distinct branches—a primary one and two secondary ones, as intimated in the description of fig. 35 D.

Unfortunately we do not possess any further sections of this most interesting specimen, hence we cannot trace the ultimate condition of these secondary branches. The ternary branch x'' of fig. 35 D has also evidently escaped from the periphery of the petiole at the interval between the points at which the sections fig. 35 D & E were made.

On tracing the further development of one of the secondary petioles in the same series of sections, we obtain yet further information respecting their modes of branching. Plate LV. fig. 35 F is the lowermost of several sections of one petiole, which, though virtually transverse, are nevertheless slightly oblique ones. In it we have the secondary crescentic bundle (*aa*), corresponding to the bundles *aa* in figures 35 A, B, C, D, & E. At x we have a ternary bundle passing out of the petiole, the bark of which latter again is much enlarged at this point. At x' we see a second ternary bundle lying immediately outside the uncurved horn of the crescent (*aa*), and evidently preparing to pass off towards the periphery as the bundle x had done, but from the opposite horn of the crescent *aa*. At x''' we find a quaternary bundle evidently going off to supply either a lateral pinnule or a leaflet. In Plate LVI. fig. 35 G we see the ternary bundle x' of Plate LV. fig. 35 F moving outwards, but in the opposite direction to that taken by x in that figure. The latter bundle, with its enlarged mass of cortical cells, has now become altogether detached, and is seen to be a separate rachis, having the relative size and form, compared with that from which it springs, of Plate LV. fig. 40 and of Plate LVI. fig. 35 H, both of which represent sections of similar twigs. Its central bundle has acquired the gutter-shaped section seen in fig. 40*. Plate LVI. fig. 35 I is the next section in this ascending series. The central bundle retains its place at *aa*, whilst its ternary branch (x') with its investing cortex has not only become of considerable size, but is giving off at x''' a quaternary twig, which may either have been the petiole of a leaflet or, more probably, the rachis of an ultimate pinnule. The vascular bundle supplying this quaternary subdivision of the rachis has obviously corresponded to x'' in Plate LV. fig. 35 F, only opposite sides of the rachis are thus occupied in the two examples. But this section (fig. 35 I) shows that whilst this ascending branch of the petiole has thus enlarged, the central vascular bundle (*aa*) is now throwing off at x'' a corresponding bundle to x', only destined for the opposite direction, being now detached from the lower horn of the crescentic bundle as x' was from the upper one. In Plate LVI. fig. 35 K, which is the fourth of this ascending series of transverse sections, we again find the rachis much reduced in size, owing to the entire separation of the large branch x' of fig. 35 I. In the original specimen this latter is now seen to be a small, detached cylindrical rachis corresponding in size and form with fig. 35 H. In fig. 35 K the small cluster of vessels x'', seen in fig. 35 I, x'', is now larger, and more nearly detached than before from the crescent *aa*. In all these specimens, as in all similar recent ferns, the two extreme horns of the crescentic bundle (*aa*), which alternately become detached to form the ternary bundles, are entirely composed of barred vessels, whilst those forming the central part of the crescent are of the reticulated type.

* It is possible that fig. 40 may be the upper portion of a secondary rachis, since at x we find it detaching a bundle like that shown in fig. 35 K.

These latter sections (figs. 35 F, G, H, I, & K) do much to clear up the obscurities of this interesting stem. We now learn that there were certainly three sets of branches given off from the primary petiole, viz. the secondary ones with the large crescentic section (*aa*) of the above figures, the ternary ones (x') of the same series, and the quaternary ones (x'''). Those represented by the letter x' were obviously given off from the barred portions of the crescentic bundles (*aa*) in the manner usually seen amongst such recent ferns as possess a similar bundle, viz. alternately from each of the two horns of the crescent. These may have been the ultimate rachis sustaining the leaflets, one of which (fig. 35 I, x''') may have been merely a small petiole of a leaflet; but even if the latter represents a yet more peripheral or quaternary series of subdivisions, I think I have now proved the existence of that simple alternate arrangement in the orientation of the ultimate bundles, the want of which was so perplexing in the larger petioles. Since I have in no solitary instance met with a petiole containing *two* crescentic bundles, it is clear that those (*aa*, *aa*) of fig. 35 E went to two distinct subdivisions of the primary petiole. Hence it seems to become an indisputable conclusion that, whatever this arrangement may signify, these secondary rachides were given off in pairs, springing alternately from opposite sides of the primary petiole, but that they in their turn bore other subdivisions, which were arranged in the usual alternating and distichous order—these distichous branches themselves either having directly borne the leaflets, or if not having given rise to other and yet smaller distichously arranged subdivisions, upon which the leaflets were planted. It is scarcely necessary to say that this arrangement is an anomalous one. I know of no recent fern in which the secondary branches of the petiole are thus given off in pairs, which pairs are distichously arranged on the primary axis, and each of which secondary petioles sustain ternary ones arranged distichously. Not only will a somewhat similar case come before us on a later page of this Memoir in CORDA's genus *Zygopteris*, but the structure of the *Rachiopteris Oldhamia* just described suggests the possibility that a somewhat similar arrangement may have existed in its case. The full meaning of these peculiar relations of the secondary branches to the primary petioles can only be cleared up by further research.

The plant represented in fig. 28 has not yet been discovered in the Lancashire district; but Plate LV. fig. 41 and Plate LVI. fig. 41 A represent two transverse sections of petioles, also with reticulated vessels, and which obviously bear some considerable resemblance to Plate LVI. fig. 39. Mr. CARRUTHERS has favoured me with the sight of a similar section to fig. 41, from the Newcastle coal-field, and for which he was indebted to Professor KING, of Galway.

The next plant to be described belongs to a type that has already been figured and described by previous observers. COTTA figured a stem from CHEMNITZ (Dendrolithen, tab. i. fig. 1) which he designated *Tubicaulis primarius*, and which he regarded as identical with the *Endogenites solenites* of SPRENGEL. The petioles attached to this stem were numerous, and each one had in its centre a vascular bundle, the transverse section of which somewhat resembled the letter H. CORDA subsequently made this plant the type of his genus *Zygopteris* under the name of *Zygopteris primæva.* Specimens of the same type were discovered by Professor RENAULT at Autun, and made the subject of an admirable paper which that careful observer published in the 'Annales des Sciences Naturelles,' 5ème série, Bot., tome xii. M. RENAULT obtained what appear to be four species of this genus, a specimen of one of which fortunately had preserved not only the petioles but the central rhizome from which the petioles sprang, leaving no room for disputing the petiolar character of these structures. Both Mr. BUTTERWORTH and Mr. WHITTAKER, of Oldham, placed in my hands specimens of this genus from the two-foot coal at a very early stage of my inquiries, and I subsequently obtained others from the same coal-mine. One of these closely resembles the species described by M. RENAULT under the name of *Zygopteris Lacattii*, and the other appears to be identical with his *Z. bibractiensis*. I have not found any of these attached to their primary stem. Mr. CARRUTHERS has referred to this genus *Zygopteris* as being very closely allied to a group of fern-stems which he has united to form his genus *Chelepteris**. I presume he merely means by this that, judging from the two specimens figured by COTTA and RENAULT, these plants belong to a group in which "the persistent bases of the stipes permanently clothe the small vascular cylinder" (*loc. cit.*), since I am not aware that specimens of any of our English tree ferns have yet been found retaining their internal structure, or that our British examples of *Zygopteris* have as yet been absolutely identified with the stem of a tree fern.

Plate LVI. fig. 42 represents a transverse section of a petiole which, in its general features, closely resembles the *Zygopteris Lacattii* of RENAULT. These petioles always exhibit an oval section, with a major axis of about ·37 in diameter. The central vascular bundle (a) is usually detached from its normal position, through the disappearance of the inner cortical cellular tissue more immediately surrounding it. It consists of a complex group of vessels of various sizes, a transverse section of which group resembles the letter H, but with the extremities of the vertical bars bent inwards. The vessels of the central or horizontal bar (a') are always the largest, most of them having a mean diameter of ·085. Those of each of the vertical arms (a & a'') are distinctly separable into two sets—an inner one (a) consisting of vessels resembling those of the central horizontal bar (a'), but not quite so large as the latter ones are, and an outer series (a''), in which the vessels are very small, rarely exceeding ·005, and many of them not having half that diameter. Those of the inner series (a) do not seem to undergo any material change of position, either in sections of the same stem, made at different points, or in those of different stems; but it is otherwise with the smaller ones (a''). In no one instance have I seen those of each of the two vertical bars occupying precisely similar positions. Thus in fig. 42 those on the right hand (fig. 42, a'') of the vascular group are but little removed from the vertical bar, whereas on the left hand (a') they are entirely detached, and appear as two broken clusters close to the inner margin of

* "On the Tree Ferns of the Coal-measures, and their Affinities with existing Forms," Report of the British Association for the Advancement of Science for 1872, Trans. Sect. p. 98.

the outer bark. I shall be able to demonstrate that this arrangement is not the *accidental* result of some disturbing force, but is consequent upon the method in which the vascular bundles are given off to the secondary rachis or petioles. As in *Rachiopteris duplex*, these bundles going off to the secondary rachis are given off alternately from the outermost vessels of the opposite sides of the central bundle*. A specimen from Halifax, in the cabinet of Mr. CARRUTHERS, clearly shows that the new vessels which replace those that have now become separated have the closest organic connexion with the central bundle, primarily forming a part of it. M. RENAULT noticed a somewhat similar condition in his *Zygopteris Lacattii*, and rightly suspected that the arrangement was connected with the formation of the secondary bundles; but owing to the small size of the only fragment which he possessed of this species he was unable to demonstrate this connexion. I happen to have been more fortunate in this respect.

M. RENAULT pointed out that *all* the vessels of the horizontal bar, and most of those of the two vertical arcs of *Z. Lacattii*, were of the reticulated type (" vaisseaux ponctués " or " vaisseaux aréolés). A few only, in each of the lateral arcs, exhibited the scalariform type of structure. This result accords with my own observations, only I find in my examples rather more barred or quasi-scalariform vessels in the lateral arcs than M. RENAULT appears to have met with. The thin areolæ in the walls of the vessels are remarkable for their small size and definitely round or oval outlines (Plate LVII. fig. 44). The greatest diameter of the vessels is not more than ·0004, and ranges between that and ·00029. Fragments of this tissue approach nearer to those constituting the mineral charcoal so common in the Coal-measures, than any other which I have hitherto seen. The innermost cortical layer is very imperfectly represented in my examples, this tissue being generally more or less destroyed. Portions of it preserved in various specimens, as at fig. 42, *g*, exhibit a rather delicate form of parenchyma, which obviously correspond with that described and figured by M. RENAULT. That observer found the tissue in question penetrated longitudinally by large elongated cellules with proper walls, which he believed to have been gum-canals. The middle bark (*h*) and the outer one (*k*) are well preserved in my specimens. In the transverse sections the former appears as composed of rather thick-walled cells, which diminish in size as we proceed from within outwards. Plate LVII. fig. 43, *h*, exhibits these cells as seen in the vertical sections, where they are arranged in somewhat regular vertical lines (orthenchyma). The cells have square ends; but as we approach the periphery they gradually become elongated vertically, and their extremities become pointed and overlapping, thus passing into the very narrow elongated prosenchymatous cells (*k*) which constitute the outermost portion of the bark.

* I have recently found a specimen in which these bundles of smaller vessels have been given off simultaneously from opposite sides of the central H-shaped bundle, and are now located in similar positions immediately within the bark, but in the opposite foci of the elliptical section. In living ferns in which the distichous arrangement prevails these secondary rachides are sometimes given off in pairs. The petiole may possibly belong to a distinct species with opposite secondary pinnules.—Nov. 9, 1874.

The vertical section represented in Plate LVII. fig. 43 exhibits a vascular bundle (*m*) going off to some lateral appendage; and it will be observed that it has carried along with it a narrow investing cylinder of the innermost bark (*g*) enclosed in a broader one of the middle parenchyma (*h*). I have already referred to the arrangements of the outermost vessels (a'', a'') of the two lateral arcs of Plate LVI. fig. 42, as well as to the supposition of M. RENAULT that these tissues might possibly become detached from the main bundle to supply lateral ramifications of the frond. My specimens demonstrate the correctness of this inference. Fig. 43, *m*, shows that such bundles are given off, and that after leaving the central vascular axis they diverge rapidly outwards. On the right hand of fig. 42, as already observed, we see these vessels (a'') but little removed from their corresponding lateral arc, whilst to the left the similar vessels (a') are wholly detached from their arc (*a*), and almost reach the inner surface of the cylinder of middle bark (*h*). In Plate LVII. fig. 45 we have a transverse section of another of these vascular axes. At the one extremity we have a large continuous band of small vessels (a'') occupying nearly their normal position, but at the opposite end we have only two small detached clusters of such vessels (a', a'), their central connecting group having disappeared: Plate LVII. figs. 46 & 47 and Plate LVIII. fig. 48 explain these conditions. These figures represent portions of three transverse sections of the same petiole made at points about the eighth of an inch apart. Fig. 46 is a segment of the bark of the lowest of the series, and in it we see that the two vascular masses (m'', m'') have just entered the middle bark (*h*). At this point they are located in one common oblong areola (*g*), which was formerly occupied by an extension of the innermost cortical cells. Each of these vascular bundles still exhibits the irregular outline and somewhat square form that we see at a' on the left-hand side of Plate LVI. fig. 42. The middle and outer cortical layers are here unaltered. Plate LVII. fig. 47 exhibits one extremity of the central vascular bundle (*a*), which presents the appearances already referred to in the instance of fig. 45, a'; viz. there are two detached clusters of small vessels left (a' & a'); but those central vessels which ought to link these two detached clusters into one linear group (as at fig. 45, a'') have gone to form the two bundles already seen at fig. 46, m'', m''. In fig. 47 we find that these bundles (m'', m'') have not only penetrated further into the bark, but the section of each of them has now assumed a cylindrical form, whilst the single areola within which they were enclosed in fig. 46 is now divided into two, separated by a band of the parenchyma of the middle bark (*h*). The bark has also become enlarged at this point. In Plate LVIII. fig. 48 this enlargement of the petiole has increased yet more. We now find the ordinary parenchyma of the middle bark at *h*. At k' we have a layer of small cells like those seen near the periphery of the petiole; at h' we have a second mass of middle-bark parenchyma, and at *k* we have the ordinary prosenchymatous cells forming the outermost layer of the stem. The layer of small cells at k' seems to indicate the approach of the entire separation of the lateral branch or branches from the primary petiole, and the reappearance in the latter of the two layers of middle and outer barks, *h* & k', in their normal positions and dimensions as seen in fig. 46. One of the lateral bundles (m'') continues its outward course in the more horizontal direction which the upper portion of the similar bundle is seen to follow in fig. 43, producing the more elliptical form seen both in the section of the bundle itself and of the areole representing the missing cellular tissue by which the bundle was immediately invested. The second bundle (m') is now much smaller in size, and has not advanced so far as its companion from the point at which it entered the middle bark. I presume it is either going to some secondary rachis of smaller dimensions than that to which the larger bundle m'' is proceeding, to become a secondary bundle in the same rachis as the larger one, or to become wholly abortive. It is not easy to determine which of these suggestions is the correct one. We are here brought face to face with the same difficulty as that encountered in *Rachiopteris duplex*. For double bundles to enter a common rachis is an ordinary occurrence amongst recent ferns; but unfortunately I fail to discover amongst these fossil secondary petioles any so furnished. Their bundles appear to be single ones in all the plants of the *Zygopteris* type.

Amongst many other specimens from the neighbourhood of Oldham, for which I have been indebted to Mr. J. BUTTERWORTH *, were the two represented in figures 49 & 50, and which are obviously the same plant as that described by M. RENAULT under the name of *Zygopteris bibractiensis*. The central vascular bundle has been somewhat disturbed, probably by the shrinking of the inner cortical layer (g), rather than by any external pressure; but it is easy to see that at a' we have the usual horizontal vascular bar, at the extremities of which we have the two vertical arcs (a, a), one arm of one of the latter being accidentally detached from its normal position at aa. Two features distinguish this vascular axis from that of the *Z. Lacattii* of RENAULT:—(1) all the vessels composing it are barred, none of them being reticulated; (2) each of the two vertical arcs (a) consists of a double layer of vessels, very differently arranged from those of *Z. Lacattii*. As in the latter case this double layer consists of an inner series (a), the vessels of which are large, and an outer one (a'') composed of much smaller vessels; but in *Z. bibractiensis* these do not merely constitute a double series of larger and smaller vessels in such close apposition as to constitute but two portions of a common cluster, but the two sets of vessels are so arranged as to form one unbroken linear series, constituting a loop or circle, the two sides of which have been brought into close approximation. The very small area which this loop encloses has been shown by M. RENAULT to be occupied by a delicate parenchyma. The following is the terse description of this arrangement given by the French botanist:—" Les bandes parallèles situées aux extrémités de la ligne

* Mr. BUTTERWORTH has recently furnished me with a second and very beautiful example of this petiole. It agrees in every respect with the above description, except that in it the innermost cells of the inner bark, *i. e.* those in immediate contact with the large vascular axis, are very much smaller even than those forming the rest of that inner tissue. They almost form a special sheath to the vascular axis. This new specimen agrees with that described above in showing that the lacunæ in the inner bark of the latter are the accidental results of desiccation. It differs, however, in not exhibiting any traces of the peripheral hairs (fig. 49, k'). The band of small vessels (fig. 49, a'') is continuous and unbroken, as well as in close contact with each vertical bar (fig. 49, a) of the transverse section of the vascular axis. I still find no gum-canals in its bark.—Nov. 9th, 1874.

horizontale du faisceau vasculaire, au lieu d'être simples et formées d'une seule ligne de faisceaux, paraissent divisées en deux lames, formées de vaisseaux de grosseurs très-différentes et séparées par du tissu cellulaire assez mal conservé; ces deux bandes se rejoignent par leurs extrémités" (*loc. cit.* p. 171). It is the loop-like continuity of the parallel bands of large and small vessels at each of their extremities that constitutes the characteristic feature of this plant. In the specimen which I have figured this arrangement is well shown at the lower end of each of the vertical arcs seen in the transverse section of the bundle. At the upper extremity of the arc to the right this arrangement has been disturbed by the accidental detachment of the fragment (*aa*).

The innermost cortical layer (*g*) is much better preserved in my specimens of this species than in those of *Z. Laçattii*, though partial desiccation or some similar disturbing agency has caused much of it to disappear and thus interrupted its continuity. In the upper part of the section about one fourth of it has so disappeared, and even in the remaining portion a ring of large lacunæ exists in it, which obviously did not characterize the plant in its normal state. It consists of a delicate parenchyma. In the vertical section (Plate LVIII. fig. 50) its cells (*g*) are seen to be arranged in the irregular vertical columns so common amongst Cryptogamic plants. This tissue evidently corresponds closely with that observed by M. RENAULT occupying a similar position in *Zygopteris Lacattii*, only in the latter plant numerous lines of vertically elongated cells exist—supposed by M. RENAULT to be reservoirs of gum, but of which I find no trace in the specimen under consideration. The middle and outer barks correspond closely with those of *Z. Lacattii.* At *h* we have the more strongly marked middle parenchyma, consisting of cells with much thicker walls than occur in the inner bark; but, as in the latter, they are arranged in irregular vertical lines. On approaching the surface of the petiole this parenchyma rapidly passes into the prosenchyma (*k*) which forms the thick outermost layer of the bark.

The latter tissue exhibits one feature not described by M. RENAULT, and which I have not observed in any of my specimens of *Z. Lacattii.* Both the longitudinal and transverse sections are furnished with a number of conical protuberances (figs. 49 & 50, *k'*), which are obviously abortive hairs. Transverse sections of these hairs have a perfectly circular outline, and show them to consist of some of the thick-walled prosenchymatous cells of the outer bark deflected outwards. They are evidently of the same nature as the appendages already described in connexion with Plate LII. fig. 13, and similar though smaller examples of which abound on the petioles of the living *Pteris umbrosa*, only from their size and strength in the plant under consideration they must have resembled blunted spines.

None of the writers who have described examples of CORDA'S genus *Zygopteris* have entertained the least doubt that the plants included in it were petioles of ferns; and my investigations have led me to the same conclusion. The discovery, both by COTTA and M. RENAULT, of stems to which, in some instances, these petioles were attached, led me to search diligently amongst the nodules of the Oldham two-foot coal, in hopes of finding some traces of similar stems. The only thing of the kind which I have discovered is the central vascular axis of a stem, a transverse section of which is represented in Plate LVIII. fig. 51. This axis is surrounded by a quantity of disorganized cellular structure, which doubtless represents the cortical tissues, but their disorganized condition obscures their true nature. The axis thus transversely divided consists of five crescentic masses (*a*) of irregularly arranged vessels, enclosing a pentagonal area (*b*), the angles of which are prolonged into five long radiating arms. This area is occupied by parenchymatous cellular tissue. The maximum diameter of the entire vascular axis is about ·125. In many respects this axis approaches very closely to that of a plant described by M. RENAULT (*loc. cit.* p. 172, pl. 10), and which that observer has referred to CORDA'S genus *Anachoropteris**. This example is too incomplete tc enable me to determine its exact relationships; but it is interesting to find specimens of this type at Oldham associated with *Zygopteris*, because it is an additional example illustrating the remarkable resemblances that exist between types which we have discovered associated in the Lancashire deposits, and those found by M. RENAULT similarly associated at Autun. That the type just described is very distinct from any of those described in my previous Memoirs is unquestionable. This plant appears to approach so near to the *Anachoropteris Decaisnii* of RENAULT that it will not be necessary to give it a separate name.

Since there are other fern-petioles from the Oldham beds yet to be considered, I will not make any general observations upon those now described, since that can be better done when the entire series of objects which appear to have belonged to that group of plants have been investigated. These remarks are especially applicable to a fine series of examples of the *Palmacites carbonigerus* of CORDA. The plant has recently been described from specimens found at Autun by Professor RENAULT (Comptes Rendus), who has arrived at exactly the same conclusions respecting it as those which I had previously announced at the Bradford Meeting of the British Association for the advancement of Science in September last. I there expressed my conviction that the plant was not, as had been supposed, an *endogenous* stem, but a fern allied to the Marattiaceæ. Without being aware of this determination M. RENAULT has arrived at a precisely similar conclusion.

I have again to acknowledge my indebtedness to the cabinets of my friends Mr. BUTTERWORTH of Shaw, Mr. NIELD and Mr. J. WHITTAKER of Oldham. Mr. GRIEVE'S specimens from Burntisland have again proved of the utmost value to me, whilst Professor RENAULT has laid me under great obligations by kindly sending me specimens of several of his Autun fossils for the purpose of comparison with my British ones. Last, but not least, I have to thank my old friend and fellow worker in our common field, Mr. CARRUTHERS. He has not only thrown open his cabinets for my inspection in the freest manner, but as Director of the Botanical Department of the British Museum his official aid has always been afforded to me in whatever way I sought his assistance.

* Mr. BINNEY has recorded the discovery of similar specimens in the lower Coal-measures of Lancashire. See 'Proceedings of the Literary and Philosophical Society of Manchester,' Jan. 21, 1873.

Description of the Plates.

Rachiopteris aspera.

Plate LI. fig. 1. Transverse section of a matured petiole, magnified 16 diameters.
" fig. 2. Longitudinal section of fig. 1, magnified 20 diameters.
" fig. 3. Vessels of vascular bundle: A, reticulate; B, barred; C, spiral.
" fig. 4. Two lacunæ of the bark, from a vertical section, magnified 65 diameters.
" fig. 5. Tangential section of the outermost layer of the bark, magnified 80 diameters.

Plate LII. fig. 6. Transverse section of the middle portion of a petiole, magnified 16 diameters.
" fig. 7. Transverse section of upper part of a petiole, with the gutter-shaped vascular bundle, magnified 16 diameters.
" fig. 8. Transverse section of the petiole yet nearer to the tip, the vascular bundle becoming circular, and the abortive hairs conspicuous, magnified 16 diameters.
" fig. 9. Transverse section of the petiole near its extremity, with small cylindrical bundle, magnified 16 diameters.
" fig. 10. Transverse section of the extreme termination of a petiole, magnified 16 diameters.
" fig. 11. Longitudinal section of a young petiole, with transverse layers of dense cells, enlarged 12 diameters.
" fig. 12. Portion of a section like fig. 11, magnified 30 diameters.
" fig. 13. Longitudinal section of the upper part of a petiole, with secondary pinnules and leaflets, magnified 16 diameters.

Plate LIII. fig. 14. Longitudinal section of a secondary pinnule, magnified 16 diameters.

Pecopteris.

Plate LII. fig. 15. Transverse section of a leaflet of a *Pecopteris*, magnified 20 diameters.

Rachiopteris aspera.

" fig. 16. Section of a leaflet or leaflets of *Rachiopteris aspera* (direction doubtful), magnified 20 diameters.

Pecopteris.

Plate LIII. fig. 17. Longitudinal and transverse section of part of a leaflet of a *Pecopteris*, magnified 20 diameters.
" fig. 18. Obliquely longitudinal section of a leaflet of a *Pecopteris*, magnified 16 diameters.
" fig. 19. Leaflet of a *Pecopteris*, enlarged 20 diameters.

Rachiopteris Oldhamia.

Plate LIII. fig. 20. Transverse section of a matured petiole, magnified 32 diameters.

" fig. 21. Transverse section of the upper part of a petiole, magnified 32 diameters.

" fig. 22. Transverse section of upper part of a petiole, with the gutter-shaped vascular bundle, magnified 32 diameters.

" fig. 23. Transverse section of a petiole near its extremity, with the vascular bundle cylindrical, magnified 32 diameters.

" fig. 24. Transverse section of the extremity of a petiole, magnified 32 diameters.

Plate LIV. fig. 25. Longitudinal section of a petiole like fig. 20, magnified 65 diameters.

Plate LIII. fig. 25 A. Transverse section of a petiole, with a cluster of small vessels at one side, preparing to become detached as two secondary bundles, magnified 32 diameters.

" fig. 25 B. Transverse section of a petiole like fig. 20, giving off trifid vascular bundles to secondary rachis, magnified 32 diameters.

Plate LIV. fig. 26. Transverse section of a smaller petiole giving off trifid secondary vascular bundles, magnified 32 diameters.

" fig. 27. Longitudinal section of a petiole giving off a large secondary rachis, magnified 32 diameters.

Rachiopteris duplex.

Plate LV. fig. 28. Transverse section of a petiole, magnified 8 diameters.

Plate LIV. fig. 29. Longitudinal section made through the longer axis of fig. 28, magnified 8 diameters.

" fig. 30. Vascular bundles of a matured petiole disturbed by pressure, but with the crescentic bundle (a') separating from the extremity of the "hour-glass" bundle, magnified 24 diameters.

" fig. 31. Reticulated vessel of the "hour-glass" bundle, enlarged 280 diameters.

" fig. 32. Another modified form of fig. 31, magnified 280 diameters.

" fig. 33. Small semireticulated vessel from the surface (a'', fig. 30) of the "hour-glass" bundle, magnified 280 diameters.

" fig. 34. Barred vessel from the cortical side of the canal (a'', fig. 30), magnified 280 diameters.

Plate LV. fig. 35. Vascular bundle of a matured petiole, the crescentic one subdividing into two secondary ones (a', a'), magnified 20 diameters.

" fig. 35 A. Part of a transverse section of a primary petiole, giving off two bundles (*aa*, *aa*) to two secondary petioles, one of which in turn is giving off the ternary bundle (x), enlarged 5 diameters.

Plate LV. fig. 35 B. A second transverse section made higher up in the petiole, displaying the same arrangements as the last, but with two ternary bundles (x, x) removed further away from the secondary ones (aa, aa), enlarged 5 diameters.

" fig. 35 C. A third transverse section of the same made still higher up, and with the left-hand ternary bundle (x'') clearly defined, enlarged 5 diameters.

Plate LVI. fig. 35 D. The fourth section, with lines of prosenchymatous cells (k) arranged in three divergent lines, and indicating the approaching separation of the petiole into four parts, viz. a primary, two secondary, and one ternary petiole, enlarged 5 diameters.

" fig. 35 E. The fifth section, in which the ternary branch (35 D, x'') has disappeared, and the two secondary ones (y, y) are further enlarged preparatory to becoming similarly detached.

Plate LV. fig. 35 F. Lowermost of a series of transverse sections of a secondary petiole, with its central crescentic bundle at aa; a ternary bundle (x) is proceeding outwards from one side of the petiole, and a second one is being given off at x', in the opposite direction from the opposite horn of the crescent; enlarged 8 diameters.

Plate LVI. fig. 35 G. A second section made a little above the last, with the upper ternary bundle (x') moving outwards towards the periphery, enlarged 8 diameters.

" fig. 35 H. The ternary bundle (x of figure 35 F), from a section intermediate between F and G, and now become an independent ternary rachis, enlarged 8 diameters.

" fig. 35 I. A yet higher section than fig. 35 G, with the ternary bundle (x') displaying a quaternary branch (x'''), and a new bundle being separated at x'' from the central crescent for liberation in the upward direction, enlarged 8 diameters.

" fig. 35 K. A still higher transverse section, in which the ternary bundle (x' of fig. 35 I) no longer appears, it having become detached as the centre of an independent rachis, similarly, *though in the opposite direction*, to that in which the bundle x became detached from fig. 35 F. A new bundle is now preparing to be given off from 35 K, x'' in the same direction as 35 F, x. Enlarged 8 diameters.

Plate LIV. fig. 36. Portion of a vertical section of the middle bark (fig. 29, h), magnified 80 diameters.

Plate LV. fig. 37. Oblong cells of a vertical section of the outermost portion of the middle bark (h), passing into the prosenchymatous form of the outermost layer (k), magnified 80 diameters.

" fig. 38. Prosenchymatous cells of the outermost bark, from a vertical section, magnified 80 diameters.

Plate LVI. fig. 39. Transverse section of a large secondary petiole, magnified 8 diameters.

Plate LV. fig. 40. Transverse section of a yet smaller secondary petiole, magnified 8 diameters.

„ fig. 41. Transverse section of a petiole, resembling fig. 39, from Oldham, enlarged 16 diameters.

Plate LVI. fig. 41 A. Another petiole, from Oldham, similar to fig 41, enlarged 16 diameters.

Rachiopteris Lacattii.

Plate LVI. fig. 42. Transverse section of a petiole, magnified 16 diameters.

Plate LVII. fig. 43. Longitudinal section, giving off a vascular bundle to a secondary petiole, magnified 20 diameters.

„ fig. 44. Reticulated vessel of fig. 43, magnified 280 diameters.

„ fig. 45. Transverse section of a detached vascular axis, magnified 20 diameters.

„ fig. 46. Part of the bark of a transverse section into which the two irregularly formed vascular bundles (m'', m'') have entered on their way outwards towards one or two secondary petioles, magnified 20 diameters.

„ fig. 47. Portion of a transverse section of the same specimen as fig. 46, but made a little higher up in the petiole, and with the vascular bundles (m'', m'') assuming a cylindrical form, magnified 20 diameters.

Plate LVIII. fig. 48. Part of the bark of a section of the same specimen, but made yet higher up, and with one of the vascular bundles apparently becoming abortive, magnified 20 diameters.

Rachiopteris bibractiensis.

„ fig. 49. Transverse section of a petiole, magnified 20 diameters.

„ fig. 50. Longitudinal section of fig. 49, magnified 20 diameters.

Anachoropteris Decaisnii.

„ fig. 51. Transverse section of the vascular axis of a stem apparently identical with the *Anachoropteris Decaisnii* of RENAULT.

The letters of reference employed in the Plates correspond with those employed in the previous memoirs, except in the case of one or two.

a. Central vascular axis.
h. Middle cortical layer.
g. Inner cortical layer.
k. Outer cortical layer and its appendages.
x. Ultimate subdivisions of the vascular bundles supplying branches of the rachis.

Fig. 1.

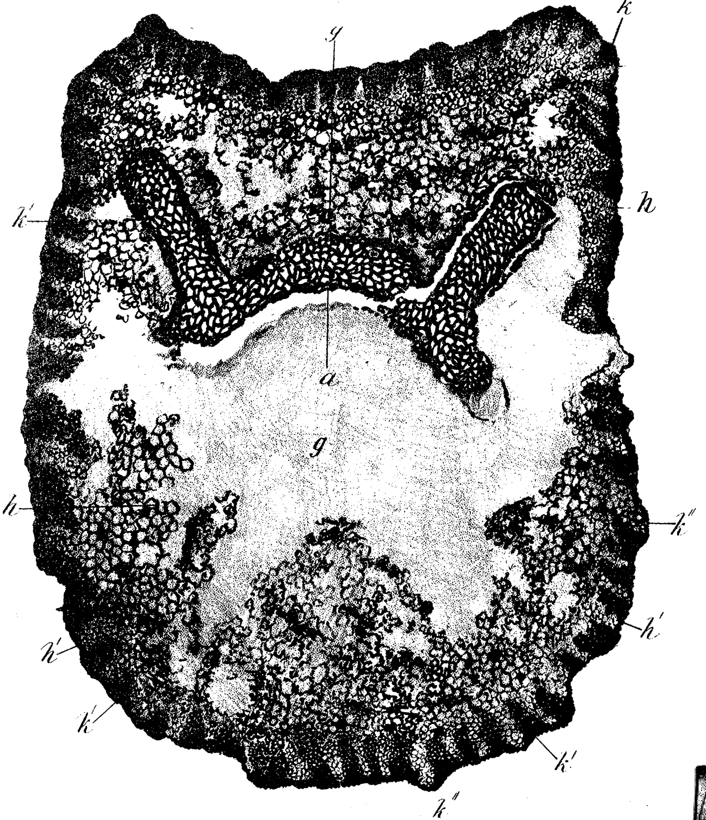


Fig 4.

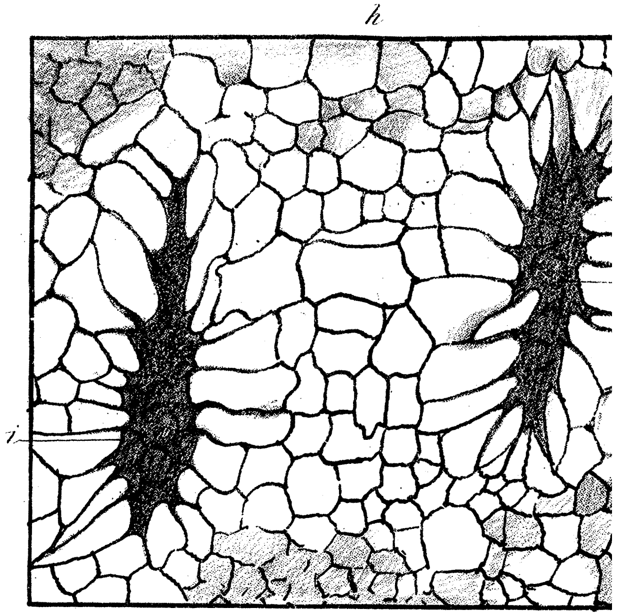


Fig. 3. C.

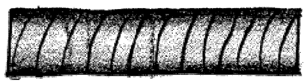


Fig. 3. B.

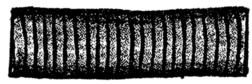


Fig. 2.

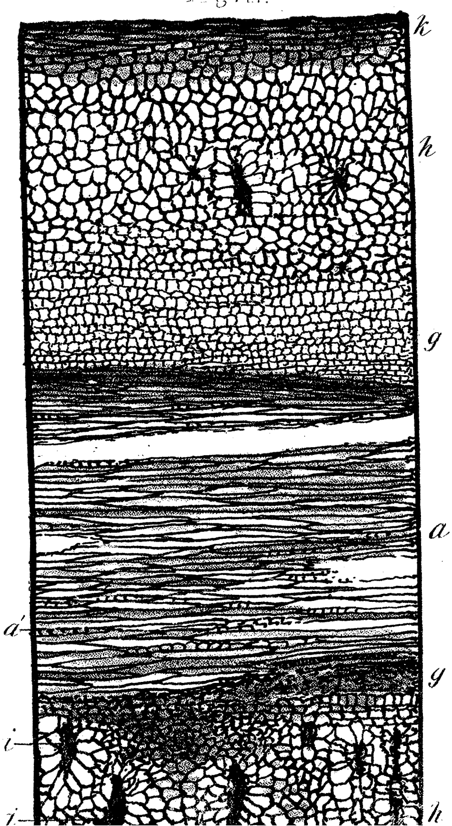
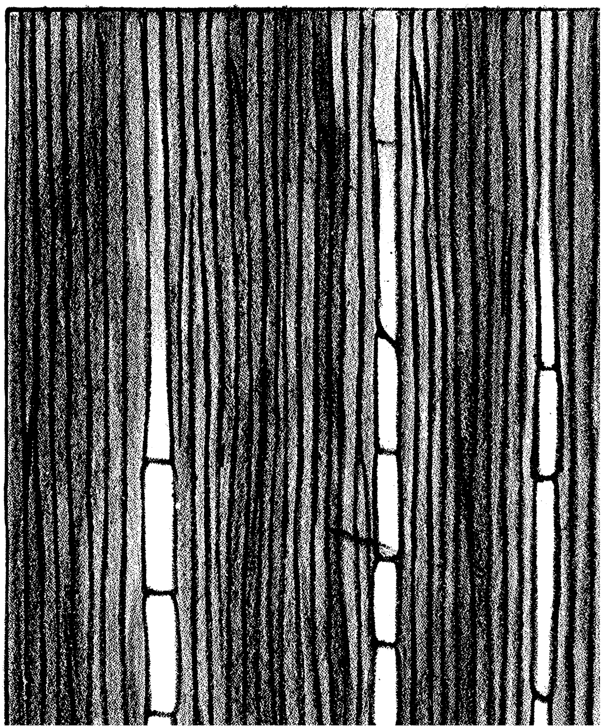
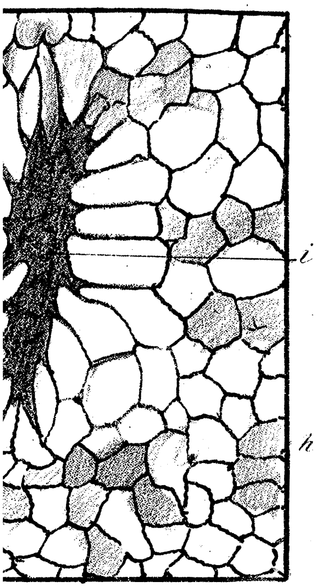


Fig. 5.





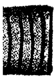
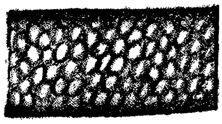
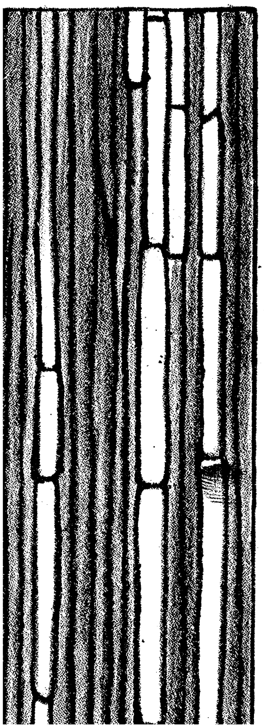
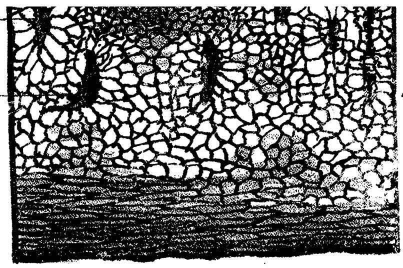
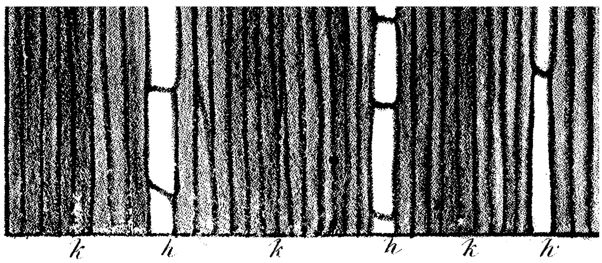


Fig.3.A.



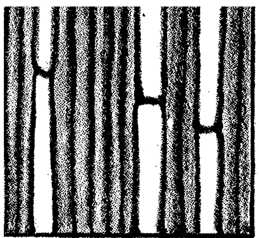






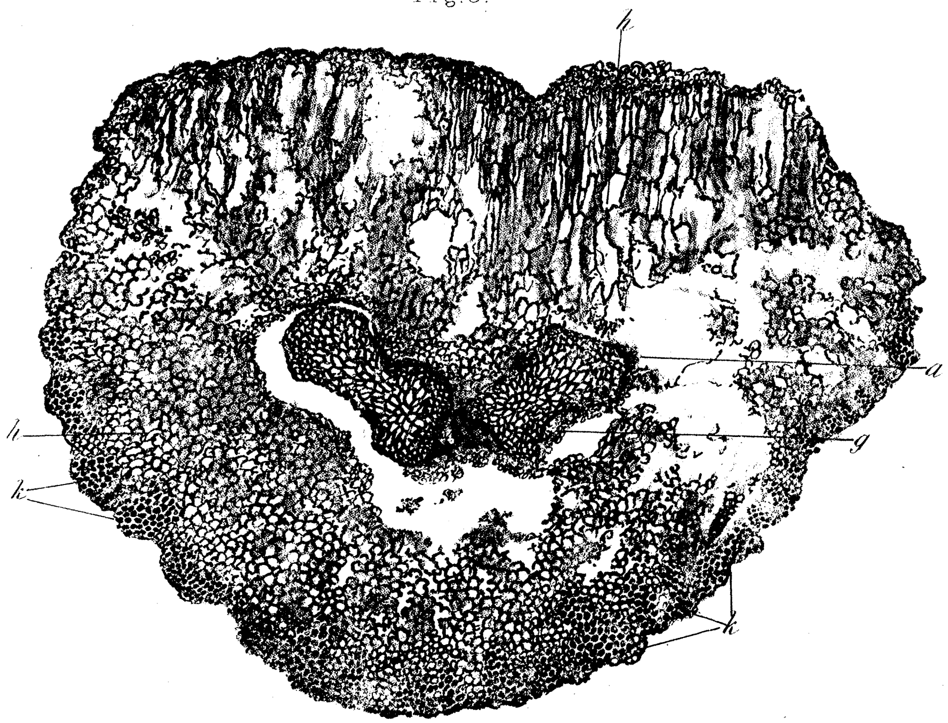
W. C. Williamson, Auto. Lith.

Maclure & M



achure & Macdonald, Lith. London.

Fig. 6.



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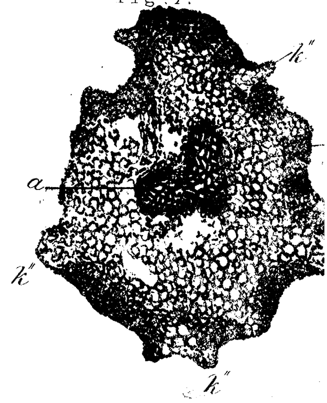

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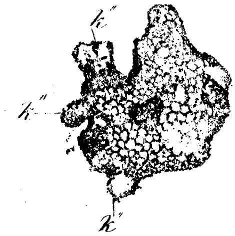
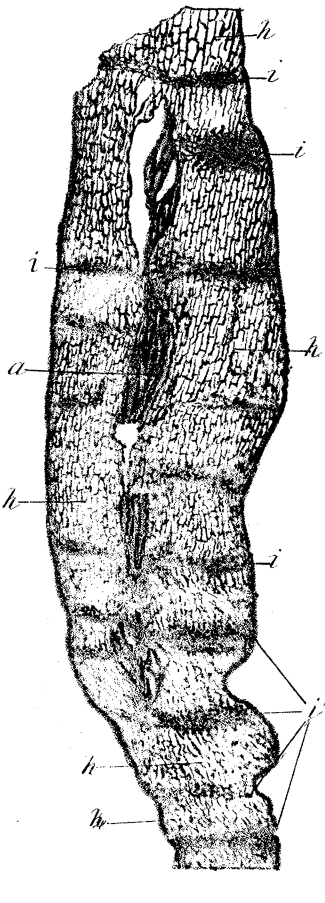


Fig. 13.

Fig. 11.



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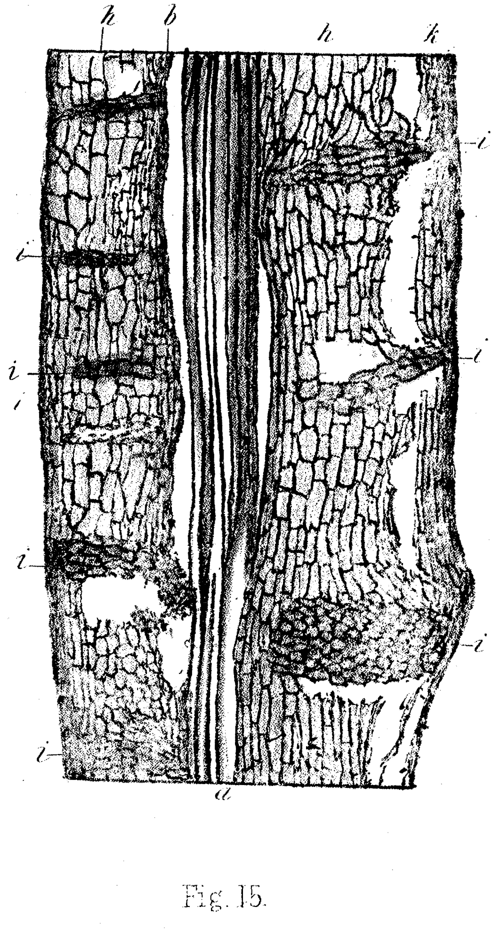


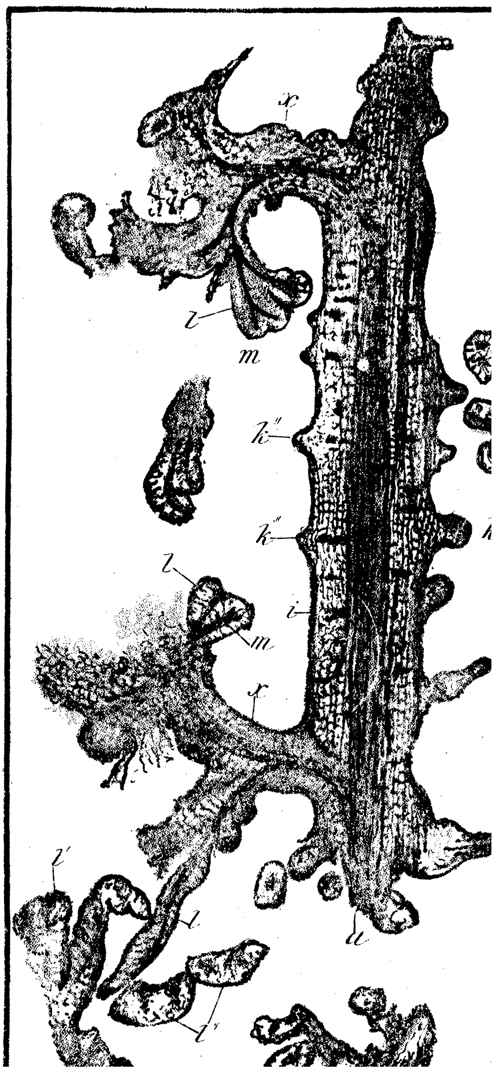
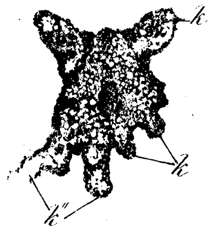


Fig. 15.

Fig. 16.

Fig.10

Fig.9.



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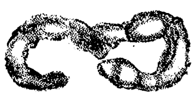

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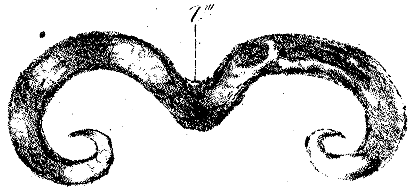

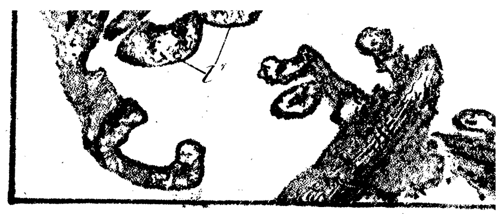

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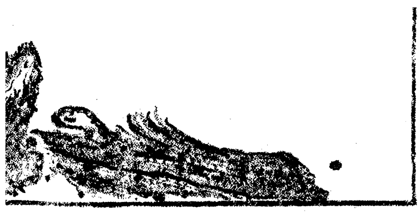

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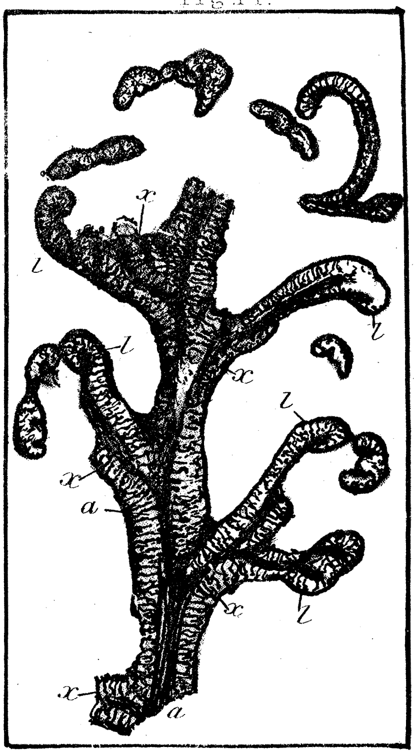

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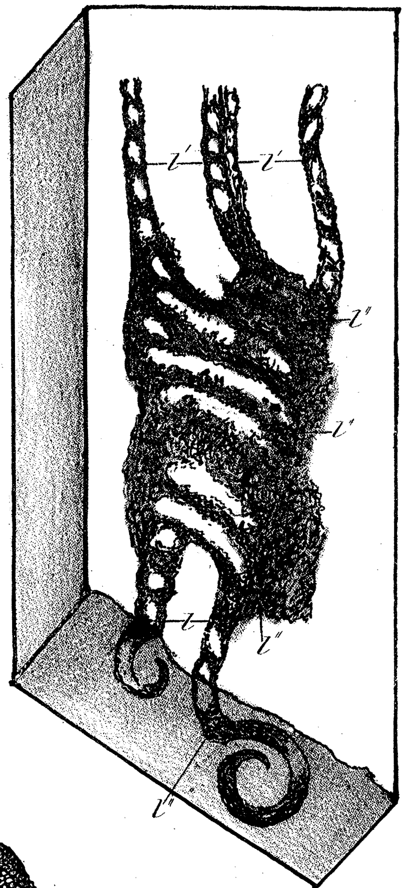
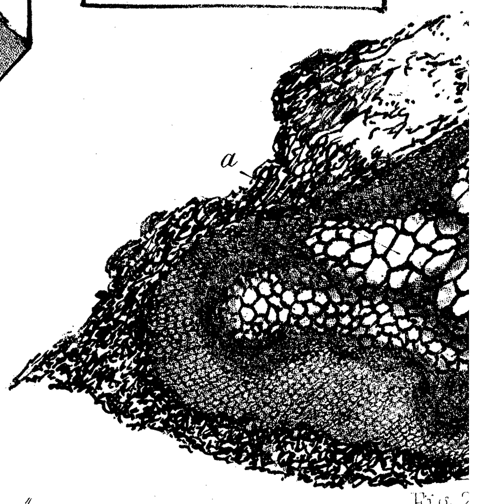


Fig. 18.

Fig. 25.



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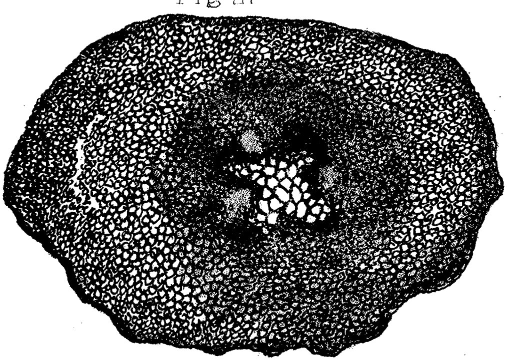
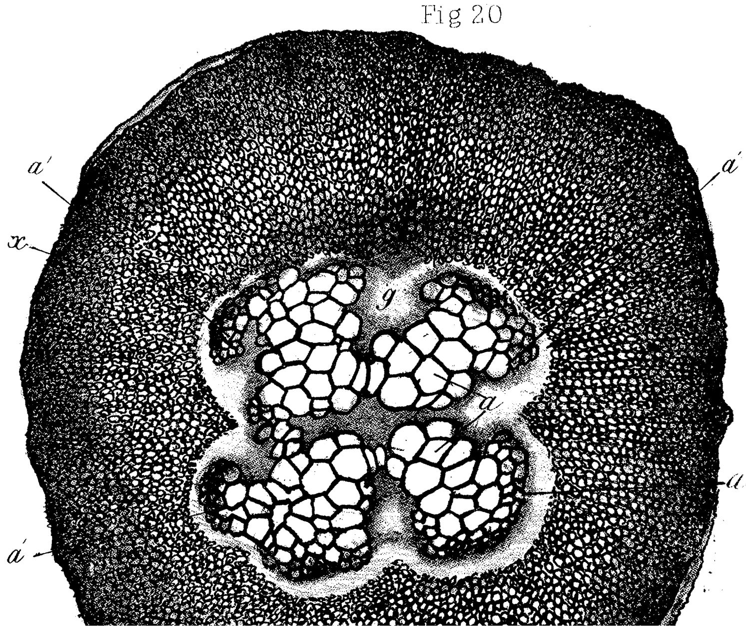


Fig. 23

Fig. 24

Fig. 20



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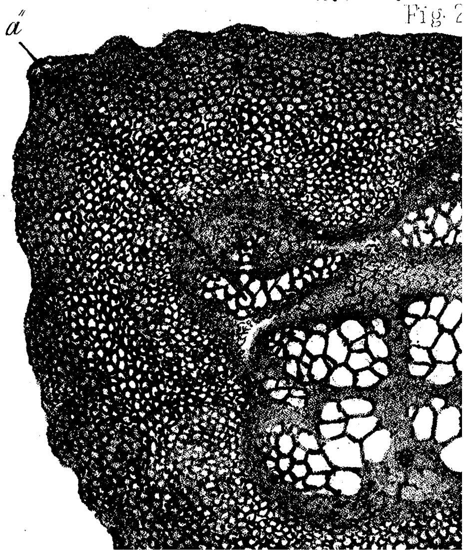

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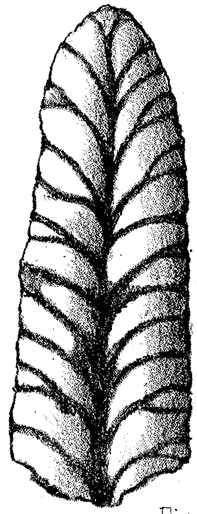


Fig 22

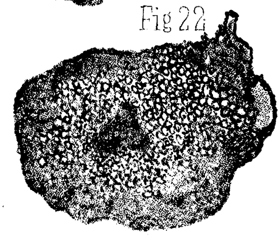


Fig 25.B.

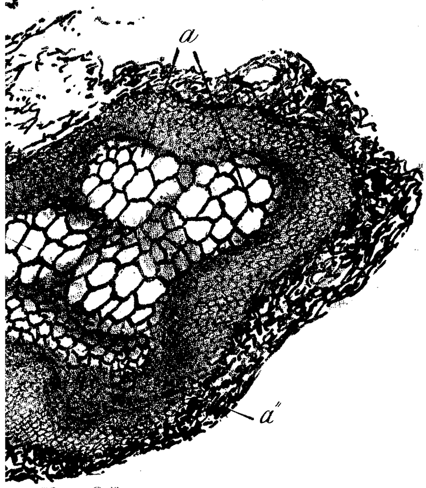
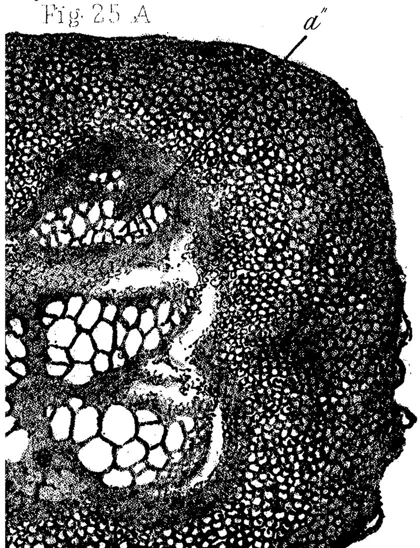
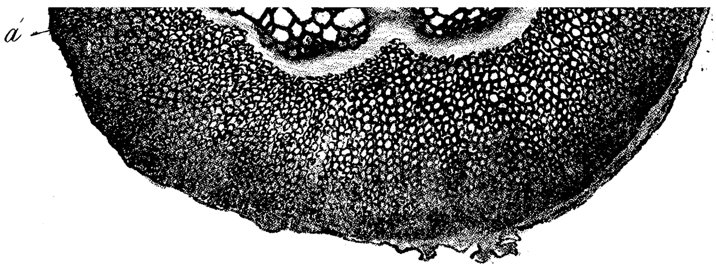
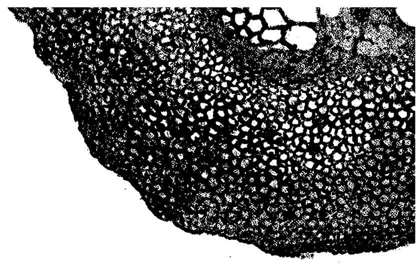


Fig. 25 A







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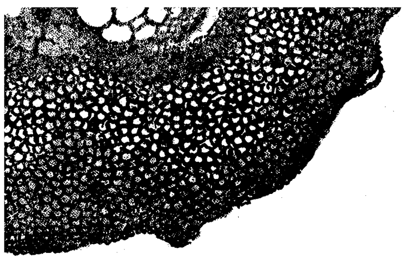

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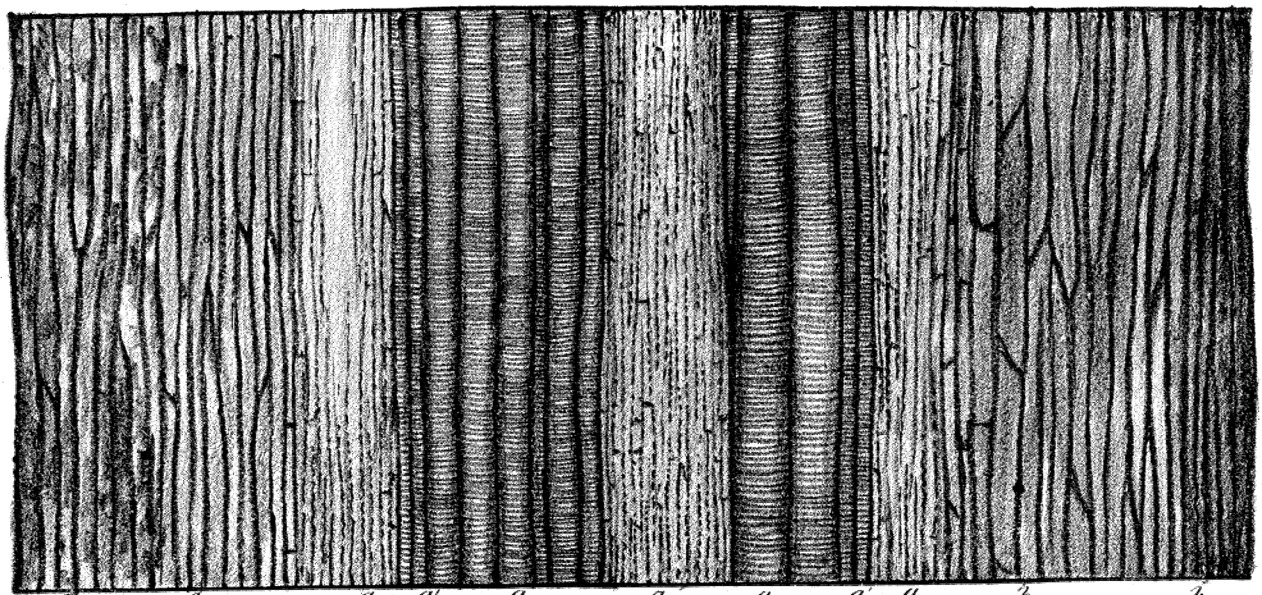
Fig. 25.



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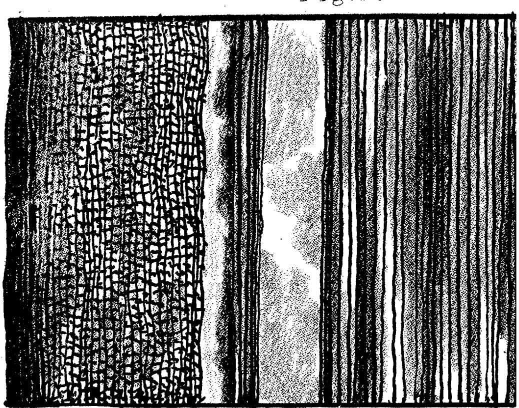

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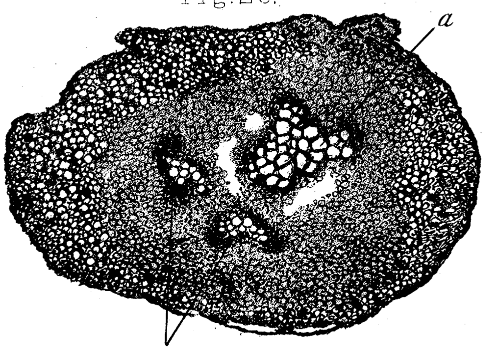

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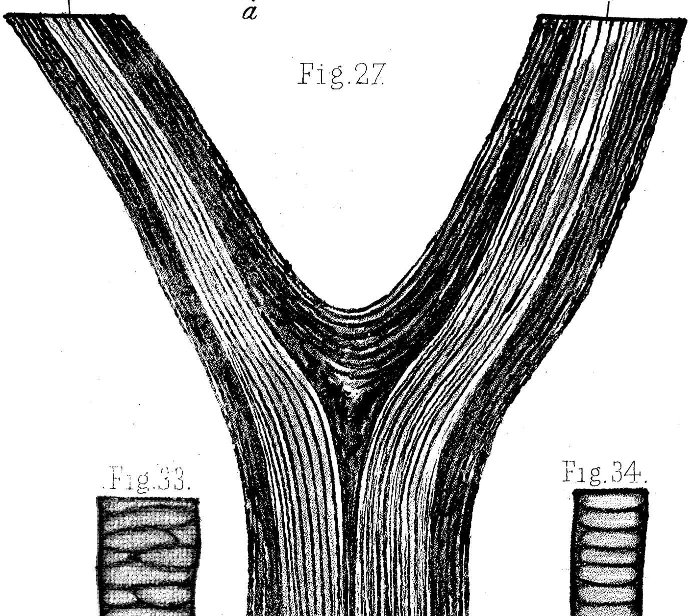

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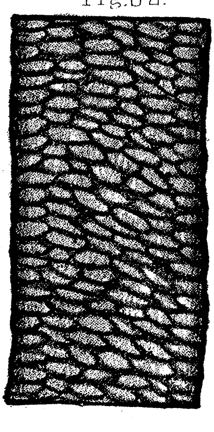

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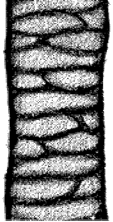

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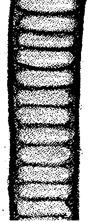
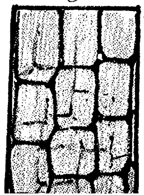
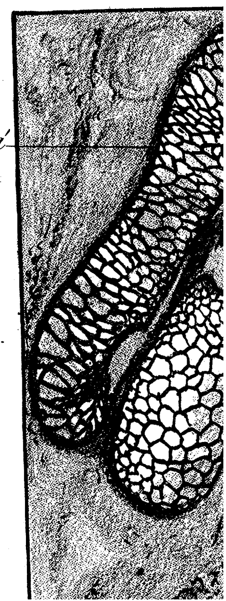


Fig 36





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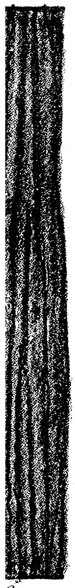

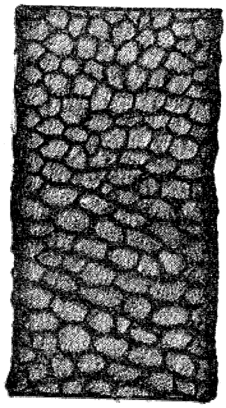

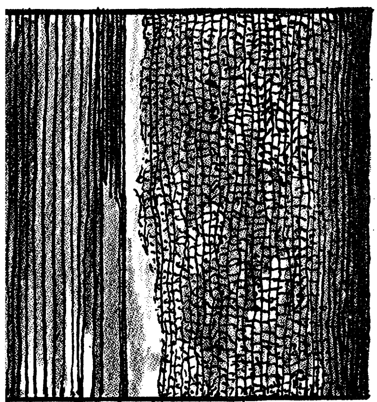

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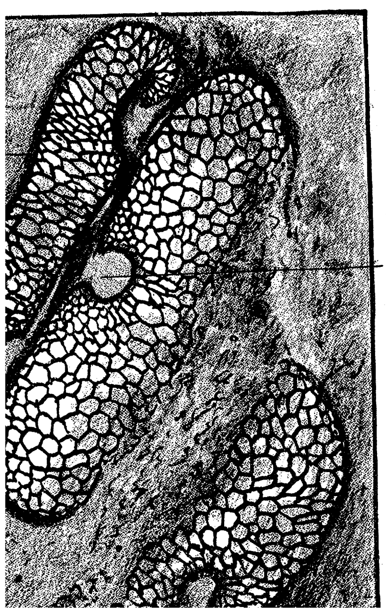

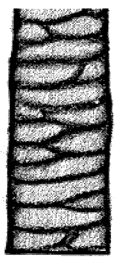

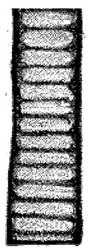

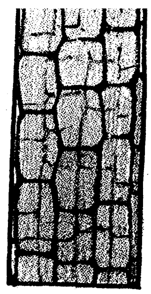

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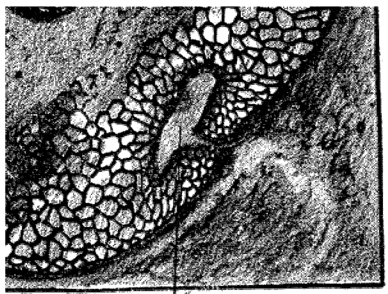
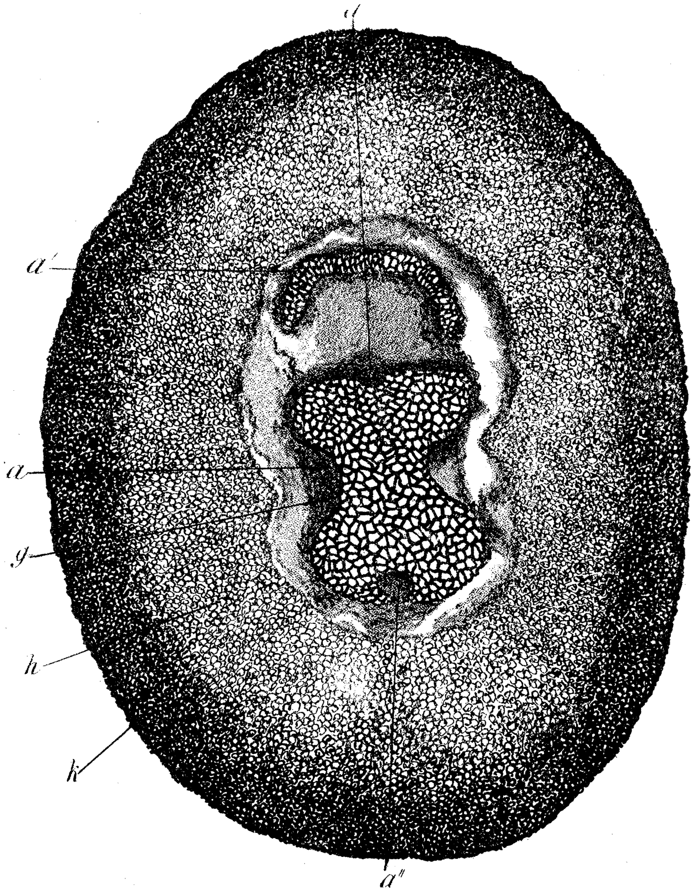


Maclure & Macdonald, Lith. Londo

Fig.28.



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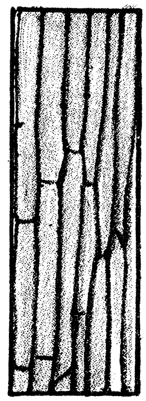

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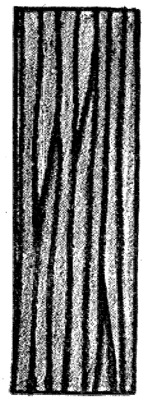

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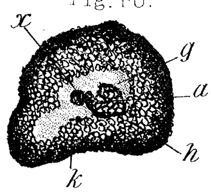
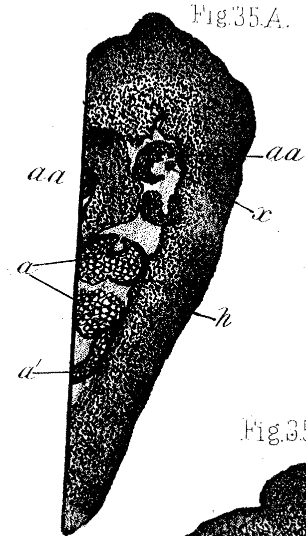


Fig.35.A.



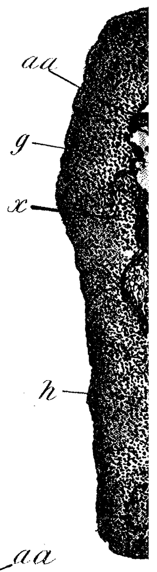


Fig.35.

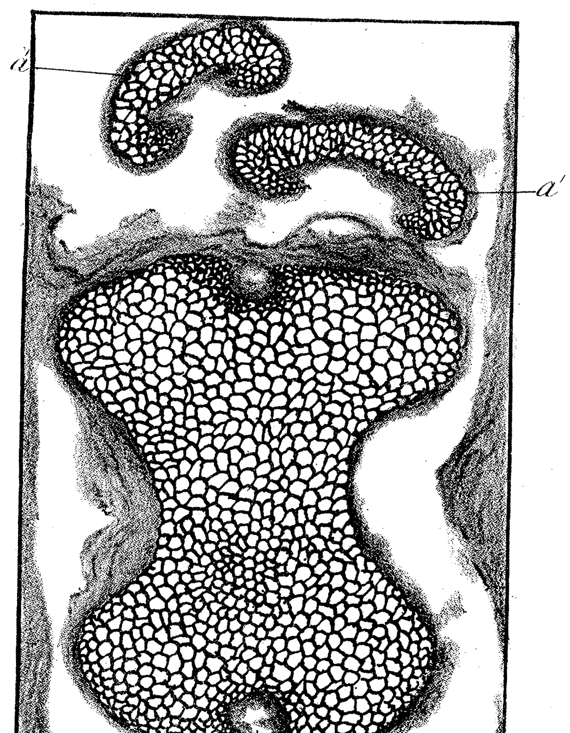


Fig.35, C.

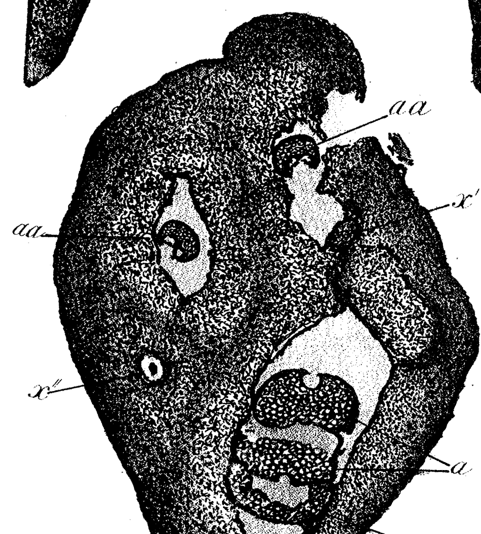


Fig. 41.

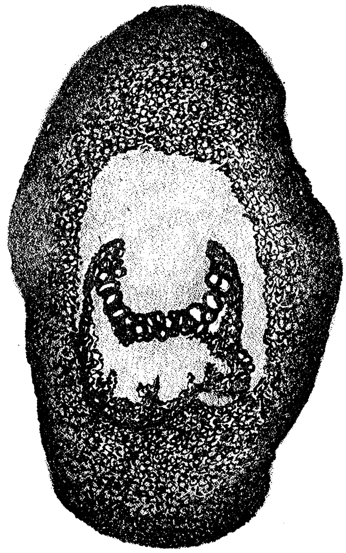


Fig. 35, E.

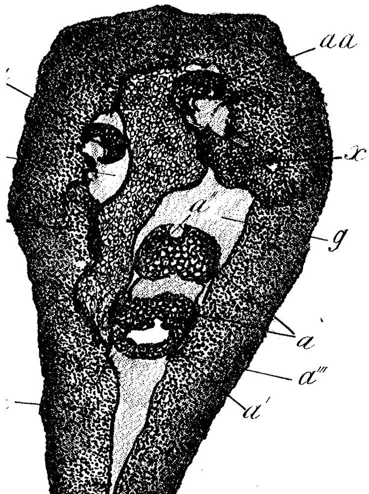
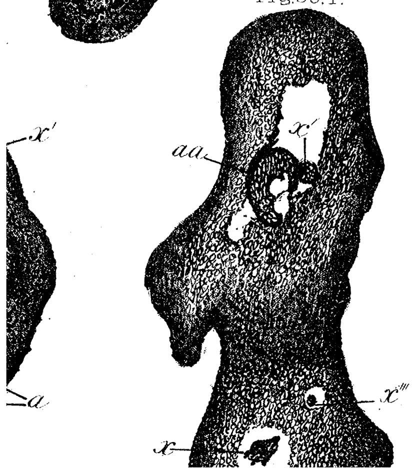
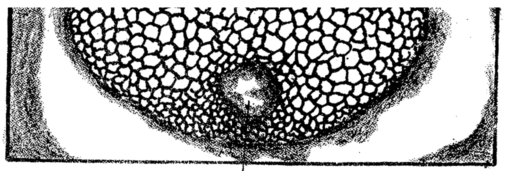
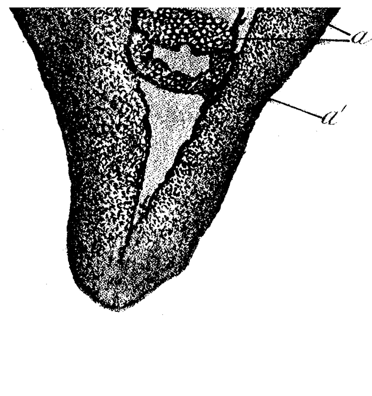


Fig. 35, F.







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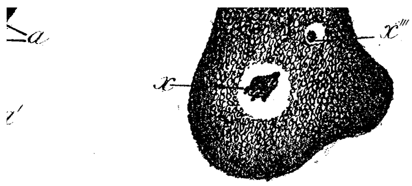

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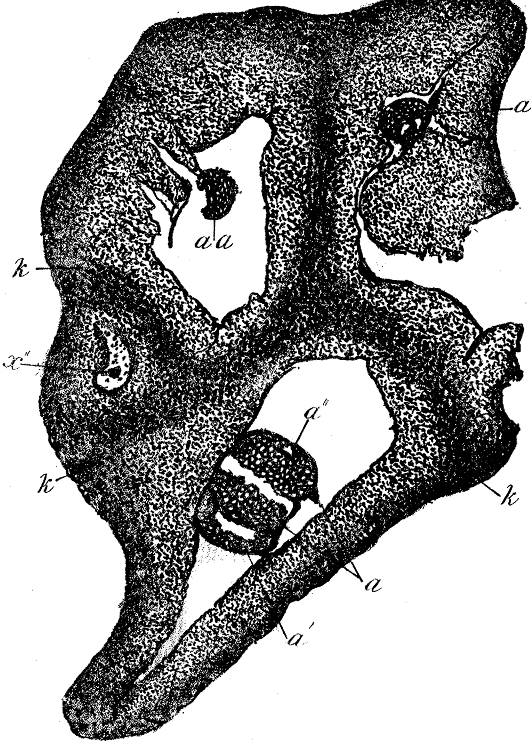
Williamson.

Fig. 35. D.



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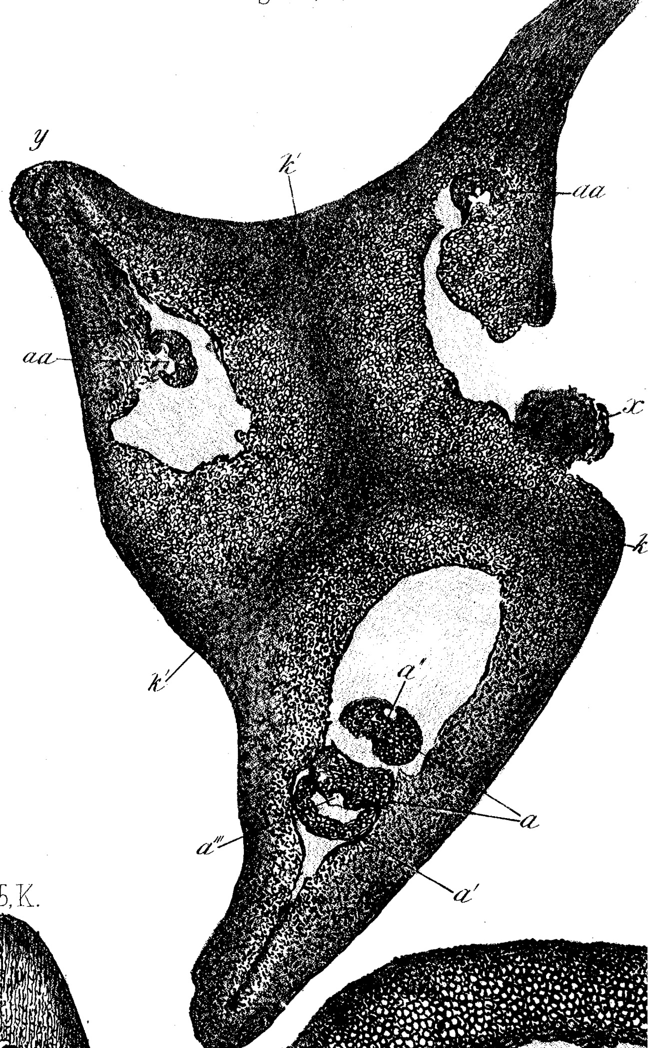


Fig. 35. I.

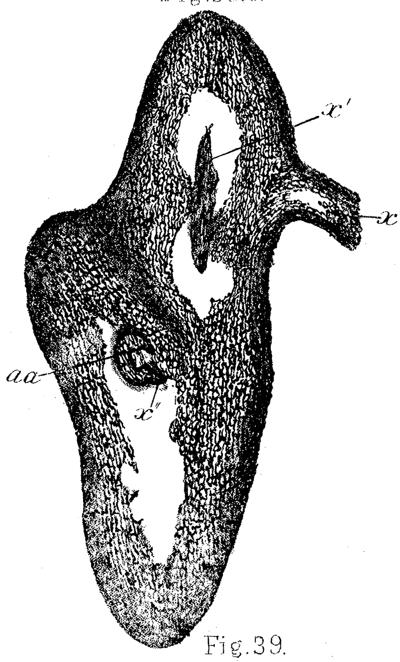
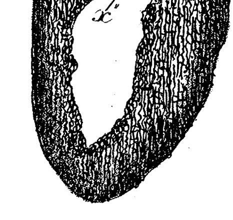


Fig. 35, K.



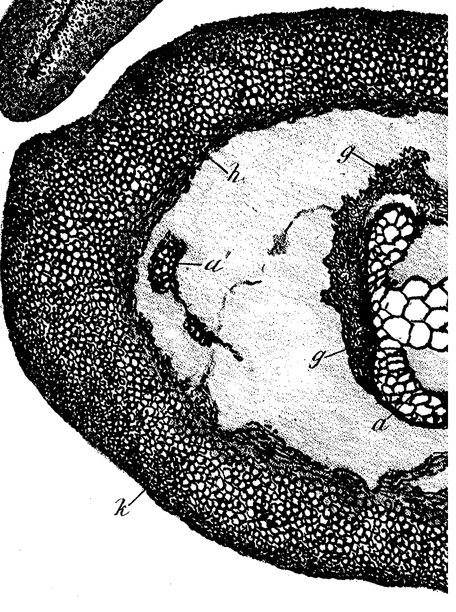


Fig. 39.

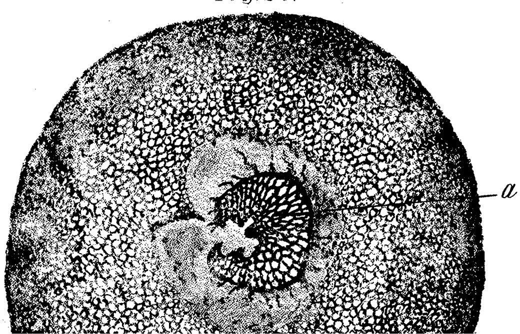


Fig. 41, A.

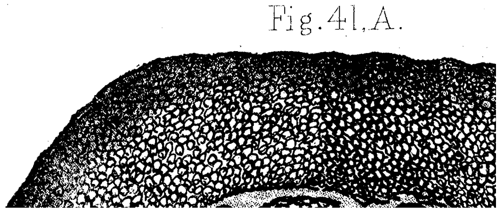
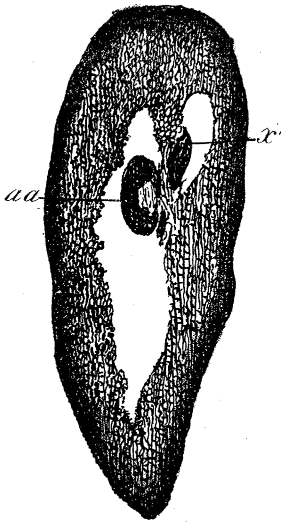


Fig. 35, H.

Fig. 35, G.



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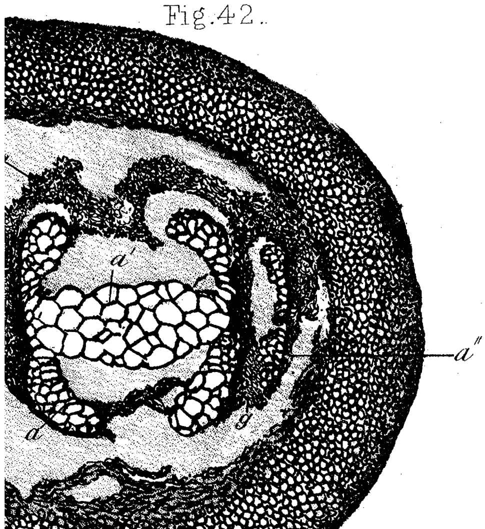

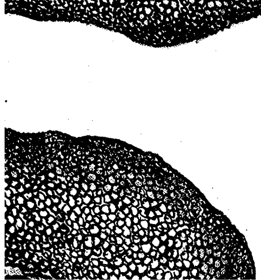

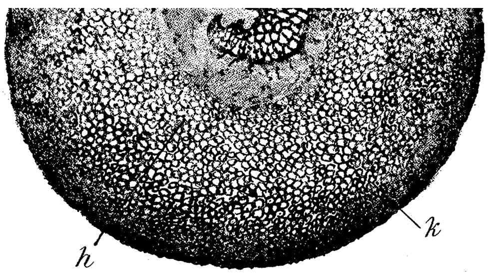

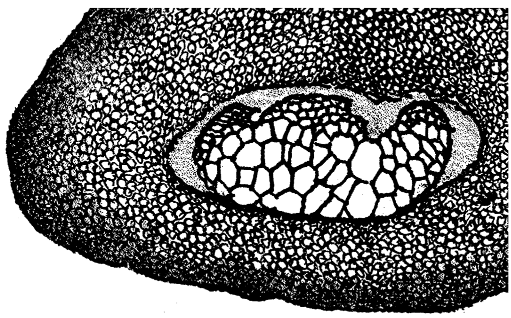

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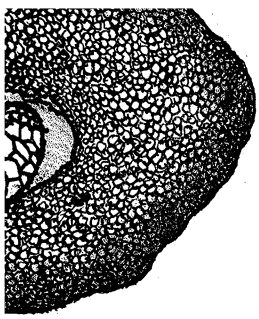

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Fig 43

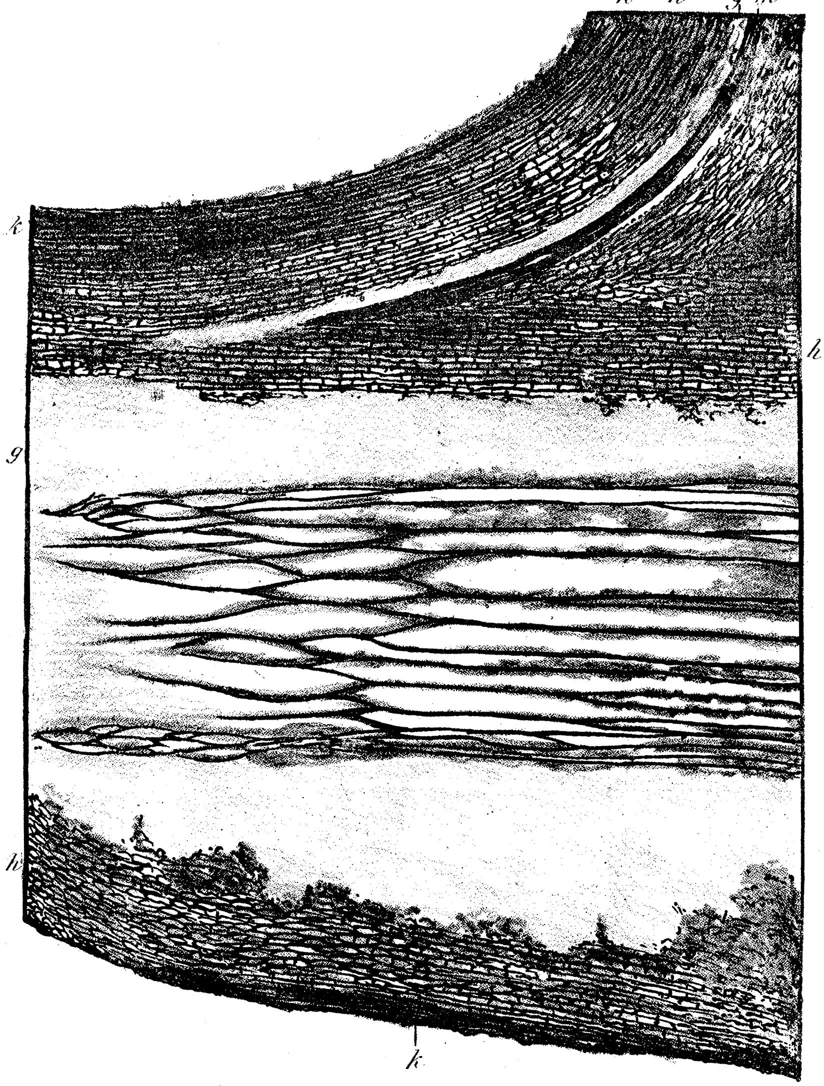


Fig.4

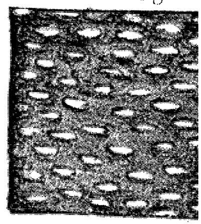


Fig.45

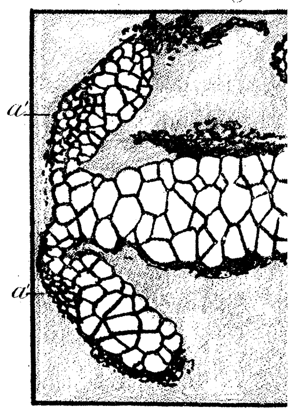


Fig 46

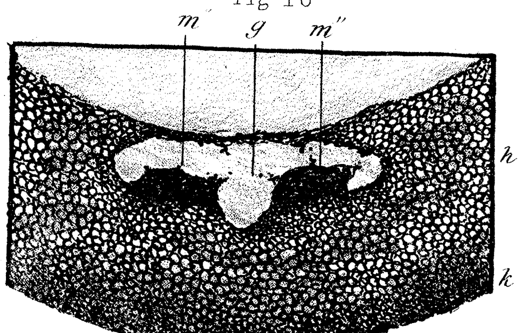
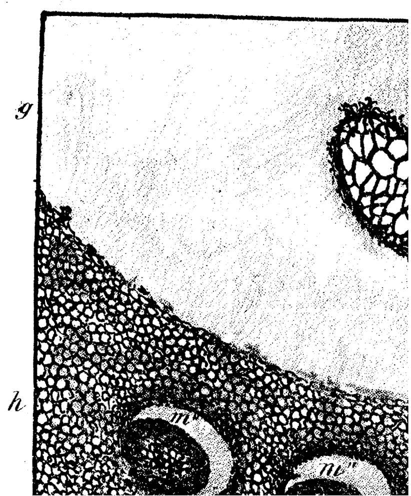


Fig 47



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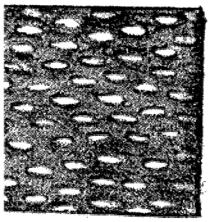

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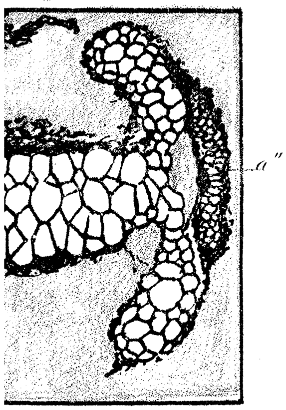
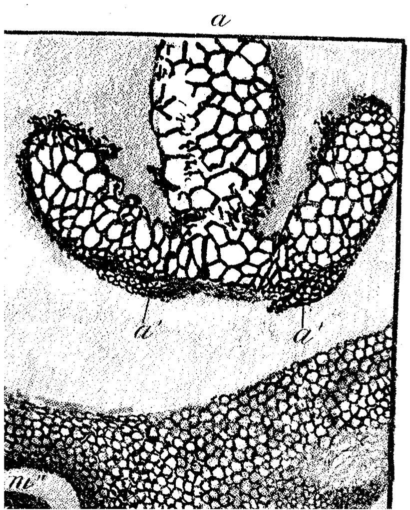
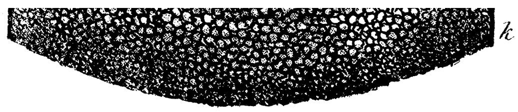
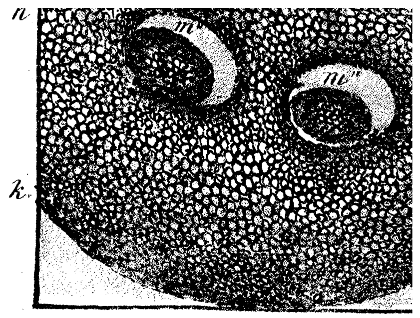


Fig 47







W. C. Williamson, Auto. Lith

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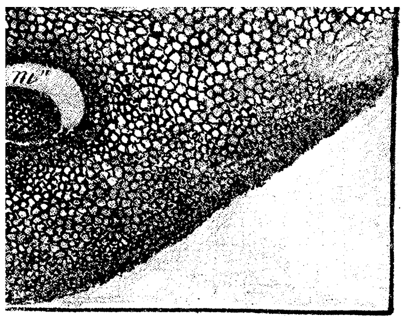
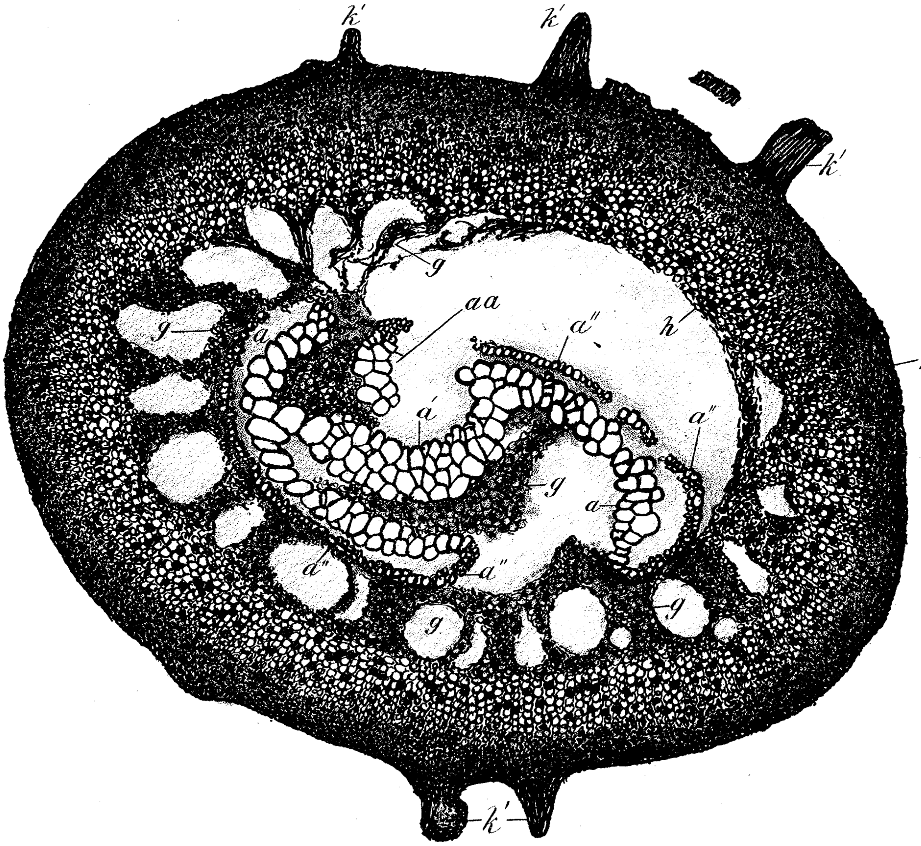
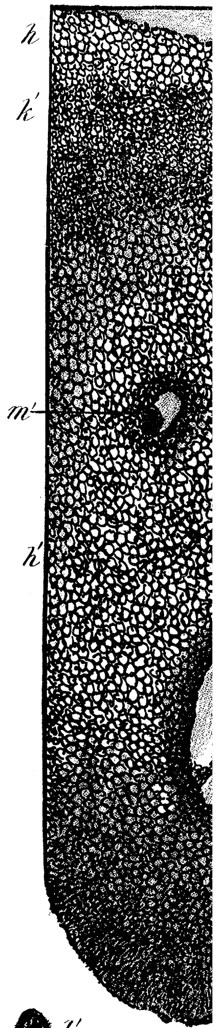


Maclure & Macdonald, Lith. London.

Fig. 49.





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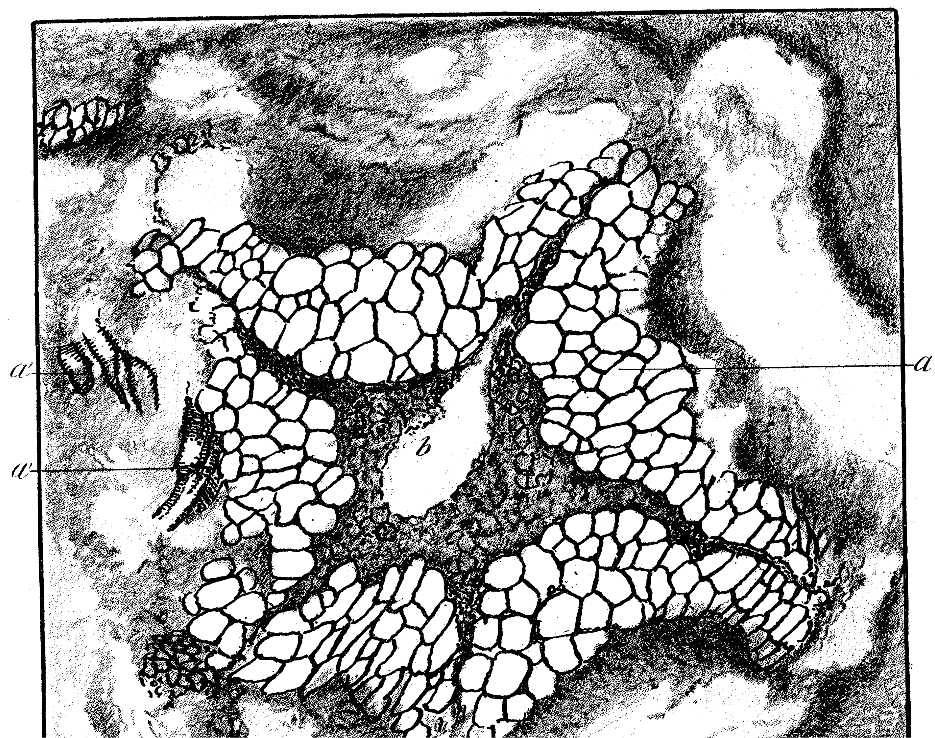

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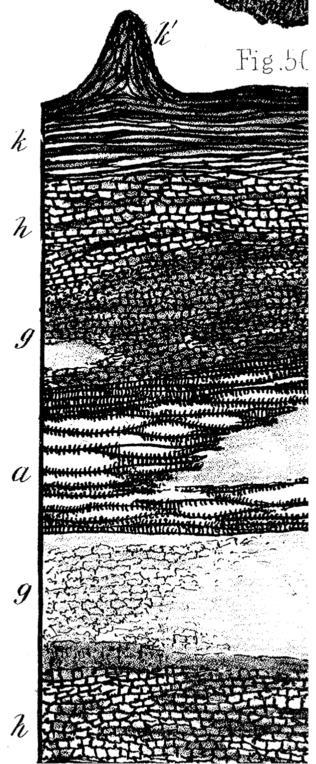

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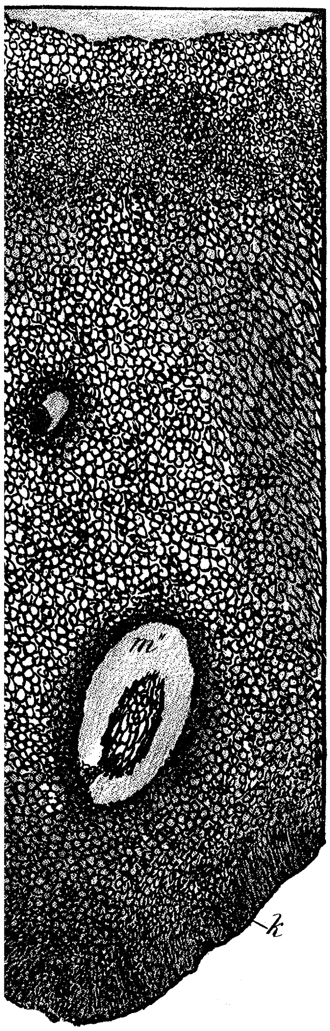

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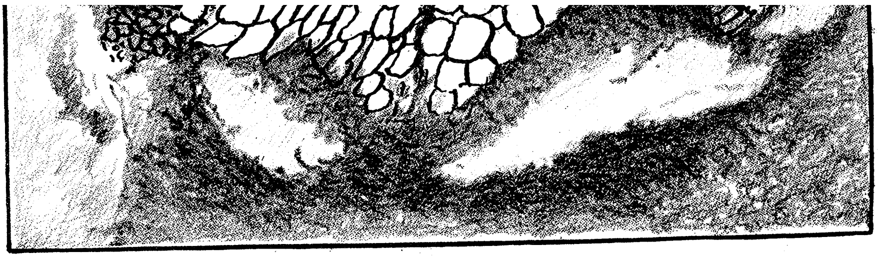
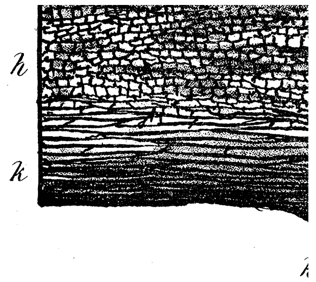
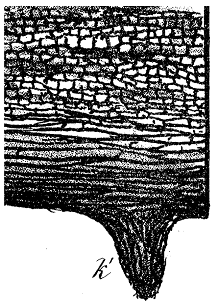




W. C. Williamson. Auto. Lith.



Maclure & Macdonald, Lith. London.

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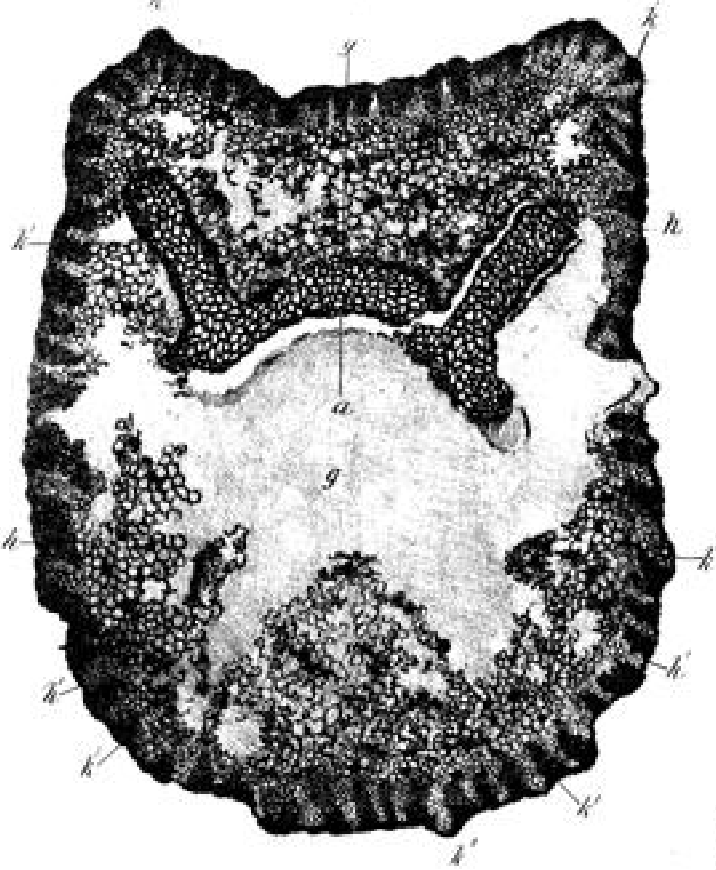

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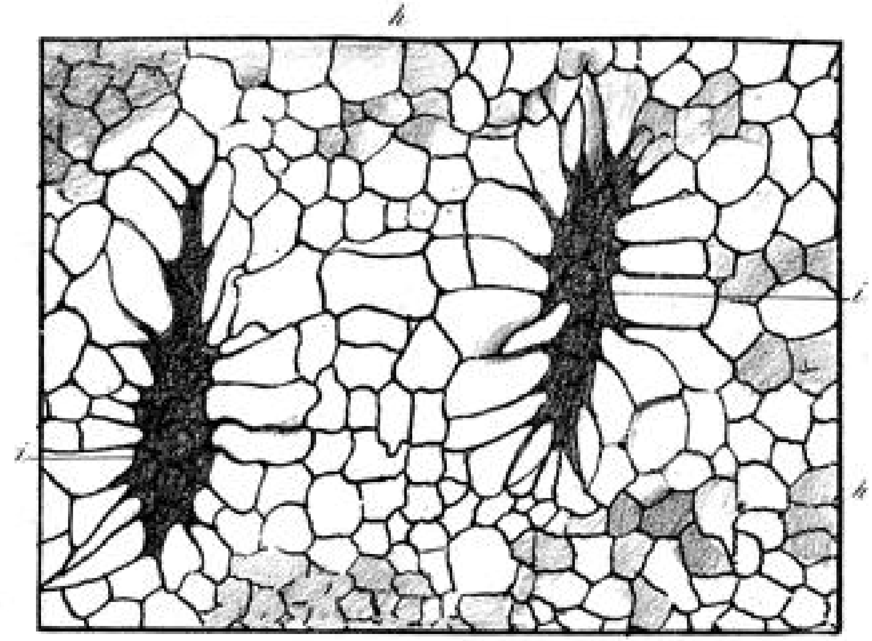
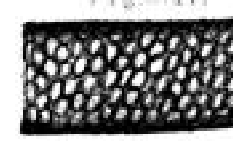


Fig. 3. C.

Fig. 3. B.

Fig. 3. A.



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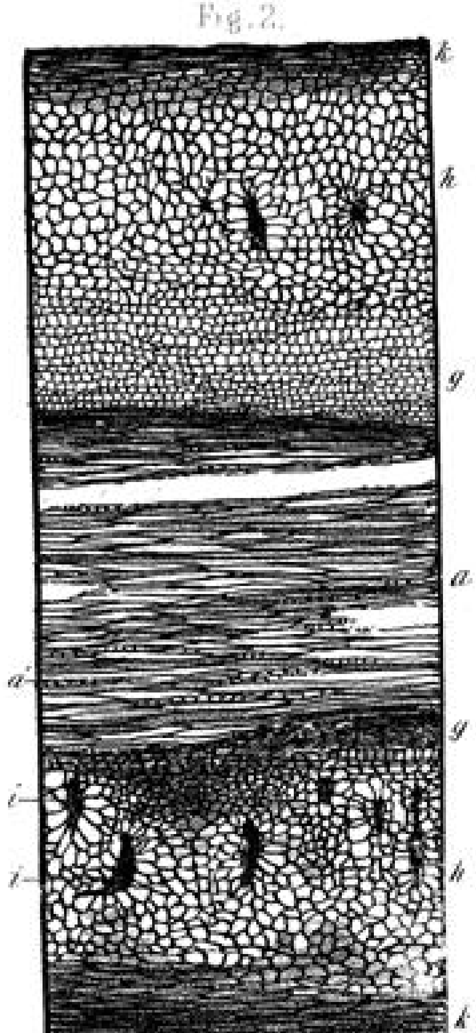

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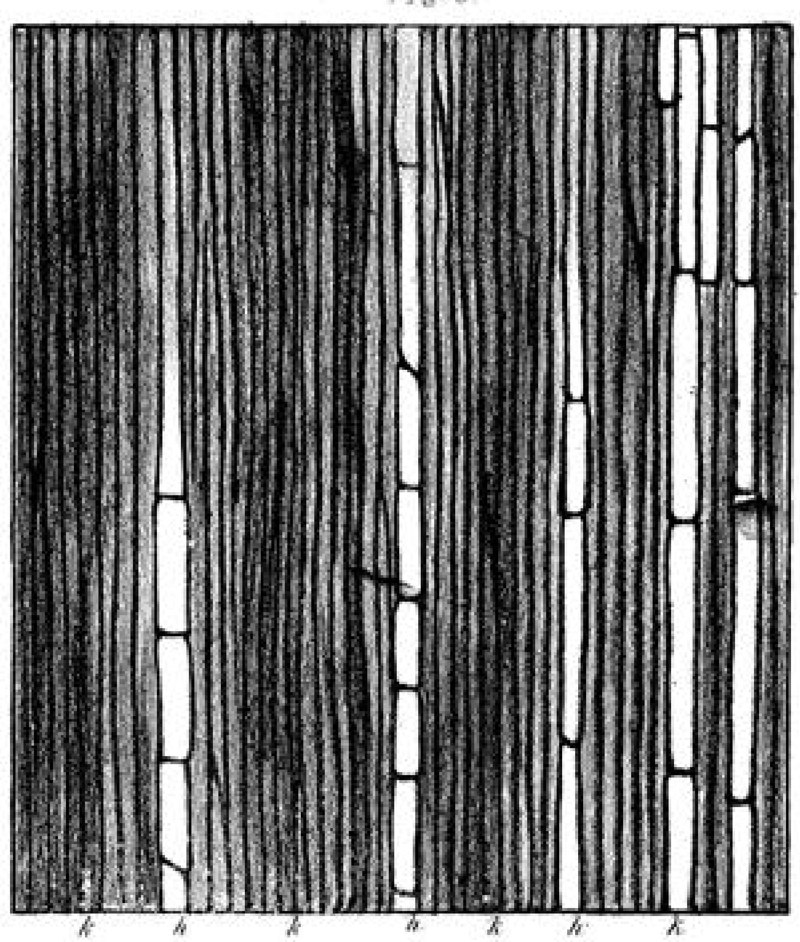

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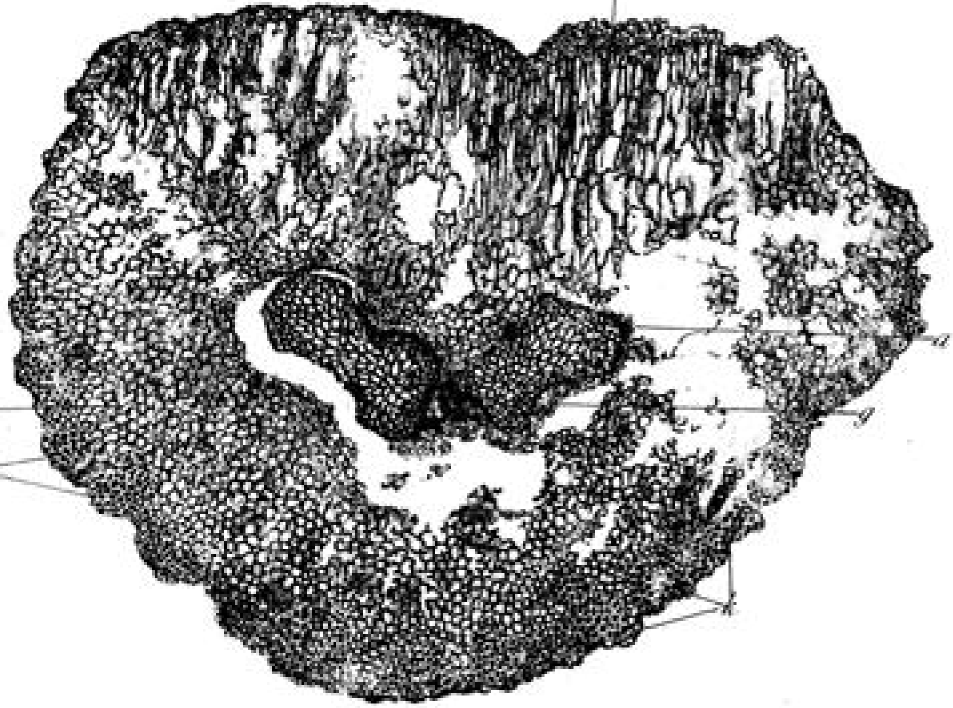

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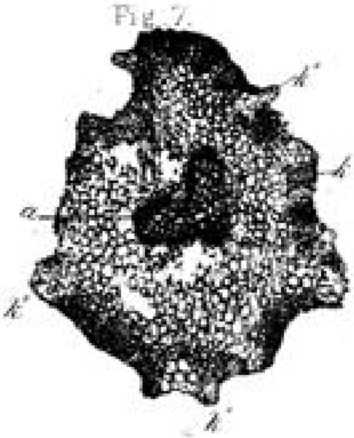

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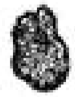

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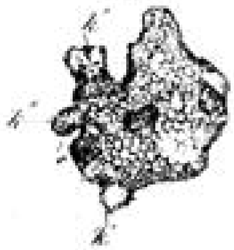

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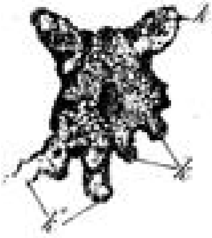

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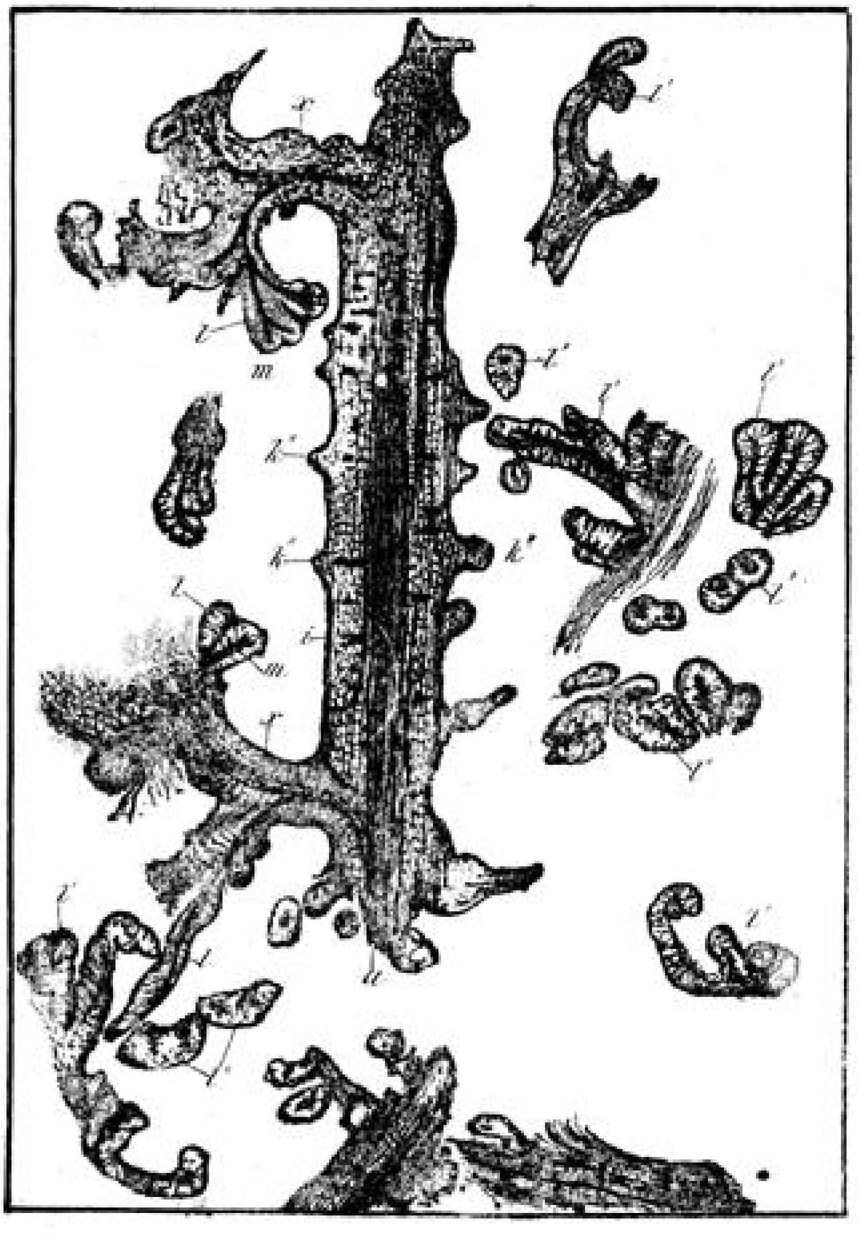

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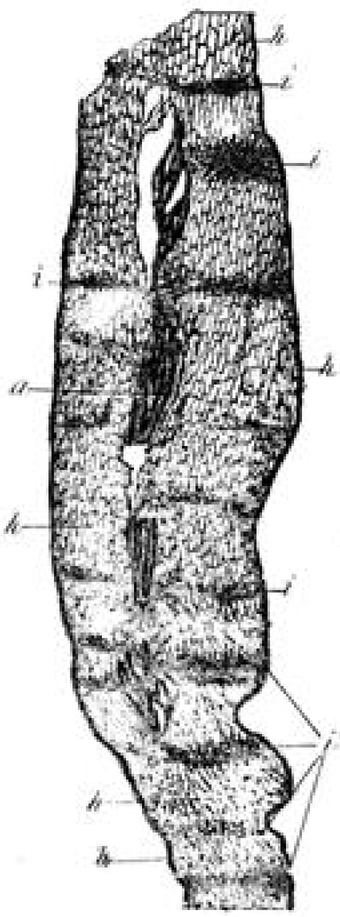

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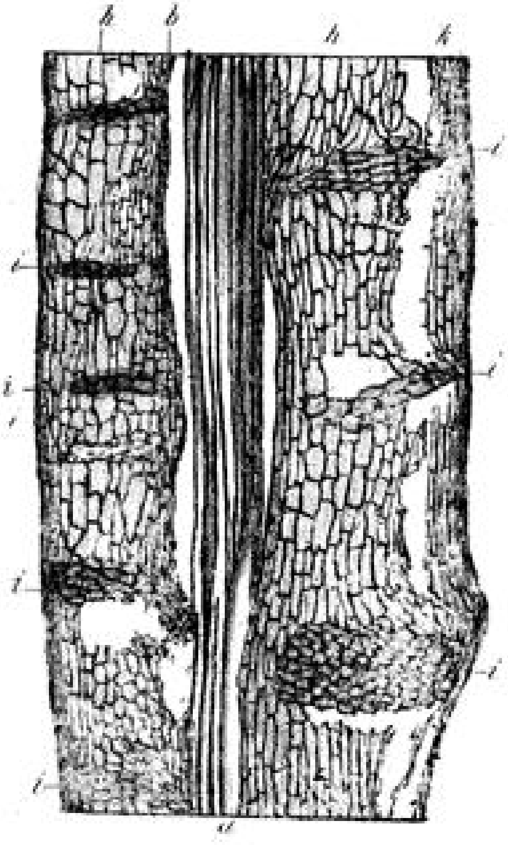
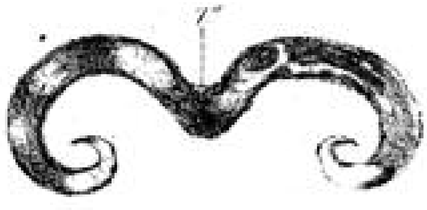


Fig. 14.

Fig. 15.



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

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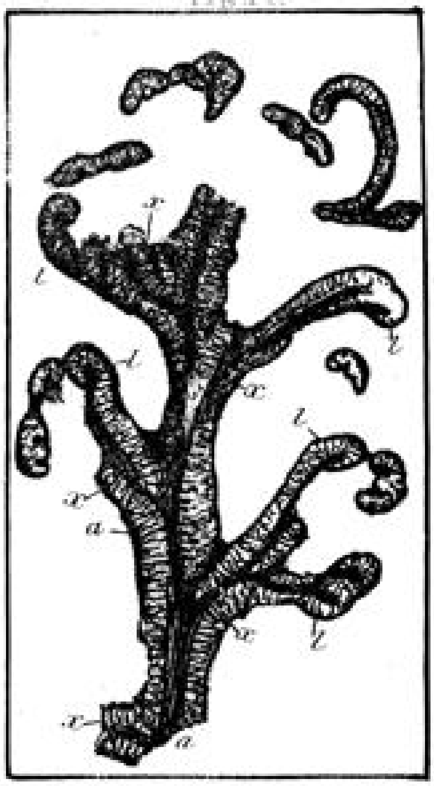

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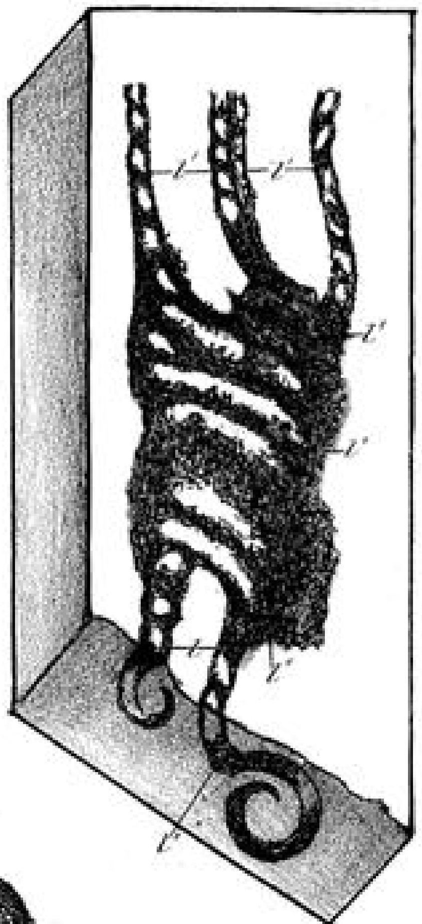

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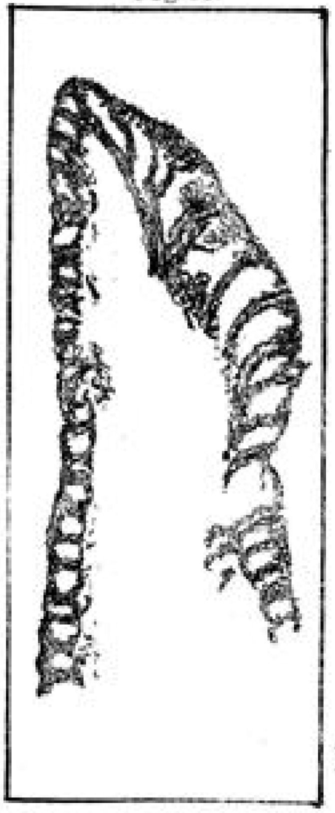

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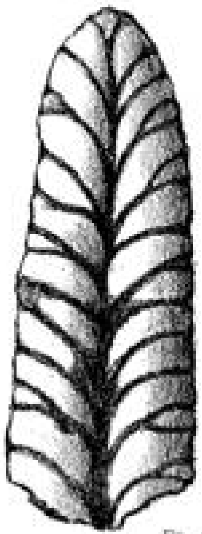

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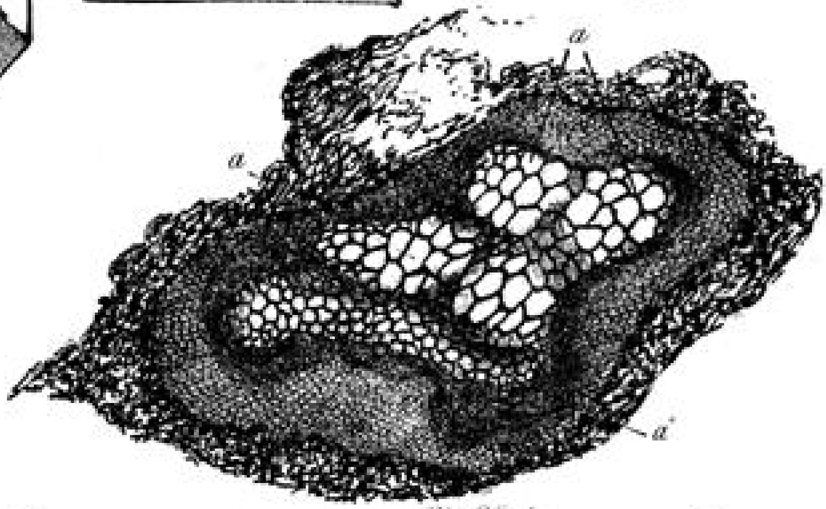

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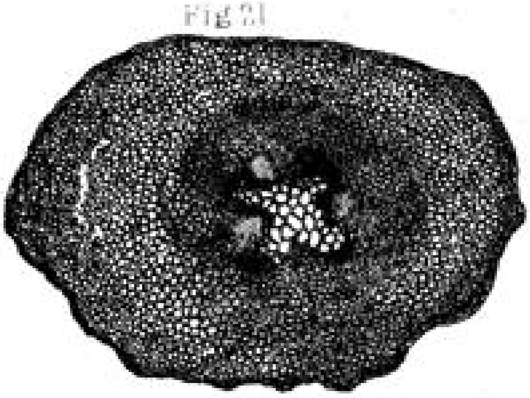

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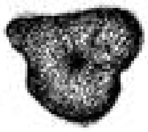

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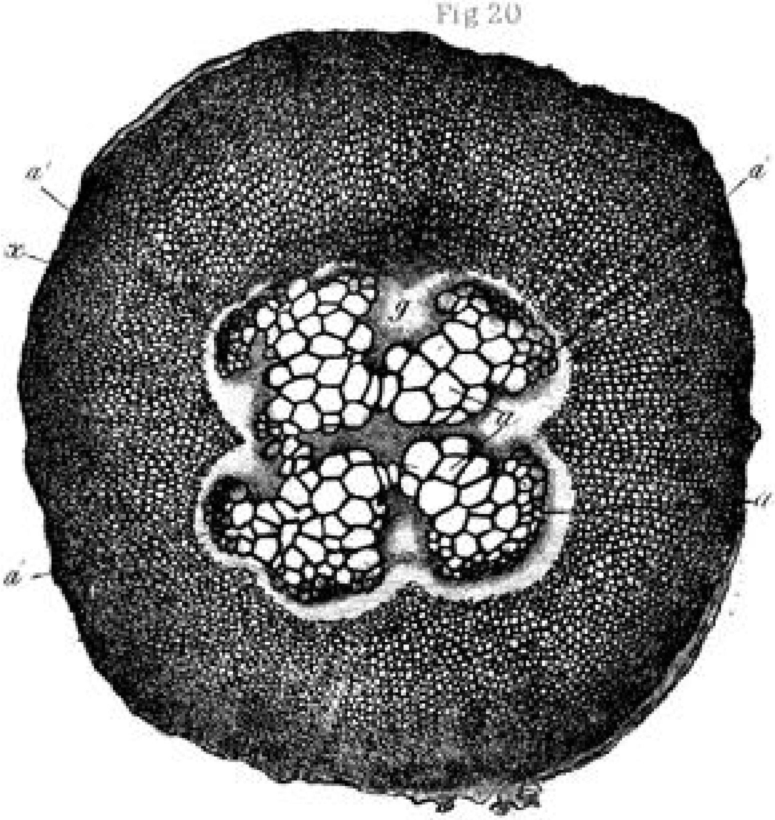
Fig. 20.



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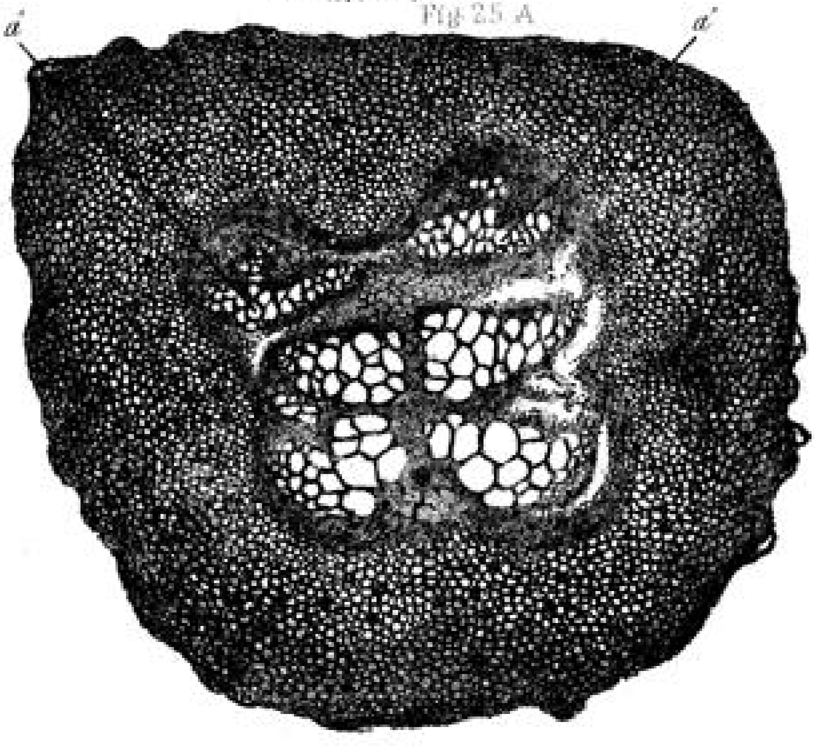

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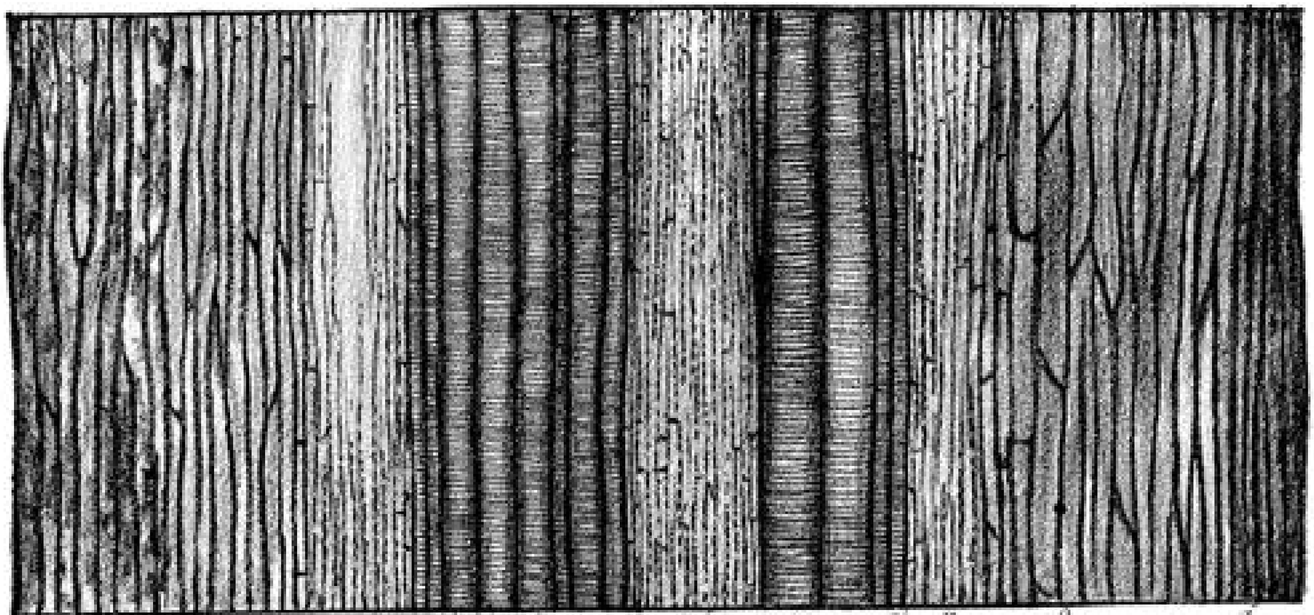

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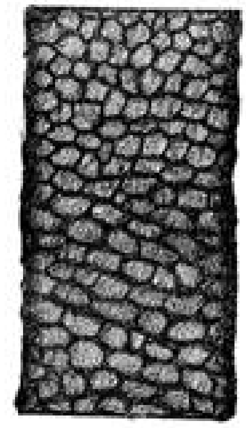

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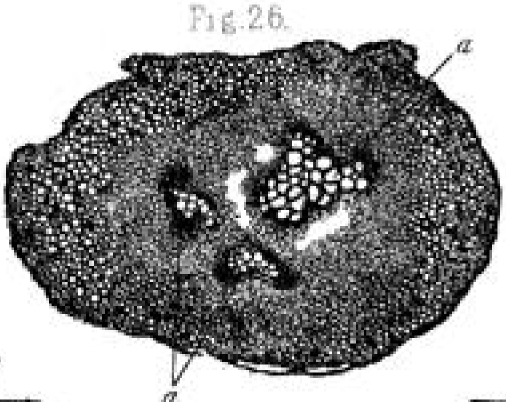

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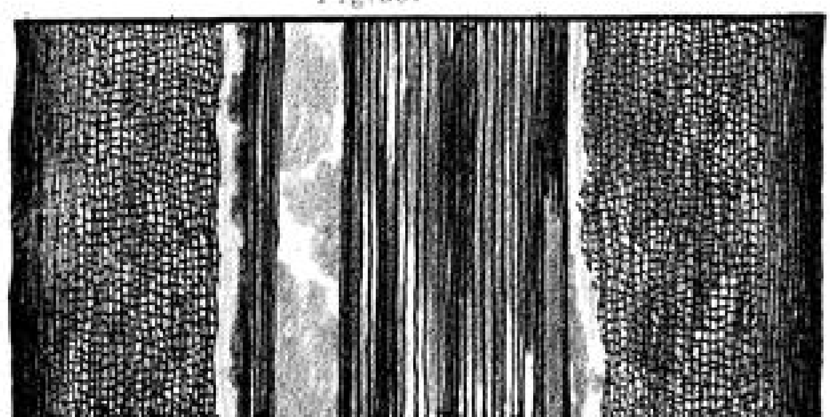

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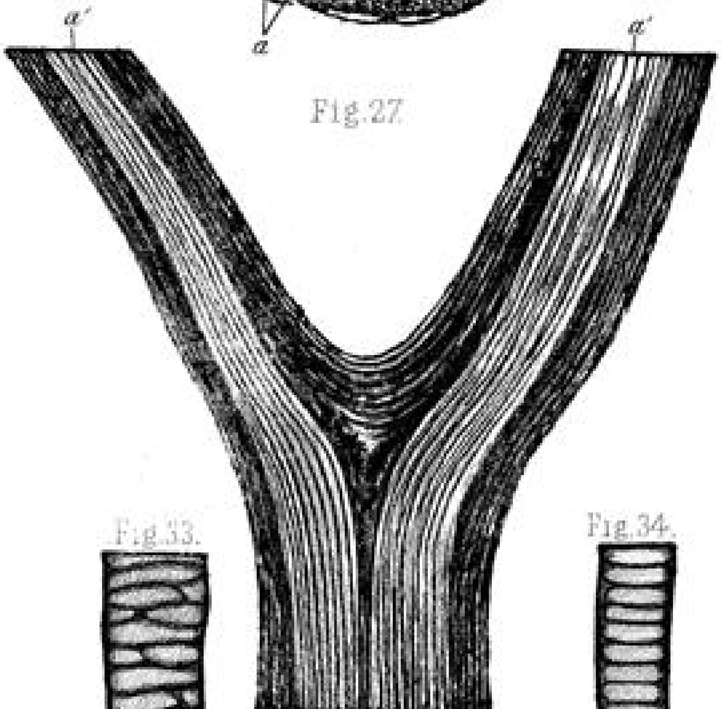

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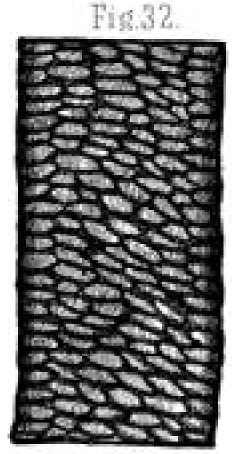

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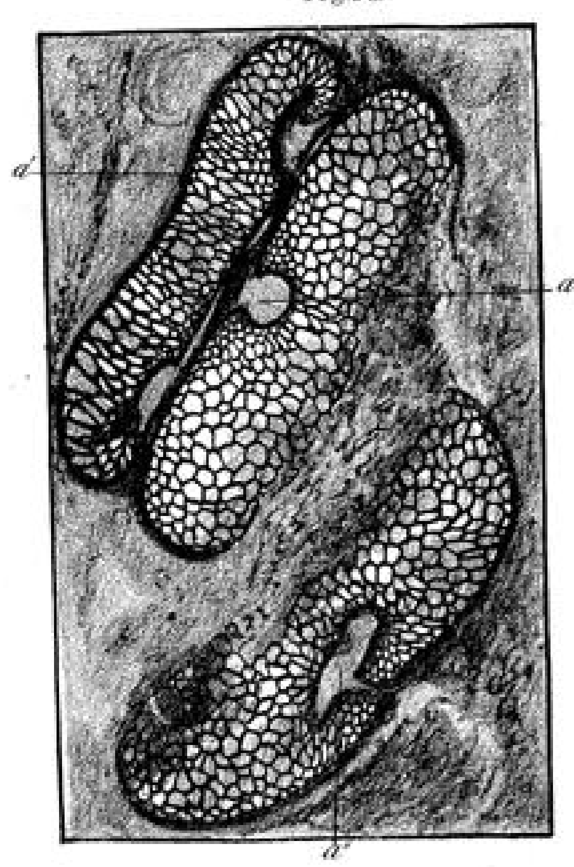

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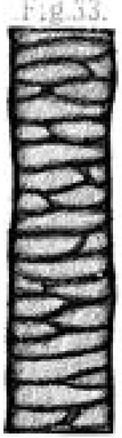

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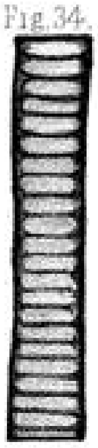

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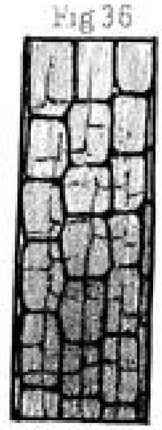


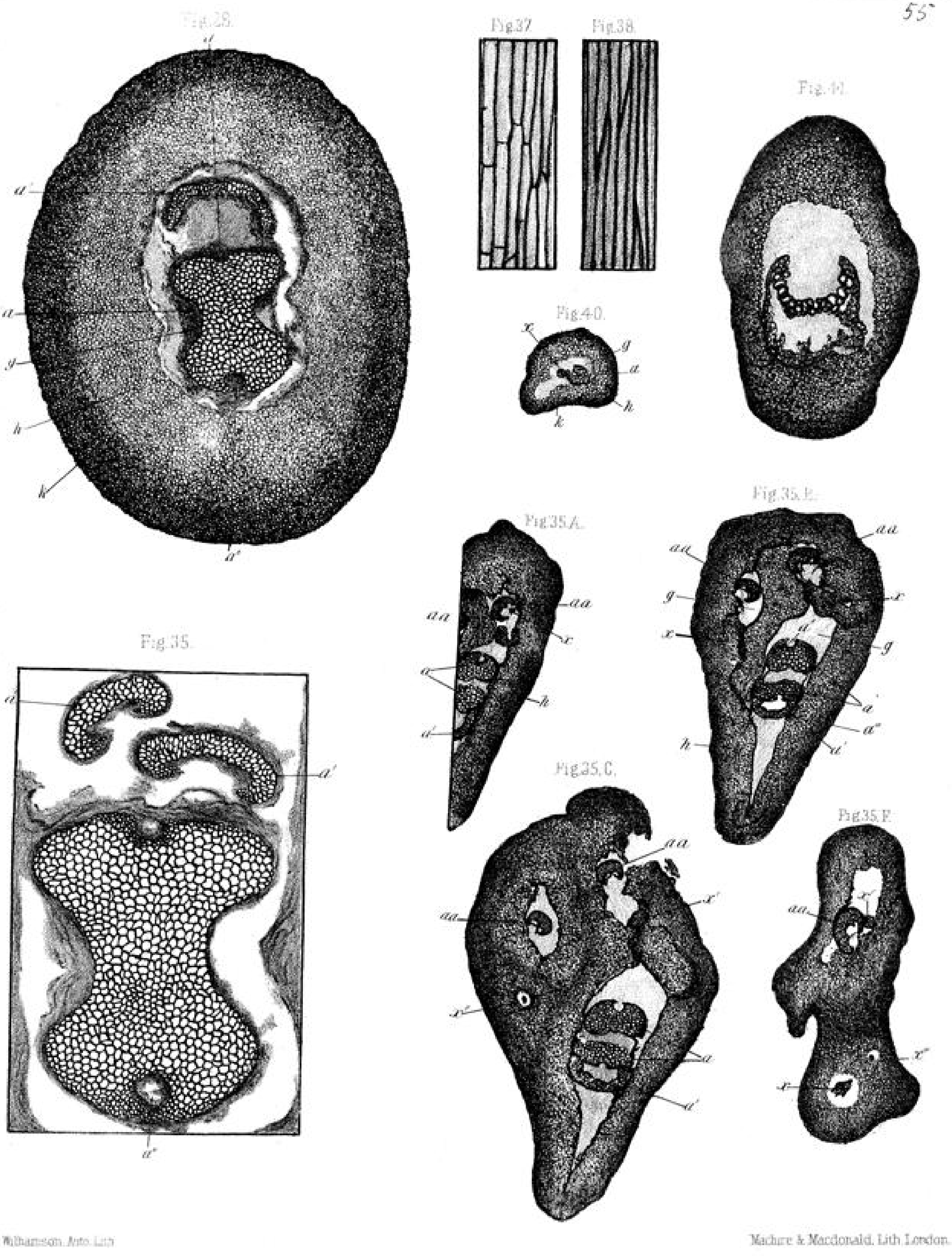
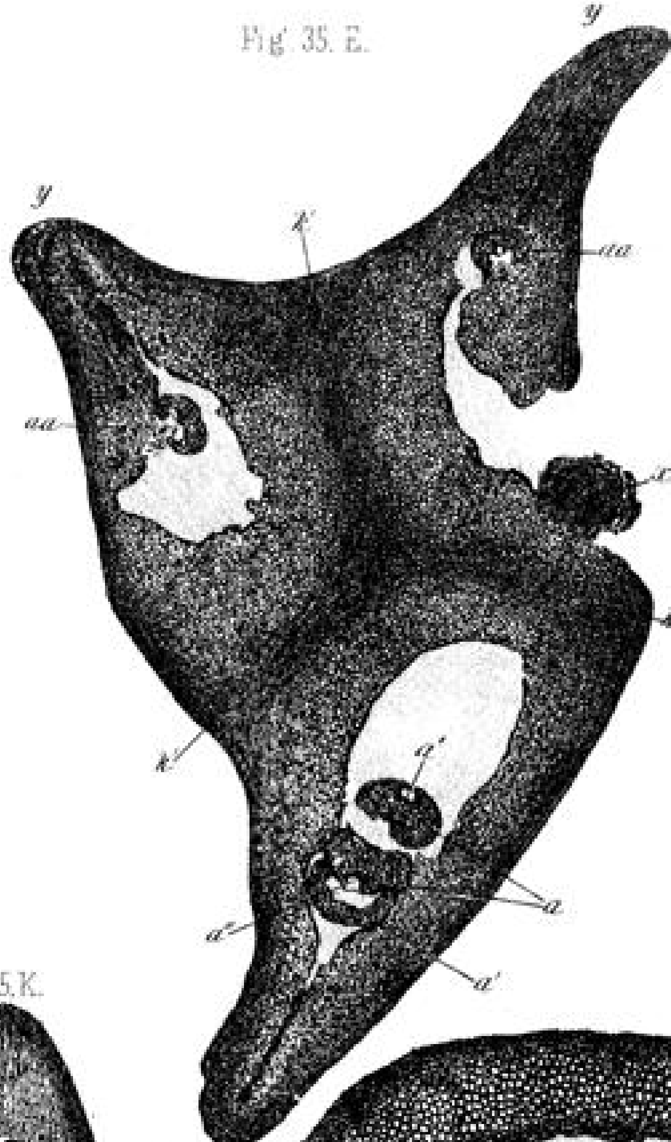


Fig. 28.
Fig. 37.
Fig. 38.
Fig. 41.
Fig. 40.
Fig. 35.
Fig. 35. A.
Fig. 35. B.
Fig. 35. C.
Fig. 35. F.

Fig. 35. D.

Fig. 35. E.



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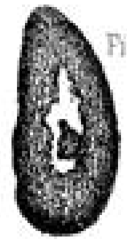

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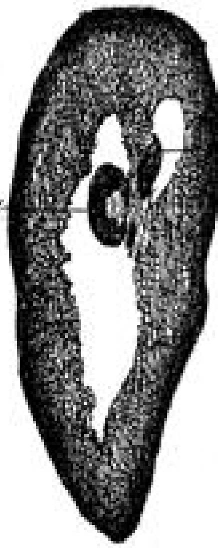

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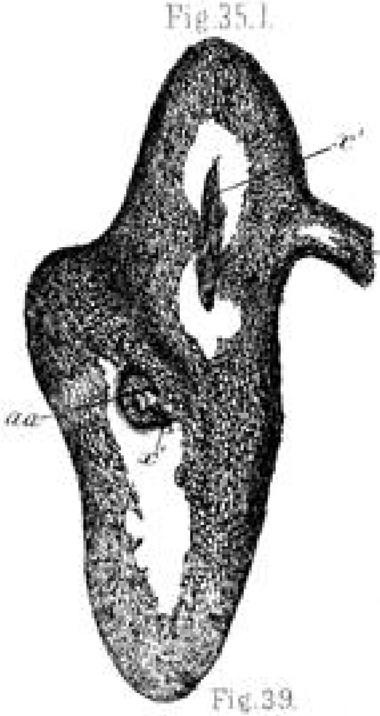

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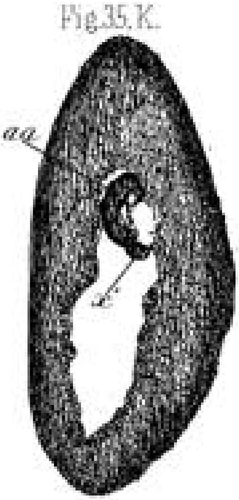

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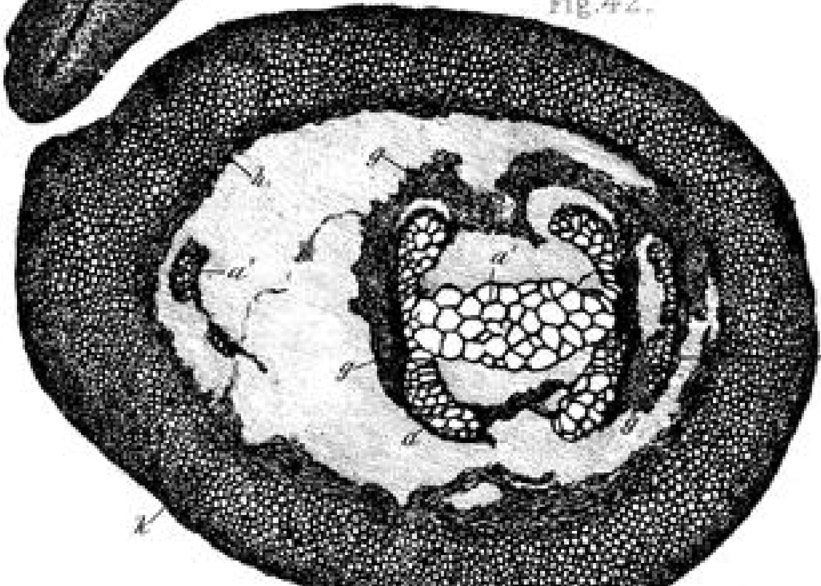

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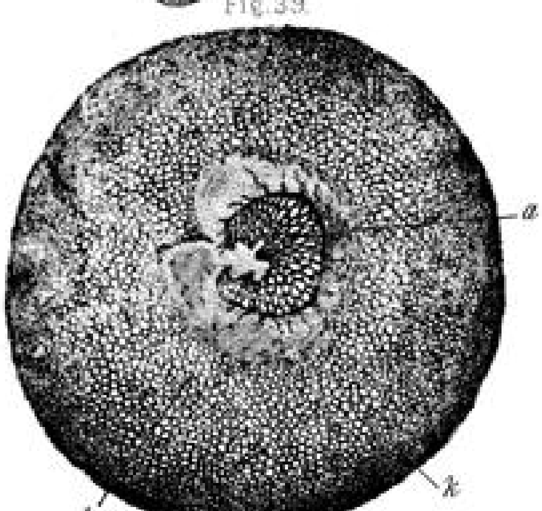

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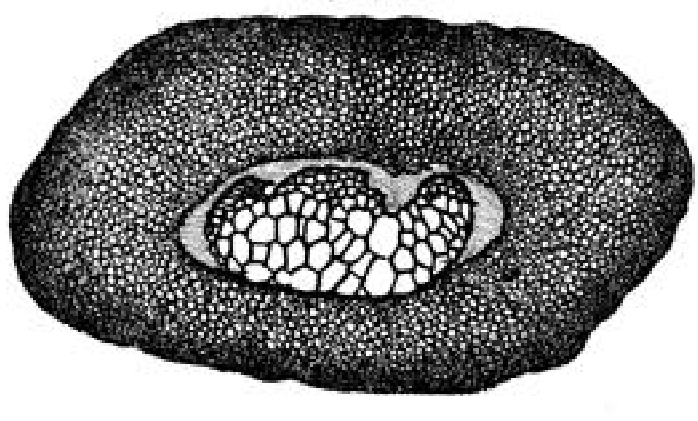

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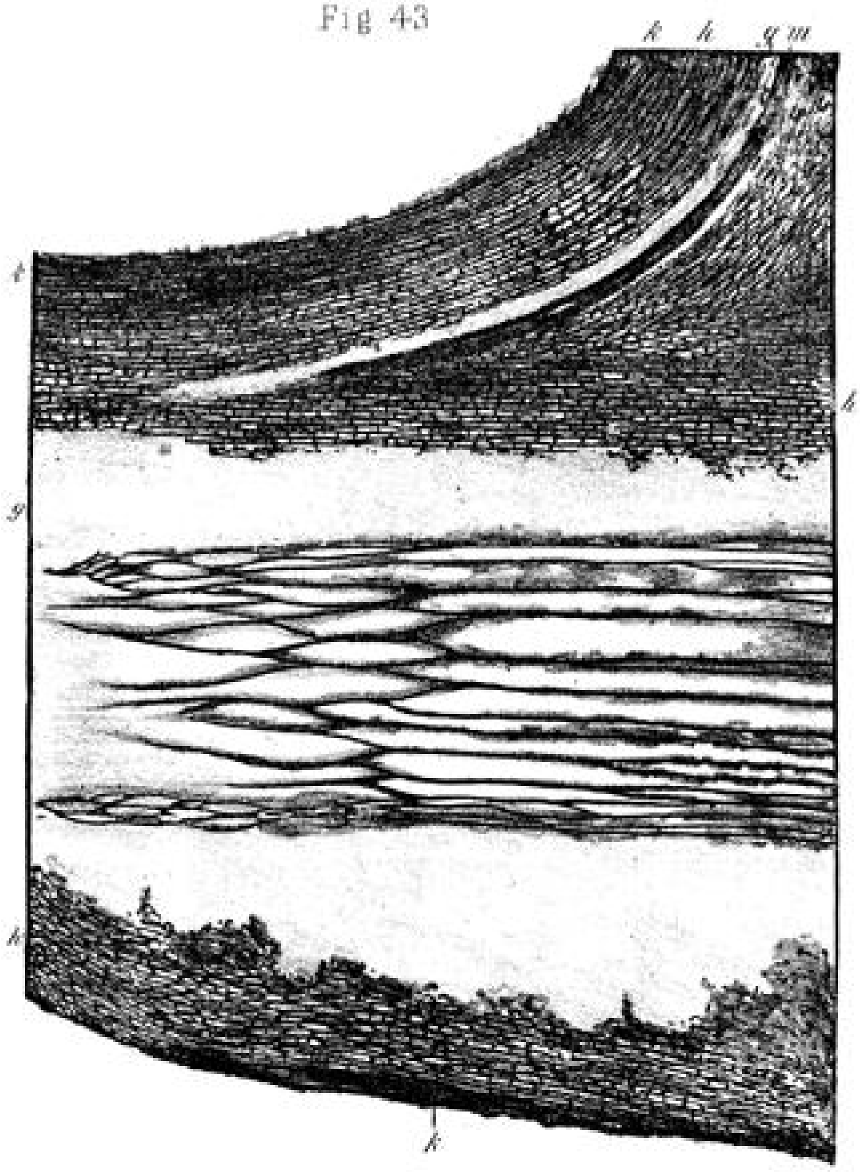

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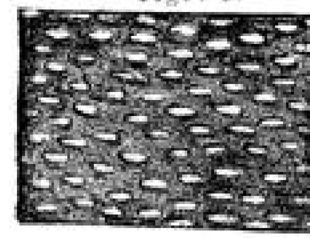

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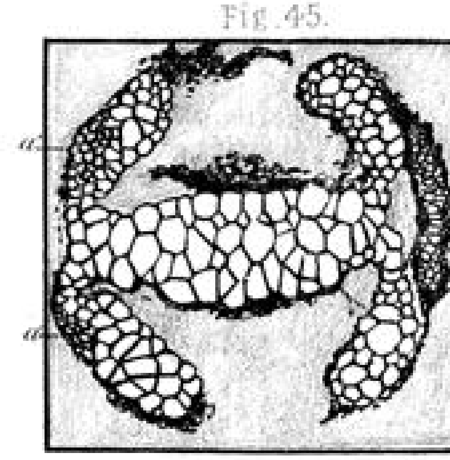

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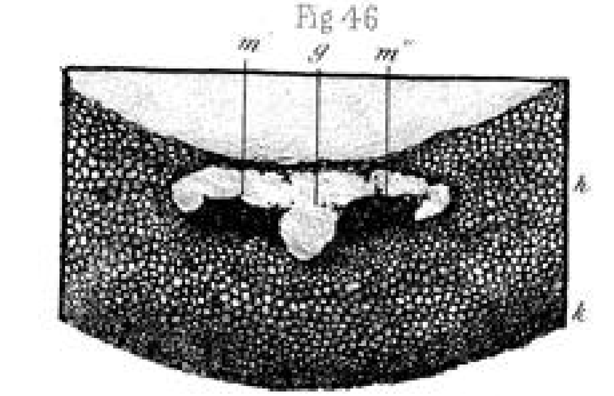
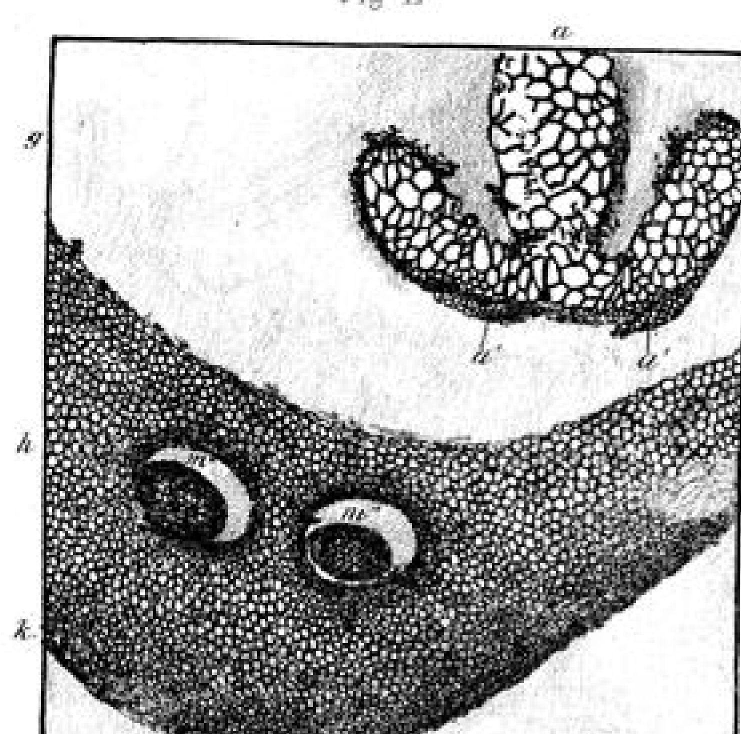


Fig 47



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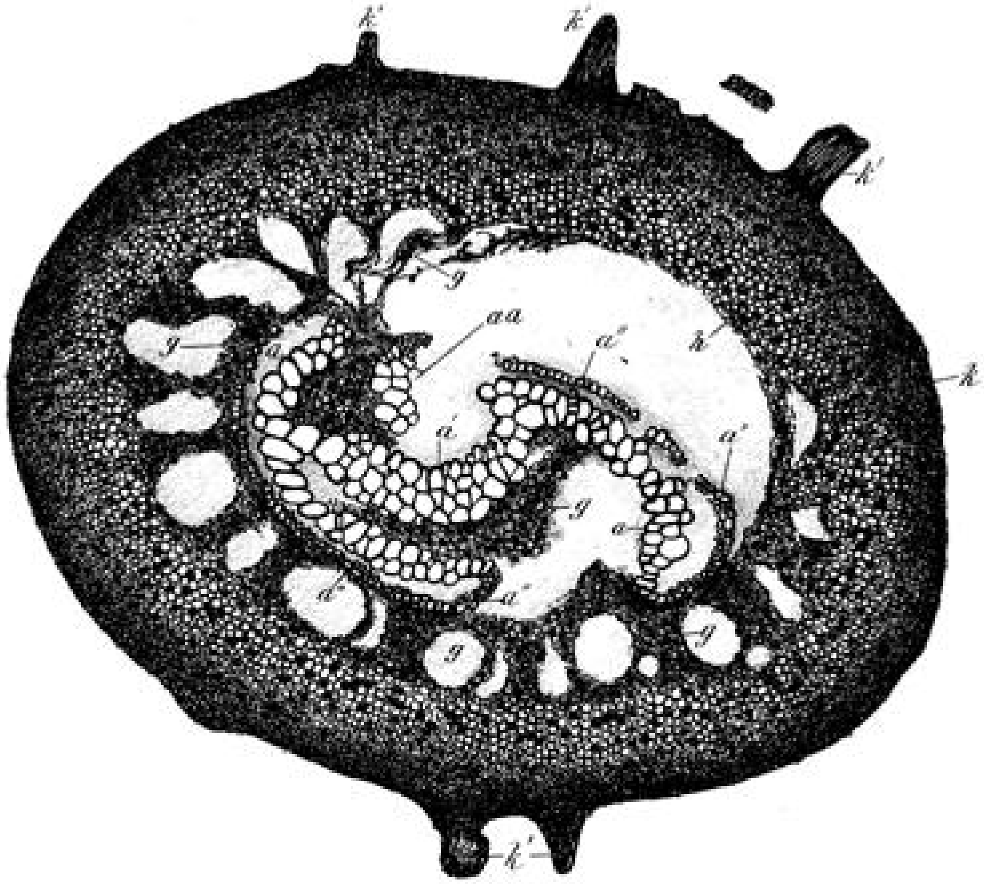

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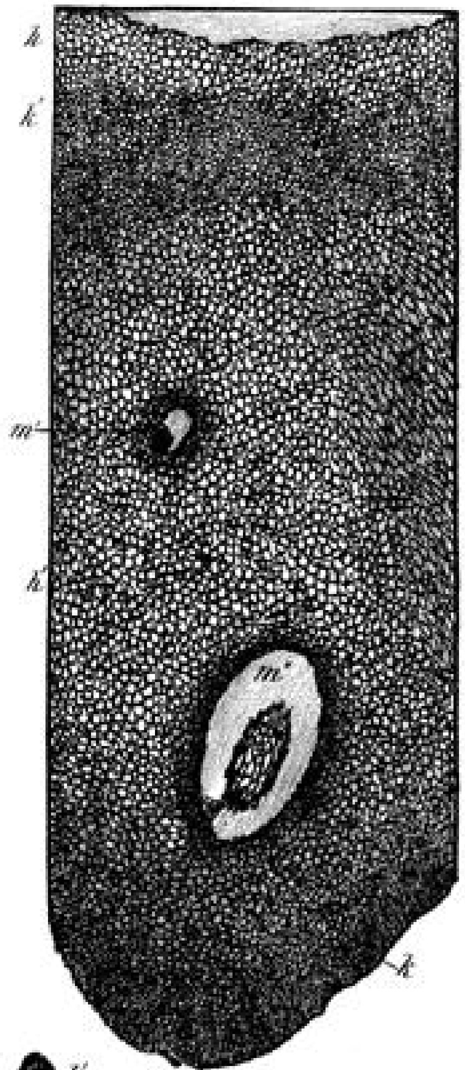

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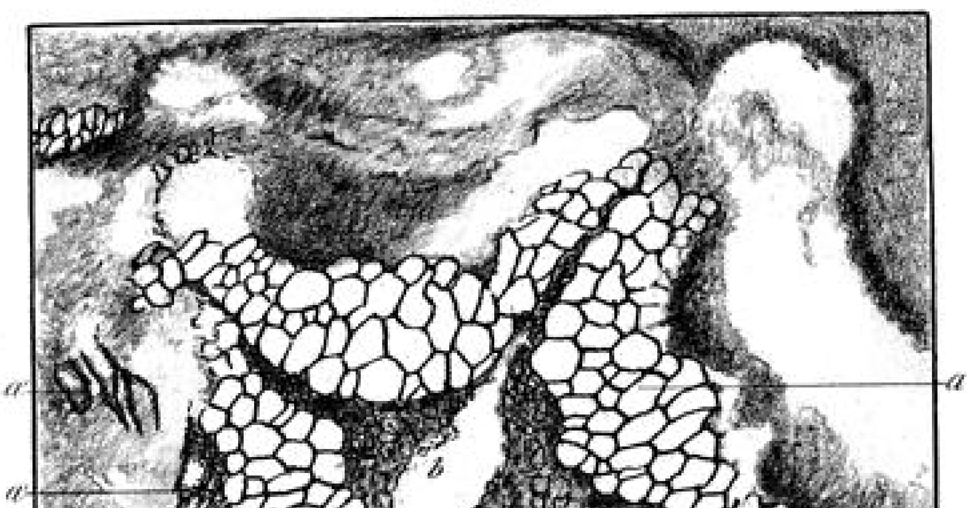

Fig. 50.