

III. *On the Organization of the Fossil Plants of the Coal-Measures.*—Part XI.  
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[PLATES 47–54.]

IN his recently-published memoir entitled “Structure Comparée de quelques tiges de la Flore Carbonifère” (‘Nouvelles Archives du Muséum, 1879’), M. RENAULT says (*loc. cit.*, p. 246):—“Si les Sigillaires ne sont que l’état plus agé de certains Lépidodendrons, comme le pense M. WILLIAMSON, plusieurs conséquences découleront de cette identité.

“1°. Toute Sigillaire étant représentée dans son très jeune âge par un axe uniquement Lépidodendroïde, nous devons naturellement rencontrer de jeunes Lépidodendrons construits sur autant de types que nous aurons d’axes internes différent de Sigillaires. En effet, en admettant le *Sigillaria vascularis* de M. BINNEY comme type de Sigillaire, nous aurions trois structures différentes pour les axes des jeunes Lépidodendrons correspondants.

“*a.* Cylindre ligneux, représenté par un cercle continu de vaisseaux scalariformes, renfermant une moelle centrale parcourue par de nombreux faisceaux vasculaires également scalariformes. (État jeune du *Sigil. vascularis*.)

“*b.* Cylindre ligneux, formé par un cercle continu de vaisseaux scalariformes, entourant une moelle n’offrant aucune trace de vaisseaux. (État jeune des *Diploxyton*.) D’après M. WILLIAMSON, le *L. Harcourtii* serait le représentant de ce type.

“*c.* Cylindre ligneux, formé par une couronne discontinue de faisceaux vasculaires, scalariformes, circonscrivant une moelle dépourvue de faisceaux vasculaires. (État jeune des Sigillaires des genres *Favularia*, *Leioderma*, et probablement *Rhytidolepis*.) Jusqu’à présent, le second de ces types Lépidodendroïdes seul aurait été reconstruit.”

Having thus defined what he regards as the three distinct types of *Sigillaria* for which corresponding Lepidodendroid branches ought to be found, M. RENAULT proceeds to show what Lepidodendroid types exist according to his views. These are again three in number, all of which he considers to be modifications of the type of *L. Harcourtii*:—

“1°. *Lepidodendron Rhodumnense*.

“2°.            ,,           *Harcourtii*.

“3°.            ,,           *Jutieri*.

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“ Dans le premier type, les rameaux et la tige sont pourvus d'un axe ligneux, formé de larges vaisseaux rayés sans aucune trace de tissu cellulaire interposé, les plus gros vaisseaux sont au centre, les plus petits à l'extérieur.

“ Les cordons foliaires partent toujours de faisceaux vasculaires placés à la périphérie de l'axe ligneux. En dehors on rencontre une écorce formée d'une couche parenchymateuse, puis d'une zone de cellules prosenchyme, qui, dans les vieilles tiges, peut prendre un accroissement considérable, enfin d'une couche cellulaire due en grand partie aux coussinets des cicatrices foliaires.

“ Dans le second type, les rameaux et la tige renferment un cylindre vasculaire continu entourant une moelle; du côté de cette dernière, les vaisseaux rayés qui le constituent sont larges, et deviennent plus petits vers le périphérie.

“ Les faisceaux vasculaires, qui envoient des cordons aux feuilles sont également placés à la périphérie du cylindre ligneux; ce cylindre est entouré d'un tissu parenchymateux assez solide, suivi d'un parenchyme corticale un peu plus lâche, enfin d'un zone de cellules étroites plus allongées, disposées en séries régulières.”

M. RENAULT'S third type, not yet described in detail, will be noticed later. I cannot accept these definitions as in accordance with known facts. I am prepared to demonstrate that we have found the Lepidodendroid representatives of his Sigillarian types *a* and *b*, and that, unless I much mistake, his *Lepidodendron Jutieri* represents *c*. I think that the young growths of the Arran Lepidodendron recorded in my last memoir (Memoir X., Plate 1, figs. 1, 2) correspond with M. RENAULT'S *Lepidodendron Rhodumnense*; in a more advanced stage it represents his *L. Harcourtii*; and in its matured condition it becomes a Diploxyloid tree.

In addition, M. RENAULT has omitted from his list of Lepidodendroid forms that which BINNEY has named *L. vasculare*, and which, as the following pages will demonstrate, is the Lepidodendroid representative of M. RENAULT'S Sigillarian group *a*.

I may further notice another observation, in which M. RENAULT says: “ Si certains Lepidodendrons se transforment en Sigillaires par le fait seul de l'âge, c'est à dire par l'apparition plus ou moins tardive d'un bois exogène en dehors de l'axe lépidodendroïde, on doit admettre que l'addition de couches ligneuses ne modifie pas la structure primitive, propre de cet axe, que les faisceaux vasculaires qui ont émis des cordons foliaires ont dû conserver leur disposition particulière et leur structure générale primitive. Les cordons foliaires eux-mêmes déjà formés, et parcourant les feuilles, n'ont pas dû changer de constitution pendant l'accroissement exogène de la tige ” (*loc. cit.*, p. 247).

I have already shown in my description of the Arran plant, as well as in some measure in that of the Burntisland one (Memoir III., Plate 41, figs. 1, 2, and 3; and Plate 42, fig. 9), that such changes do occur; and I shall now have to advance evidence demonstrating not only that the vasculo-medullary elements, both cellular and vascular, do increase in size and number *after* they have been surrounded by the exogenous zone, but that, in like manner, the foliar vascular bundles are lengthened as the exogenous

zone increases in thickness, enabling them still to maintain their connexion with the bases of the leaves that remain attached to the growing stem.

M. RENAULT represents the first of his Sigillarian types by the *Sigillaria vascularis* of Mr. BINNEY, but which is really a state of the common *Lepidodendron selaginoides*. When M. RENAULT denies that a Lepidodendroid state of this supposed Sigillarian plant exists, he overlooks the fact that Mr. BINNEY long ago described and figured a partially decorticated specimen in this condition under the name of *Lepidodendron vasculare*.\* In that memoir Mr. BINNEY correctly points out that the plant only differs from his *Sigillaria vascularis* in the absence from the former of an exogenous zone.

Fig. 1 represents a transverse section of a branch of this plant, enlarged about 13 diameters, its actual diameter in the longer direction being nearly  $\cdot 8$ . In its centre is the vasculo-medullary axis, *a*, the periphery of which consists of a continuous zone, sharply defined externally, composed of numerous barred vessels. More internally, cellular elements are interposed between these clusters of vessels, until, in the central portion of the axis, the vessels are either isolated or combined in very small groups. The medullary cells are of two kinds, as pointed out in my memoir, Part II., Plate 24, fig. 3. The barred or reticulate character of many of these cells affords an infallible guide to the identification of this plant.

Fig. 2 represents a segment of the only specimen I have seen in which *all* the cortical tissues are preserved; for this specimen I am indebted to Mr. CASH, of Halifax. At *a* we have the periphery of the vascular zone. At *b* is the innermost cortex, separable into three parts—an internal zone, *b*, consisting of very minute cells; a middle area, *b'*, in which the cells are of larger size; and an outer one, *b''*, in which they exhibit a tendency towards a cyclical arrangement. In this zone the foliar vascular bundles, *c*, are invariably intersected, in these transverse sections, at right angles to their *vertical* course. Enclosing this endophloëm we have a middle cortical layer, *d*, which is very rarely preserved, its place being usually vacant, as in fig. 1, *d*. This zone consists of very delicate parenchyma, the cells of which at its inner margin, *d'*, exhibit a disposition towards a radial arrangement. The vascular bundles pass through this zone in an *oblique* direction. The yet more external zone, *e*, is almost invariably preserved in these young branches. It consists of strongly-defined thick-walled cells, which diminish in size from within outwards—the compressed aspect of those shown at fig. 2, *e'*, being obviously accidental. The smaller peripheral cells gradually pass into crescentic clusters of radially disposed prosenchymatous cells, *f*. Fig. 1 demonstrates that these prosenchymatous or bast tissues are first developed in the convex outward extensions of this portion of the bark which underlie the several leaves. The latter organs, composed of coarse parenchyma, are seen at *g*, *g'*. At *g'* is the single foliar bundle; in each of the three leaves of fig. 1 in which this bundle appears there are

\* 'Quarterly Journal of the Geological Society of London,' May, 1862, p. 110, plate 6.

peculiar condensations,  $g''$ , of the cellular tissue of the leaf. In fig. 2,  $g''$ , we find a similar condensation of the peripheral part of the leaf through which the bundle  $g'$  originally passed.

Whilst the specimens described are Lepidodendroid branches identical with the type  $a$  of M. RENAULT'S three Lepidodendroid groups, they soon acquire an exogenous vascular zone, *i.e.*, assume a Sigillarian organization. I am indebted to Mr. CASH, Mr. SPENCER, and Mr. BINNS, of Halifax, and to Mr. J. AITKEN, of Urmston, near Manchester, for numerous specimens illustrating this portion of the subject.

Fig. 3 is the vasculo-medullary axis of a specimen like figs. 1 and 2, but with the beginnings of an exogenous zone,  $h$ . This exogenous growth commenced at a single point at the circumference of the vasculo-medullary axis, from which point it extended laterally in opposite directions, as well as radially, until it enclosed the vasculo-medullary axis in a complete cylinder, composed of vascular wedges separated by numerous medullary rays. In the specimen fig. 3 this growth has begun opposite to the point  $x$ , and has extended round little more than one-third of the circumference of the medullary axis. Whilst the transverse sections of the vertical portions of the foliar bundles are grouped closely round the axis at  $c$ , they are separated from it at  $c'$  by the interposition of the exogenous zone,  $h$ . Their normal position is in the innermost cortical layer, which is necessarily pushed outwards by the growing exogenous zone.

Fig. 4 is a segment of another section, enlarged 12 diameters, in which a further exogenous development has taken place; and fig. 5 represents the vasculo-medullary axis and inner bark of another section from the same specimen, enlarged 28 diameters. In these specimens the exogenous zone has enclosed fully two-thirds of the circumference of the vasculo-medullary axis. As in fig. 3, the characteristic barred cells of the medulla are conspicuously numerous. The details of the structure of the bark seen in fig. 1 reappear in fig. 4, with the one exception, that the prosenchymatous or bast layer,  $f$ , instead of filling small detached crescentic areas at the base of each leaf, has now become a thick and continuous zone. The regular continuity of its peripheral border,  $f'$ , makes it clear that the additions to its thickness have been made to that periphery, and not to its inner margin where it becomes merged in the outer parenchyma,  $e$ . In more than one of my previous memoirs I have expressed my conviction that this has been the case, and the examples now described appear to confirm those conclusions. It further appears clear that this increase in the thickness of this bast layer is, like the development of the exogenous zone, an indication of a corresponding advance in the age of the stem. The leaf  $g$ , with its single vascular bundle  $g'$ , exhibits a similar appearance to what we see in fig. 1,  $g'$ .

Fig. 6 represents the central axis of another stem, in which the exogenous zone has completely encircled the primary vasculo-medullary axis. A considerable portion of the latter structure has been destroyed, I presume before mineralisation. With these two exceptions, this section is a repetition of fig. 5. The innermost bark,  $b$ , is now more or less detached from the primary vasculo-medullary axis, and encloses the

numerous *transverse* sections of the foliar vascular bundles,  $c'$ , their more internal portions,  $c$ , passing almost horizontally through the exogenous zone.\*

When my memoir, Part II., was written, I was unacquainted with any further advance in the exogenous development of this stem than is seen in the specimens just described; but it is otherwise now. The cabinets of Mr. AITKEN and Mr. CASH have furnished me with several specimens displaying the same stem in various stages of further Diploxyloid growth. Fig. 7 represents one for which I am indebted to Mr. AITKEN, enlarged nearly six diameters. The central vasculo-cellular medullary axis has a mean diameter of about  $\cdot 25$ .† In another specimen in Mr. AITKEN'S cabinet the diameter of this axis is fully  $\cdot 4$ , which is also the diameter of the same structure in a similar section for which I am indebted to Mr. CASH. In a series of specimens in my cabinet, the entire stems of which exhibit a gradual increase in size, I find that in the youngest, in which there is no exogenous growth, the diameter of the vasculo-medullary axis is  $\cdot 02$ . In the next, in which the exogenous zone has completed two-thirds of the circle, it is  $\cdot 05$ . In another, in which the exogenous zone has completed its circle, it is  $\cdot 1$ . In fig. 7 it is  $\cdot 25$ , whilst in Mr. AITKEN'S and Mr. CASH'S specimens it has attained to  $\cdot 4$ . We thus find that this central axis steadily increases in magnitude with the general growth and age of the branch; and an examination of the specimens shows further that this increase is not due to a mere enlargement of the cells and vessels of which this vasculo-medullary axis is primarily composed, but to an enormous, though gradual, increase in their number. It thus becomes evident that, contrary to the views of M. RENAULT, the cells of the axis retained their genetic activity long after the exogenous zone was developed, and consequently the latter must have been capable of such interstitial changes as allowed it to expand and accommodate itself to the increasing diameter of the structure which it enclosed.

The exogenous zone,  $h$ , of fig. 7 is composed of very regular, narrow, radiating wedges, undistinguishable, on a casual glance at the transverse section, from the similar structure in a Gymnospermous branch. The medullary rays,  $k$ , are numerous and large, and nearly all of them contain more or less numerous barred cells that are elongated in the direction of the ray. The comparatively narrow cortical zone  $e$  is the same as the zone  $e$  of fig. 1, whilst the prosenchymatous zone  $f$  is now the dominant one, having more than four times the diameter of  $e$ , as well as being four times thicker in proportion than the same zone is even in fig. 4. I have frequently had occasion to point out the remarkable tendency displayed, both by the Calamitean and Lepidodendroid plants of the Coal-measures, to the extension of this prosenchymatous zone of the bark, which has here played the part of a periderm.‡

\* In illustration of these peculiarities of direction, see figs. 33 and 34 of my Memoir IX. The *vertical* direction which they follow, close to the exterior of the vascular medullary axis in the non-exogenous state, is equally transferred to the exterior of the exogenous cylinder when that structure first makes its appearance and when, by age, it has attained to large dimensions.

† These measurements are in fractional parts of an inch.

‡ This portion of the bark in fig. 7 is not devoid of further interest. I long ago ascertained that

In my memoir, Part III., Plate 43, fig. 19, I represented a section of a young dichotomising branch of the Burntisland *Lepidodendron*, in its young state, in which the vascular cylinder had divided into two horseshoe-shaped portions, and in fig. 20 of the same plate is shown a similar subdivision of the same plant in the more advanced Diploxyloid stage of growth. Fig. 8 represents a young branch of *Lepidodendron selaginoïdes* dividing in a similar manner. Each of the two halves of the vascular axis exhibits the usual horseshoe-shaped contour, the innermost cortical cells, *b''*, intervening between the two becoming contiguous to and intermingled with the medullary ones. The whole of the cortical elements and foliar-vascular bundles seen in this specimen are identical with those represented in figs. 5 and 6; but whilst at the upper side of the half, A, of the vascular axis we have the crescentic beginnings of an exogenous zone, *h*, no trace of such a zone is seen in the half B. Thus the latter is Lepidodendroid and the former Sigillarian according to the Brongniartian hypothesis. Immediately surrounding the lower half of each axis, especially of B, we find some cells, *b*, arranged in radiating lines, but no trace of vessels. This disposition of cells, occupying the position of a cambium layer, so to arrange themselves is not unimportant.

Having thus traced the history of an example of M. RENAULT'S group *a*, from its Lepidodendroid to its Sigillarian state, I will now deal with his group *b*.

The specimen of *Lepidodendron Harcourtii* described by WITHAM and BRONGNIART was made the foundation of a restored figure by the latter botanist in his 'Végétaux Fossiles.\*' The imperfection of the specimen necessarily led to imperfections in the details of the restoration.

M. RENAULT, speaking of *Lepidodendron Harcourtii* as the typical representative of his second group, says,—“On peut s'étonner qu'avec un développement semblable aucune trace de production ligneuse exogène ne se soit pas encore manifestée en dehors du cercle de faisceaux vasculaires d'où partent les cordons foliaires.” And again, “On peut donc légitimement conclure que la différence dans le diamètre des rameaux de *Lepidodendron* n'apporte pas de changements dans la disposition générale des tissus que l'on trouve dans ces plantes.” On both these points I shall offer evidence that our English specimens exhibit the conditions of which M. RENAULT denies the existence.

Fig. 9 represents a section of a superb example of the young state of *Lepidodendron Harcourtii*, for which I am indebted to Mr. AITKEN. On comparing it with the similar section of *L. selaginoïdes* it is seen to differ from that plant in two points: first, in the absence of all vessels from the area occupied by the medullary cells, causing the inner boundary of the vascular medullary zone (“étui médullaire” of BRONGNIART) to be sharply defined; and, second, in the much greater uniformity in the size and

the mineral charcoal, so abundant in almost every British coal of Carboniferous age, is largely composed of small cubical fragments of prosenchymatous bark. Fig. 7, *f*, illustrates the strong tendency of this tissue to be broken up into similar fragments.

\* Plate 21, fig. 4.

structure of the smaller cells composing the various layers of the bark. The foliar-vascular bundles also much more frequently retain their barred vessels undestroyed. They appear in the sections as dark, dense bands, instead of being represented by vacant spaces.

No example of *L. Harcourtii* in which all tissues of the stem are preserved has hitherto been described. The mean diameter of the branch figured is about  $1\frac{1}{2}$  inches. The cellular medulla, *a*, is invested by the vascular medullary zone *a'*, which, in turn, is enclosed within a dense layer of inner bark *b*, the innermost portion of which is crowded with foliar bundles. Surrounding this is the middle bark *d*, composed of small cells. This layer, which is so rarely preserved in *L. selaginoides*, is as rarely absent from *L. Harcourtii*. The cells of the innermost portion, *e*, of the outer bark are, as is usual in the *Lepidodendra*, somewhat larger, and have thicker walls, than those of the inner bark, whilst the prosenchymatous zone, *f*, appears as a continuous, wavy, but very narrow zone, curving slightly outwards opposite to the base of each leaf, and projected outwards as a sharply defined funnel-shaped prolongation, wherever one of the numerous foliar bundles, *c*, passes through it. The leaves, *g*, differ in no material respect from those of *L. selaginoides*.

Fig. 10 represents part of a transverse section of a branch of rather larger size and somewhat more developed growth.\* It exhibits the usual structure of the vascular and cellular portions of the medullary axis as well as of the inner bark. The central portion of the cellular medulla, *a*, has been accidentally destroyed. The vascular medullary cylinder, *a'*, is composed of barred vessels which diminish in size from within outwards. Its peripheral margin presents numerous radiating points, *c'*, which are the bases of as many foliar-vascular bundles. These bend upwards immediately after their orientation, as in *L. selaginoides*; hence they are intersected transversely at *c*, *c*, where they severally occupy the numerous crescentic areas intervening between the projecting points *c'*. The cells of the parenchyma of the innermost portion, *b*, of the inner bark are very minute, usually forming a dense sheath surrounding each foliar bundle *c*. In the middle portion of this inner bark is an irregular layer of cells, *b'*, of somewhat larger size; but its outer zone again consists of smaller cells, *b''*. In this outer zone a narrow band of these small cells appear arranged in radiating lines, *b'''*. This radiating zone bears an important relation to some features to be described. At *d* we have the thick middle bark with its dense foliar bundles, *c''*, *c''*.

Even in this typical *Lepidodendron*, when the branches are sufficiently advanced in growth, there appears a rudimentary zone composed of true radiating, exogenously developed, vascular wedges. Fig. 11 represents a segment of a transverse section of a portion of the zone corresponding to *b''*, *b'''* of fig. 10, enlarged 27 diameters. At *b'''* are the radiating lines of cells already referred to, and at *b''* the outermost part of the

\* It will be observed that before it begins to develop its exogenous zone this plant attains to much larger dimensions than the *L. selaginoides* does. In this respect it corresponds closely with the Arran plant.

zone. At  $c''$ ,  $c''$  we find two foliar-vascular bundles, belonging to an outer series corresponding to  $c''$  of fig. 10, whilst in the curved line between these two bundles we have a portion of the exogenous zone, composed of numerous radiating wedges,  $h$ , of barred vessels. At  $h'$ ,  $h'$ , where these wedges are deflected somewhat from their direct course, their true vascular character is demonstrated. I find this exogenous zone in so many specimens that have attained the right stage of growth as to leave no doubt whatever as to its being a normal feature of the plant. Whether or not we shall hereafter discover it developed into the more perfect Diploxyloid condition seen in other Lepidodendroids remains to be seen. We were long before we found *L. selaginoides* so developed; meanwhile its presence in *L. Harcourtii*, even in this rudimentary form, directly links that plant with the Diploxyloid or Sigillarian group of stems. In many of my specimens some large isolated cells, fig. 11,  $b$ , appear in the zone  $b''$ . In the specimen from which fig. 11 was taken these are larger and more conspicuous than usual.

In fig. 9,  $a''$ , a considerable segment of the vascular medullary cylinder is detached from the rest, leaving a hiatus in the cylinder, and carrying along with it a semi-circular loop of the innermost bark,  $b'$ , with its associated foliar vascular bundles. In my memoir, Part II., p. 224, I called attention to the fact that the large vascular bundles separated from the main cylinder to supply the tubercles of the *Halonixæ* were given off in the same way, and the bundle  $a''$  has doubtless had some similar destination. Such a division of the primary vascular cylinder differs only in amount from the dichotomous subdivision of a branch illustrated in fig. 9. In another branch of the same stem, contained in the nodule in which the example fig. 9 occurred, I found a similar bundle, of which a representation is given in fig. 12, enlarged 21 diameters. In the branch bundle of fig. 9, the central vasculo-cellular mass,  $a''$ , retains the concavo-convex form belonging to it as a small segment of a circle, and the remark applies also to the dark-coloured layer of inner bark,  $b'$ , which surrounds its convex peripheral border; but in fig. 12, the bundle  $a$  has assumed a more cylindrical contour; the dark inner bark,  $b'$ , now completely invests the bundle in the form of a six-sided cylinder, whilst the contiguous cells,  $d$ , of the middle bark have re-arranged themselves in almost concentric lines around the developing axis. On further examining the central bundle we find that what in fig. 9,  $a''$ , was merely a small concavo-convex segment of a large circle, having some cells in the concavity of its inner border, has also changed its form. The extremities of the vascular segment have been bent inwards, converting the segment into a circular cylinder,  $a'$ , which has enclosed the cells,  $a$ , that primarily only lay on one side of it.\* I am able to demonstrate that this branch, fig. 12, is merely a further development of a structure like fig. 9,  $a''$ ,  $b'$ . Mr. AITKEN kindly allowed me to make a vertical section through the specimen from which the transverse section, fig. 12, was taken. This not only enabled me to trace the bundle downwards into the condition represented in fig. 9, but to a yet lower position

\* The gap left in the vascular cylinder of the parent root stem closes in the same way by the convergence of the separated extremities of the broken circle.



where, instead of being detached from the medullary vascular cylinder, the boundary between the two was only indicated in the transverse section by two slight lateral constructions in the otherwise unbroken circle of vessels. Other sections of the same specimen in Mr. AITKEN'S cabinet exhibit similar conditions. We have here a clear proof that, contrary to the conclusions of M. RENAULT, age does bring about very important changes in the form and arrangement of the tissues in the branches of these plants. Other examples of stems in a very much younger state, for which I am indebted to Mr. AITKEN and Mr. CASH, exhibit corresponding phenomena.

My most recent researches have brought to light another very remarkable series of facts indicating the Lycopodiaceous character of the Lepidodendroid and Sigillarian stems. Whatever else may be doubtful, there is no doubt that *Stigmaria ficoides*, with its peculiar rootlets, is the root alike of *Lepidodendron* and of *Sigillaria*. I had long noticed the circumstance that the vascular bundle in each of these rootlets was rarely in the centre of the small innermost circle of cortical cells by which it is usually surrounded; but such structures are so often pushed out of their normal position in these fossil plants that I regarded this eccentric position of the rootlet bundle as accidental. The perusal of a very important paper by M. PH. VAN TIEGHEM,\* first called my attention to a peculiarity in the structure of the true roots of the Lycopods, especially of the *Selaginelleæ*, and led me to re-examine the rootlets of *Stigmaria* with the results to be described. M. VAN TIEGHEM has shown that when a rootlet belonging to any class of plants is first formed its primitive vascular elements commence by developing a small vascular bundle at each of two or more points on the periphery of a central cellular circle, from which points each bundle grows by the centripetal additions to the number of the vessels composing it, until the several bundles approach each other centripetally, and thus constitute a symmetrical group of vessels. These primary rootlet bundles are never less than two in number, with the exception of the ultimate rootlets of the *Lycopodiaceæ* and the *Ophioglosseæ*. Each terminal rootlet in these classes of plants contains but one triangular vascular bundle. This bundle first appears as one or two very minute vessels attached to one side of the small cellular cylinder within which it is located. New and larger vessels are subsequently added centripetally to these primary ones, but the bundle always remains eccentric in reference to the cellular sheath within which it is enclosed. The remainder of the cavity within the sheath is occupied by some large thin-walled cells, which M. VAN TIEGHEM regards as the equivalents of the liber of other plants. Fig. 13 represents the central portion of a rootlet of *Selaginella Martensii*, in which *a* indicates the first formed vessels of the vascular bundle, and *a'* the later, centripetally developed and larger ones. The large cells, *b*, are those which M. VAN TIEGHEM identifies with the liber, whilst *c* indicates the next innermost zone of the cortex.

Figs. 14 to 20 exhibit sections of rootlets of *Stigmaria ficoides* in various stages of

\* "Recherches sur la symétrie de structure des plantes vasculaires." Par M. PH. VAN TIEGHEM. *Annales des Sciences Naturelles.* Cinquième série—Botanique, tome 13, 1870-71.

development. The general relations of the tissues composing these rootlets to their larger exogenous roots were shown in my memoir, Part II., Plate 31, fig. 52. I now only call attention to their relationship to the rootlets of the living *Selaginella*. Fig. 14 represents the transverse section of one of these Stigmarian rootlets in the condition in which they most commonly occur. At *a* is a vascular bundle composed of barred vessels enclosed eccentrically within a small cylinder composed of the cells of the innermost cortex *c*. At *d* we have only the outer cortical layer, the intermediate tissues being rarely preserved; but these missing elements have resisted decay in fig. 15, in which example we have the space between the outer cortex *d* and the inner one *c*, occupied by a very delicate cellular tissue *e*, the three layers seen in this specimen apparently corresponding with the three cortical layers *b*, *d*, and *e*, of the branch, fig. 2. The line of demarcation between the outer and middle layers is very sharply defined. Fig. 16 represents a very small rootlet in an early stage of growth; its entire diameter not being more than .025. Its vascular bundle, *a*, only consists of four very small vessels attached eccentrically to one point of the inner side of the ring of inner cortex, *c*, whilst all that remains of the middle and outer bark is a small band of the former, *e*, and a very thin ring of the latter, *d*. The narrow band of middle bark, *e*, connecting the cylinder of inner-bark cells with the outer cortical zone is of common occurrence in this form. In the specimen figured, some of the cells of the outer zone have become partially detached from the outer ring. It will be observed that the diameter of the entire young rootlet is less than that of the central inner bark cylinder of a matured rootlet represented in fig. 18.

I fortunately possess proof that these small rootlets belonged to very young roots. The enormous thickness to which the exogenous Stigmarian roots were capable of attaining is well known, and since these thick roots often appear to terminate abruptly like the end of a cucumber, it has been thought by some that they never were of small dimensions. This, however, is an error. The youngest plants can have had no true Stigmarian exogenous root but only rootlets, and the stage of growth at which the exogenous structures first made their appearance has yet to be discovered. It however appears certain that the latter were primarily of very small size, and furnished with proportionally minute rootlets, each of which had but a correspondingly small number of vessels. I have before me a section of the bark of a very small Stigmarian root, from Mr. AITKEN'S cabinet, the entire diameter of which does not exceed .2, and which is giving off several rootlets whose average diameter is about .04. No vascular bundle in the rootlets of this specimen possesses more than from three to five very small vessels. The same cabinet contains a beautiful little section of the exogenous vascular axis of a *Stigmaria*, whose maximum diameter is .6. This has, of course, been the centre of a larger root than that just described. It gives off numerous *root-bundles* proceeding towards the periphery of the bark, each of which possesses from ten to fourteen vessels. These two specimens are the smallest examples of *Stigmaria* that I have yet met with. On the other hand, in two large Stigmarian exogenous cylinders

in my cabinet, each of which has a diameter of fully an inch and a half, I found each of the numerous root-bundles consisting of an average of about forty vessels. These facts show that as the diameter of the exogenously developed root increases with age, this growth is accompanied by a corresponding increase both in the dimensions of each rootlet and in the number and magnitude of the vessels constituting its vascular bundle.

Fig. 17 represents the inner cylinder, *c*, with the vascular bundle, *a*, of a rootlet of the same size as fig. 16, but enlarged 270 diameters. The vascular bundle, *a*, consists of but three small eccentrically placed vessels. The space *b*, occupied in the living *Selaginella* by the large, delicate cells regarded by M. VAN TIEGHEM as liber-cells, (fig. 13, *b*), is here empty. We rarely find a specimen in which this is not the case; even in transverse sections of recent Lycopodiaceous roots these cells frequently become ruptured, and their almost constant absence from the fossil ones is a proof that in the latter these structures were similarly delicate. I find them preserved in a few specimens—as in fig. 15—where they prove to be of much smaller size relatively to the vessels than in the living plants.

Fig. 15 represents a yet larger rootlet, enlarged 37 diameters, in which all the tissues are preserved. The vascular bundle, *a*, has increased to six vessels of larger dimensions, and, as already stated, the ring of inner cortex, *c*, encloses the representatives, *b*, of the “cellules libériennes” of M. VAN TIEGHEM. The outermost cells, *c'*, of the inner cortex exhibit a somewhat defined transition from those of the middle bark, suggesting an homology with the “membrane protectrice” of the French botanist. The cells of the middle bark, *e*, are here well preserved and consist of parenchymatous tissue, very much more delicate and thin-walled than those of either the inner, *c*, or the outer cortex, *d*.

Fig. 14 is a section of a rootlet of the most usual size and aspect. It is enlarged 21 diameters, its actual breadth being about  $\cdot 2$ . The vascular bundles, *a*, and their surrounding cylinders of inner bark *c* of two similar rootlets are further enlarged in figs. 18 and 19. We now find that the vessels of fig. 18 have increased to 18, and in fig. 19 to 22 in number. But even this is not the final increase, since I have two rootlets in my cabinet each of which has a diameter of fully  $\cdot 4$ . The central portion of one of these is represented in fig. 20, in which the vessels composing the bundle have increased to 38 in number, the last formed ones, *a'*, being much smaller in size than those which immediately preceded them. The first formed ones, *a*, have, in this instance, become accidentally detached from the inner bark cylinder, which is a rather unusual occurrence.

The illustrations I have given will, I think, demonstrate the fact that we have in each of these rootlets a single vascular bundle that commences its development eccentrically in relation to the centre of the rootlet to which it belongs, and that, proceeding from this one pole, it is developed centripetally, the extent of that development, including the number of its constituent vessels, bearing a general relation to the age of the

rootlet so far as is indicated by its size. Excepting in the magnitude of its liber-cells, the resemblance to the corresponding organs in the *Selaginelleæ* is complete. Seeing that this peculiar structure only exists in the recent Lycopods and *Ophioglosseæ*, and that no other resemblance exists between the fossil *Lepidodendra* and *Sigillariæ* and the *Ophioglosseæ*, we must fall back upon the Lycopods as the plants with which this form of rootlet indicates true affinities. On forwarding characteristic specimens of these rootlets to M. VAN TIEGHEM he at once replied, expressing his conviction that they belonged to a Lycopodiaceous plant.\*

It is now fully established that *Stigmaria ficoides*, to which these rootlets belong, is the root of *Sigillaria*, as well as of *Lepidodendron*. The structure of these rootlets therefore adds an additional link to the long chain of evidence, indicating the close affinity of the *Sigillariæ* with the Lycopods.

But there is yet another feature in these exogenous Lepidodendroid stems which may prove to have some bearing upon the problem of evolution: this is, the presence of numerous barred cells in the medullary rays, to which fact I have already made a slight reference. In my memoir, Part II. (Plate 27, fig. 23, *a*, p. 236), I called attention to the existence of such cells in the triangular spaces that appear to project outwards from the medullary sheath, and are intercalated between the inner extremities of the vascular wedges of the exogenous zone; and in the same memoir (p. 238) I further pointed out that such cells entered into the composition of the medullary rays. This is not only the case with the Arran plant described in my last memoir, but I now discover them to be abundant in the various exogenous states of *Lepidodendron selaginoides*, and to be especially conspicuous in the peripheral layers of the more matured branches. Fig. 21, *k*, represents peripheral portions of two medullary rays of fig. 7, enclosing between them a single wedge of the barred vessels. Fig. 22 represents a portion of another, but similar, section, taken from the point where the exogenous zone, *h*, joins the medullary sheath, *a*. A number of small vessels, *x*, *x*, appear in all sections similar to the latter one, respecting which it is difficult to determine whether they are to be regarded as belonging to the medullary cylinder or to the exogenous zone. Where the medullary rays originate amongst these small vessels, oblong barred cells enter conspicuously into their composition, apparently associated with cells that are not barred. The increase in the number of these barred cells as we follow the course of the ray centrifugally is accompanied by a corresponding increase in its diameter as seen in such transverse sections as fig. 7.

CORDA found similar cells in the medullary rays of his *Diploxyylon cycadeoideum*, as pointed out in my memoir, Part II.; but he did not distinguish these rays from foliar bundles, which he believed them all to be. Tangential sections, however, show

\* "Par la structure du cylindre central, et par la division dichotomique qu'on y observe en plusieurs endroits, vos racines appartiennent bien certainement à une Lycopodiacée de la famille des Selaginellées." *In litera*, Oct. 30, 1879.

clearly that this is a mistake, as is obvious from the fact that even in transverse sections these rays are seen to be very much more numerous than the foliar bundles.

What gives an interest to this frequent occurrence of barred cells in the medullary rays of these exogenous Lycopods is the fact pointed out by DE BARY ('Vergleichende Anatomie,' p. 505), that amongst living plants such cells are chiefly confined to the medullary rays of Gymnosperms and especially to the *Abietinæ*.

#### GENERAL CONCLUSIONS RESPECTING THE CARBONIFEROUS LYCOPODS.

I think I am justified in expressing my conviction that the present memoir confirms the views I have so long advanced, viz. : that at least many of the Lepidodendroid plants acquire, through advancing age, those characteristics that have hitherto been relied upon to distinguish the Sigillarian from the Lepidodendroid forms. In his latest memoir, already quoted, M. RENAULT combines his fossil Gymnospermous Phanerogams in one group, to which he gives the common name of "Diploxylés," and in a foot-note (*loc. cit.*, p. 260) he says: "Sous ce nom je réunis toutes les plantes qui, dans le faisceau libéro-ligneux de la tige ou des feuilles, présentent un double accroissement, l'un centripète, l'autre centrifuge." My friend here reasserts the old Brongniartian hypothesis in all its definiteness. If the evidence produced in the preceding pages is not sufficient to demonstrate the erroneousness of this hypothesis, I am wholly unable to conceive what kind or number of facts would accomplish that end.

The enormous number of Lepidodendroid and allied plants that have now been described by M. RENAULT and myself seem to me to justify an attempt to ascertain what bearing our discoveries may have upon the problem of Evolution. In making this attempt we must not forget that, whilst our researches have been confined to carboniferous plants, the discoveries of Dr. DAWSON have shown that the differentiation of the Gymnospermous Dadoxylons from the Cryptogamic Lycopods was as definite in the Devonian age as in that which succeeded it. Nevertheless, it seems to have been during the later portion of the Palæozoic epoch that the great changes were effected which caused the arborescent Lycopods to be replaced by the oolitic Gymnosperms; and it fortunately happens that the plants which have furnished so rich a morphological harvest belong to that important period of transition.

In endeavouring to ascertain possible genetic relationships between plants, Geologists have to consider: 1st, external form; 2nd, the successive appearances of different types of elementary tissue; 3rd, the arrangement of those tissues in the several vegetative organs; 4th, the reproductive structures.

The study of external forms has occupied, and still occupies, so many observers that I shall not now dwell upon this subject. Outward resemblances, taken alone, are very unsafe guides, though they are too often the only ones that we can obtain. I would make but two observations in reference to them: So far as external appearances are concerned, I am wholly unable to draw a line between *Lepidodendron* and *Sigillaria*,

either as regards bark, leaves, or roots. I would further call attention to the fact that, so far as externals are concerned, the fine *Lycopodium ulicifolium* recently imported from Khasia Hills in northern India in a living state, only requires to be raised upon an arborescent stem to furnish an exact copy of the ancient *Lepidodendra*. Its thick, succulent, dependent branches, devoid of all adventitious roots; its oblong, flat, spirally-arranged leaflets, which leave, when they fall, a distinct Lepidodendroid cicatrix; and its huge, often dichotomous, strobili, usually six inches in length, remind us most vividly of the dependent branches of the Palæozoic Lycopods.

The successive developments of the various vegetable elementary tissues is not unimportant. The modification of spiral tissue known as the "barred" vessel—the "vaisseau rayé" of the French Palæo-botanists, and which approximates closely to the modern "scalariform" tissue—has long been known to be the prevalent vascular element amongst Palæozoic plants. Either in its ordinary shape, or in its "reticulated" modification, it is common to the *Calamites*, the *Sphenophyllums*, the *Asterophyllites*, and the *Lyginodendra*. Amongst our British *Lepidodendra* we have as yet found only the simple barred form; and this statement applies not only to the plants recognised by my opponents as Lycopodiaceous, but also to those Diploxyloid ones for which they claim Gymnospermous rank.

It is a fact of some importance that I have failed to detect in any one of our British fossil Lepidodendroids (including *Sigillaria*) a trace of those fibres with areolated "margined pits" which exist abundantly in all living Cycads, in which latter, as I showed long ago,\* modifications of the spiral and the pitted states can be discovered in the same individual vessel.†

But M. RENAULT has discovered in France an important group of carboniferous plants which undoubtedly possess the barred and areolated tissues in the same stems, to which group he has given the name of *Poroxyllées*; as he points out, these Poroxyllons appear to connect the *Sigillaria* on the one hand with the Gymnospermous *Cordaites* on the other.‡ This very important discovery, the reality of which there is apparently no reason to doubt, unquestionably links the Palæozoic *Lycopodiaceæ* to the Gymnosperms of the same age, so far as elementary structures are concerned, as completely as any Evolutionist need desire. The arrangement of these elementary tissues into vegetative organs leads us to the same conclusion. The ample development of an exogenous vascular zone in true Cryptogams is demonstrated in the preceding pages as well as in my previous memoirs. In the young *Lepidodendron* the centripetal representative of the vascular medullary sheath, which even BRONGNIART recognized as an "étui médullaire," is not only enormously large, but it is the sole

\* "On the Structure and Affinities of some Exogenous Stems from the Coal-measures," 'Monthly Microscopical Journal,' Aug. 1, 1869.

† It must not be forgotten that Dr. DAWSON considers that he has discovered this tissue associated with barred vessels in some of the Canadian *Sigillaria*.

‡ *Loc. cit.*, p. 273.

*direct* link between the roots and the leaves. In a large number of plants the exogenous zone is merely a superadded structure. In the first instance, as in *Lepidodendron Harcourtii*, this latter zone is but feebly represented. Nevertheless this is a first term in a succession which ends in the same zone assuming dimensions that dwarf the relatively narrow, but still cylindrical medullary sheath of the plants in which the enlarged exogenous growth occurs. In such plants as *Sigillaria spinulosa* and *elegans* the medullary sheath is no longer an unbroken cylinder. It appears as a circle of detached vascular bundles. The exogenous zone now grew more vigorously than the medullary sheath, hence the latter was broken up into separated wedges, leaving intervening spaces through which a direct cellular communication was established between the medulla and the medullary rays of the exogenous zone. Nothing of the kind existed in the lower Lepidodendroid forms. In them the medullary sheath cut off all such direct communication. These changes bring us very near to the narrow medullary sheath, composed, as in living Gymnosperms, of spiral vessels, seen in the British *Dadoxylons* and in the St. Étienne *Cordaites*; and, considering how many "missing links" have been discovered during the last five years, I have little doubt but that our continued researches will supply yet further transitional forms, and thus establish the unbroken unity of this chain of vegetable structures.

Hence, though once holding a different view, I am now convinced that so far as we are acquainted with the organisation of the plants of the Coal-measures, such facts as I have briefly referred to are in thorough conformity with the doctrine of Evolution, and that these most characteristic plants can no longer be quoted in opposition to that doctrine.

Our knowledge of the fourth point, viz.: of the organs of reproduction amongst the carboniferous plants, is as yet too imperfect to admit of our employing them as witnesses. They teach most definitely the doctrine of the persistence of types. But the lack of information respecting alike their autogeny and their phylogeny is amply compensated by what we learn from similar organs amongst their living representatives.

I would only add, in conclusion, that whilst I believe I have now demonstrated the transition from the young Lepidodendroid states of M. RENAULT's two groups *a* and *b* (see page 1) up to their matured Sigillarian conditions, there yet remains his third type of Sigillarian stem *c*, of which no Lepidodendroid state has in his opinion yet been discovered. He says that such a *Sigillaria* would require, according to my views, a Lepidodendroid representative having the following characteristics:—  
 "c. Cylindre ligneux formé par une couronne discontinue de faisceaux vasculaires, scalariformes, circonscrivant une moelle dépourvue de faisceaux vasculaires" (*loc. cit.*, p. 247); but such a Lepidodendron M. RENAULT tells us has not yet been found. Yet he announces on page 249 of the same volume that he has found a new Lepidodendron of which he has not yet obtained sufficient knowledge to enable him to say much about it; but he already sees that he can define its broad features as follows:—"Le cylindre ligneux ne serait représenté que par une couronne de faisceaux

vasculaires isolés entourant la moelle et d'où partiraient les cordons foliaires. Dans ce type on ne trouverait ni l'axe complètement vasculaire du *L. Rhodumnense* ni le cylindre ligneux continu du *L. Harcourtii*." Surely this plant fulfils the chief requirements of M. RENAULT's third type *c*, his definition of which I have just quoted. But even were it otherwise, the example of the *Lyginodendron Oldhamium* described in my memoir, Part IV., shows that a medullary sheath may be continuous in a young state (see Memoir IV., Plate 22, fig. 2) and yet be broken up into widely separated vascular bundles (*idem*, fig. 3) through advancing age and growth. In these respects the structure of the medullary cylinder in *Sigillaria elegans* and *spinulosa* presents almost a fac-simile of the conditions seen in the larger stems of my *Lyginodendron Oldhamium*.

*Calamostachys Binneyana.*

Much as has been already accomplished in the investigation of this interesting fruit, we are far from knowing its entire history. I am now able however to fill up two lacunæ in that history. We have hitherto been ignorant of the nature and position of the organic union of the sporangia to the sporangiophores; but I found in the cabinet of Mr. CASH, of Halifax, a transverse section that gives the required information. A portion of this section is shown in fig. 23, *k* being a part of the outer cortex of the strobilus. At *v, v*, are two sporangiophores, one of which retains its peripheral, expanded disk at *v'*, and a marginal portion of the other is seen at *v''*. The disk consists of a mass of parenchyma, amongst the cells of which an extension of the bundle of spiral cells that passes along the peduncle of the sporangiophore, is seen prolonged towards the margin of the disk; as the bundle approaches this margin its cells multiply as is the case with the similar structures in the sporangiophores of the recent *Equiseta*, as well as in other very different structures—*e.g.*, the terminations of the hair-like emergences of the *Droseræ*. The peripheral surface of the disk appears to have been composed of a layer of oblong cells, which are planted perpendicularly to it. At *v''* and *v'''* we see that each sporangium is not connected with the peltate end of the sporangiophore by the entire base of the former, as is the case with the living *Equiseta*, but by a very narrow neck of cellular tissue attached to a point a little within the extreme overhanging margin of the sporangiophore; the remainder of the base of the sporangium being entirely free, as is seen at *u'*.

My second discovery is a still more important one. All the examples of this *Calamostachys* hitherto described, possess but one kind of spore. But some years ago I found a fragment, still in my cabinet, in which the sporangia were filled with spores of about three times the diameter of those with which I was familiar. My immediate conviction was that these were macrospores—but the specimen being so fragmentary, and there being no microspores connected with it, I durst not rely upon its apparent indications since it was possible that it might only represent some transitional state of the common form of spore. The correctness of my surmise is however established



by the specimen from the Halifax beds represented in fig. 24, and for which I am indebted to Mr. J. AITKEN. It is a slightly oblique and longitudinal section. Hence the sporangia of the upper part have been cut through, almost tangentially, on one side of the vascular axis, whilst the lower ones have been similarly intersected on the other.

Nothing further need be said of the general organization of the plant than that the barren disks with their bracts are seen at  $t$ ,  $t'$ , whilst the sporangiophores of the fertile verticils are variously intersected at  $v$ . The importance of the specimen resides in its spores. All the sporangia of the uppermost of the three fertile verticils, as well as those to the right of the middle one,  $v$ , are filled with the small spores which have now been so often figured and described. The three to the left of the middle verticil, and all the four of the lowermost one,  $u'$ , contain macrospores. The relative sizes of these two classes of spores are shown in figs. 25 and 26, which are enlarged 220 diameters. The microspores are about  $\cdot 0031$ , and macrospores occur as large as  $\cdot 01$ , most of them equalling  $\cdot 0093$ . The latter exhibit an outer sporangial wall,  $a$ , as well as an inner one,  $b$ , whilst a dark-coloured mass,  $c$ , exists in the centre of most of the examples. The outer wall of fig. 26 has not been intersected on both its surfaces on the plane of its maximum diameter; hence it appears thicker in the figure than it is in reality.

It is scarcely necessary to say that this discovery of macrospores and microspores in *Calamostachys Binneyana* supplies another link connecting this strobilus with the *Lycopodiaceæ* in the same measure that it separates the fruit from the *Equisetaceæ*. That no plant belonging to the latter order ever possessed both macrospores and microspores is more than we can venture to affirm; but that no living representative of the group is known to do so is an unquestionable fact—hence to include an heterosporous *Calamostachys* in the Equisetaceous order will involve so large an alteration in the definition of the characteristics of this order as would practically involve the creation of a new one. On the other hand, this discovery strengthens my old conviction that the true affinities of this strobilus are with the *Lycopodiaceæ*. The verticillate arrangements of the fruit, and of what I believe to be the leaves of this plant (*Asterophyllites* or *Sphenophyllum*) constitute no difficulty preventing us from accepting this conclusion. BRONGNIART long ago pointed out how commonly a verticillate foliage occurred amongst living Lycopods.\* Fig. 27 represents the best specimen I have seen of a section which has passed tangentially through the margins of three of the horizontal barren disks,  $t$ , and revealed the form of the bracts,  $t'$ , which ascend from each of these margins. The specimen is in Mr. AITKEN'S cabinet.

Some years ago Mr. CARRUTHERS found a fossil Fungus in a fragment of a *Lepidodendron* from the lower Coal-measures of West Yorkshire, of which he gave a brief account in his annual address to the Geologists' Association for 1876. Mr. BUTTERWORTH, of Oldham, found a second example, which was described and

\* 'Histoire des Végétaux fossiles,' Part 2, pp. 9, 10, plate 7, figs. 1, 7, and 9.

figured by Mr. WORTHINGTON SMITH in the 'Gardeners' Chronicle' for October 20, 1877, under the name of *Peronosporites antiquarius*. Mr. SMITH figures and describes the hyphæ of the Fungus as having septæ, and its supposed oogonia as containing zoospores. The existence of these zoospores was denied by Mr. MURRAY, of the British Museum, in the 'Academy' for November 17, 1877. Still more recently another example of the plant has been met with at Halifax in the cabinet of Mr. SPENCER. Fragments of Lepidodendroid bark, the cells of which are filled with fragmentary hyphæ, but with few traces of oogonia, also from Halifax, are in the cabinet of Mr. CASH. I have had the opportunity of examining all these specimens with the exception of that in Mr. CARRUTHERS' cabinet, which example he informs me is a very imperfect one compared with those more recently discovered.

I have failed to find any traces of septa in the hyphæ of this plant, and I quite agree with Mr. MURRAY in his opinion that no zoospores exist in any one of them. Some of the oogonia (fig. 33) contain black coaly matter such as is frequently found in the ordinary cellular tissues of carboniferous plants; but I believe this to be the result of infiltration, since I find it extended into the hollow tubes of some of the hyphæ (as in fig. 33, *a*), and is not confined to the oogonia themselves. Having examined the actual specimen described and figured by Mr. SMITH with the aid of a ZEISS oil-immersion lens, I have had no hesitation in arriving at the same conclusion as Mr. MURRAY has done, viz.: that its oogonia contain no zoospores. The plant has been an unicellular branching mycelium with numerous dilatations on the branching hyphæ, which dilatations seem to have been oogonia. No septal division separates the cavities of these oogonia from the hollow hyphæ prolonged from them.

Fig. 28 is a specimen from Mr. SPENCER'S cabinet. The fungus is here inclosed within the cells, *c*, of a fragment of Lepidodendroid bark. At *a* is a branching mycelium, whilst numerous extremely thin-walled capsules, *b*, are seen either detached or, as at *b'*, connected laterally in a sessile manner with the hypha. Some of the capsules are round, others pyriform and with short hyphoid necks. In this specimen the hyphæ display no traces of septa, neither are there the slightest indications of spores within the capsules.

Fig. 36 represents a portion of the specimen already figured by Mr. SMITH, for the loan of which I am indebted to Mr. YOUNG, F.G.S. Figs. 37 and 37A represent fragments of plants from Mr. SPENCER'S Halifax specimen. Figs. 29 to 33 represent various forms observed in Mr. BUTTERWORTH'S section, and which correspond very closely with the Halifax one. In fig. 29 we have the branching hypha, the branch bearing the base of an oogonium, *a*. In fig. 30 an oogonium, *a*, gives off three hyphoid branches, one of which is not only connected with a second oogonium at *b*, but displays a swelling at *c*, which appears to be the commencement of a third one. In fig. 31, *a*, we have three oogonia connected by two hyphæ; at *c* is the free base of a large oogonium, and at *d* is another, but of smaller size. Fig. 32 again exhibits two oogonia connected by a single hypha, but each oogonium again gives off another hypha

from its free extremity. Most of these modifications find their counterparts in the figs. 36, 37, and 37A.

Mr. CASH's cabinet contains several sections of a fragment of cellular bark, most of the cells of which contain broken fungoid hyphæ (figs. 34, 35, and 38), of smaller size than those just described. One of the most perfect of these is represented in fig. 34, *a*. Numerous as are these fragments, indisputable reproductive structures are extremely rare among them; but fig. 34, *b* and *c*, are examples which closely resemble in all but size some of the larger objects already described; and I met with two similar ones, fig. 38, quite equal in their dimensions to those seen in fig. 28. The exceedingly small diameter of the hyphæ in this example, compared with those in figs. 28, 29, and 30, suggest a distinction of species; but we know too little of the effect of changed surroundings upon these simple organisms to make a multiplication of names desirable. This latter form has been described and figured by Mr. CASH in a paper, "On the Fossil Fungi from the lower Coal-measures of Halifax," read before the Yorkshire Geological and Polytechnic in 1879. The specimen was discovered, along with others, by Mr. BINNS, of Halifax.

Mr. SMITH came to the conclusion that since the fossil Fungi which he described possessed, as he believed, septate hyphæ and oogonia containing oospores, they must be ranked with the *Peronosporæ*. I confess that I cannot confirm the alleged facts nor accept the inference drawn from them. That the plant is a Fungus seems most probable: equally so that its relations are with the *Saprolegniæ*. The discovery of its reproductive organs in a more perfect state will alone enable us to arrive at a perfectly satisfactory conclusion on this point.

Along with the examples described are numerous single spheres about .0012 in diameter. It was long doubtful whether or not these belonged to the supposed *Peronosporites*, but I have now no doubt as to their doing so. Their diameter is about the same as that of the oogonia of the branching specimens, and I found one in a small cluster of these objects which had developed into the state corresponding to that represented by fig. 37.

I have occasionally found long branching hyphæ without any dilatations, and which, being associated with the branching ones, I presume belong to the same plant, since they differ in no respect from the shorter hyphæ of the latter. From these facts it would appear that this organism began as a single spore-like cell within the cells and vessels of other plants. This cell threw out from one to three short hyphæ, each of which developed a capsule like an oogonium at its extremity, which, in turn, repeated the same process until a complex branching structure was produced. But under some other circumstances longer branching hyphæ, either devoid of oogonia or only bearing them at much longer intervals, were produced.

In conclusion I have again to thank Mr. CASH and Mr. SPENCER, of Halifax, and Mr. JOHN AITKEN, of Urmston, near Manchester, for the free access they have given me to their cabinets, and to Mr. BUTTERWORTH, Mr. YOUNG, F.G.S. of London, and

Mr. THOMAS BRITAIN, of Manchester, for sections of the specimen discovered by Mr. BUTTERWORTH.

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PLATE 47.

*Lepidodendron selaginoides.*

Fig. 1. Transverse section of a young twig of *Lepidodendron selaginoides*, enlarged 13 diameters. *a.* Vasculo-medullary axis. *b.* Innermost cortex. *d.* Zone from which the middle bark has disappeared. *e.* Parenchymatous portion of the outer bark, passing into the bast-layer *f.* *g.* Leaves.

PLATE 51.

Fig. 2. Segment of a similar section to fig. 1. Reference letters as in that figure. Enlarged 27 diameters.

PLATE 48.

Fig. 3. Transverse section of the centre of a twig in which an exogenous vascular zone, *h*, starting from opposite the point *x*, has extended both radially and laterally. *c, c'*, foliar vascular bundles in the innermost bark. Enlarged 36 diameters.

Fig. 4. Segment of a similar section with the exogenous zone further advanced. Enlarged 12 diameters. *i, i.* Accidental fissures in the bark.

PLATE 49.

Fig. 5. Vasculo-medullary axis and exogenous zone of a section similar to fig. 4. Enlarged 28 diameters.

PLATE 50.

Fig. 6. Central axis of a more advanced twig in which the exogenous growth, *h*, has completely enclosed the vasculo-medullary axis. Enlarged 27 diameters.

Fig. 7. Transverse section of a branch of *Lepidodendron selaginoides* of larger size, and which has reached a perfectly Diploxyloid stage of growth. *e.* Parenchymatous zone of outer bark. *f.* Bast layer of outer bark. Enlarged nearly 6 diameters.

## PLATE 49.

Fig. 8. Transverse section of the central portion of a young twig preparing for dichotomous branching. *A*. One portion of the divided vasculo-medullary axis, with an incipient exogenous zone at *h*. *B*. The other portion of the axis, without an exogenous zone, as in figs. 1 and 2. *a*. Medullary cells. *b*. Cells of inner bark. *c*. Foliar vascular bundles. Enlarged 18 diameters.

## PLATE 52.

*Lepidodendron Harcourtii*.

Fig. 9. Transverse section of a young branch  $1\frac{1}{2}$  inches in diameter. *a*. Cellular medulla. *a'*. Vasculo-medullary cylinder. *a''*. A segment of *a'* with its surrounding inner cortex, *b'*, becoming separated to supply a lateral branch. *b*. Inner bark. *c*. Foliar vascular bundles. *d*. Middle bark. *e*. Parenchymatous layer of outer bark. *f*. Prosenchymatous, or bast-layer of the same. *g*. Leaves.

## PLATE 51.

Fig. 10. Vasculo-medullary axis with the inner and middle bark of a more developed specimen. Enlarged 9 diameters. References as in fig. 9.

## PLATE 49.

Fig. 11. Segment of a transverse section of the inner bark of a more matured branch, showing a rudimentary exogenous zone. *b*. Large cells. *c''*. Foliar vascular bundles. *h*. Transversely divided exogenous vascular wedges. *h'*. Deflected vessels of obliquely intersected wedges. Enlarged 27 diameters.

## PLATE 51.

Fig. 12. A branch-bundle, similar to fig. 9, *a''*, *b'*, but from nearer to the periphery of a section, and in a more advanced stage of development. *a*, *a'*. Vasculo-medullary axis. *b*. Inner bark. *c*. Foliar vascular bundles. *d*. Middle bark. Enlarged 21 diameters.

## PLATE 53.

*Stigmarian Rootlets*.

Fig. 13. Central portion of a rootlet of the recent *Selaginella Martensii*. *a*, *a'*. Xylem

- portion of the root bundle. *b.* Phloëm portion of the same (Liber-cells of VAN TIEGHEM). *c.* Inner cortical cylinder. Enlarged 270 diameters.
- Fig. 14. Usual aspect of the transverse section of a matured rootlet of *Stigmaria ficoides*. *a.* Vascular bundle. *c.* Inner cortex. *d.* Outermost cortex. The middle bark is wanting. Enlarged 30 diameters.
- Fig. 15. Transverse section of a matured rootlet in which all the tissues are preserved. *a.* Vascular bundle. *b.* Small cells in the position of the Liber-cells of fig. 13. *c.* Cylinder of inner bark. *d.* Outermost bark. *e.* Middle bark. Enlarged 55 diameters.
- Fig. 16. Transverse section of a very young rootlet enlarged 80 diameters. *a.* First formed vessels of the vascular bundle. *b.* Space left vacant by the disappearance of the Phloëm. *c.* Cylinder of inner bark. *d.* Outermost cells of the outer bark. *e.* Remnant of the middle bark.
- Fig. 17. Transverse section of the inner cortex, *c*, and the vascular bundle, *a*, of a similar rootlet to fig. 16. Enlarged 270 diameters.
- Fig. 18. Vascular bundle and inner bark-cylinder of a rootlet like fig. 14. Enlarged 66 diameters.
- Fig. 19. Similar object to fig. 18. Enlarged 140 diameters.
- Fig. 20. Similar section of the centre of a yet larger rootlet. *a.* First-formed vessels accidentally detached from the bark-cylinder *c*. *a'*. Newest formed centripetal ones.

*Medullary rays of Lepidodendron selaginoides.*

- Fig. 21. Part of fig. 7. Enlarged 200 diameters. *h, h.* Three vascular wedges. *k, k.* Two medullary rays containing barred cells.

PLATE 54.

- Fig. 22. Part of a similar section to fig. 7, but taken from the junction of the exogenous zone, *h, h*, with the vasculo-medullary cylinder *a*, and exhibiting barred cells at the medullary extremities of the medullary rays *k, k*. *x.* Zone of small vessels uniting the vasculo-medullary cylinder with the exogenous wedges *h, h*. Enlarged 200 diameters.

*Calamostachys Binneyana.*

- Fig. 23. Part of a transverse section of a strobilus of *Calamostachys Binneyana* in the plane of a fertile verticil, enlarged 46 diameters. *k.* Outer cortex of the axis of the strobilus. *u.* Sporangia filled with spores. *v.* Sporangiohores. *v'', v'''*. Narrow points near the margins of the peltate peripheral extremities

of the sporangiophores, *v*, at which they are organically united to the sporangia. Enlarged 36 diameters.

- Fig. 24. Oblique longitudinal section through a strobilus exhibiting both macrospores and microspores. Enlarged 18 diameters. *k*. Central axis. *t*. Barren bractigerous disks. *t'*. Bracts of *t*. *v*. Sporangiohores of the fertile verticils. *u*. Sporangia with microspores. *u'*. Sporangia with macrospores.
- Fig. 25. A microspore of fig. 24, *u*, enlarged 165 diameters.
- Fig. 26. A macrospore of fig. 24, *u'*, enlarged 165 diameters. *a*. Exosporium. *b*. Endosporium. *c*. Central mass of carbonised matter.
- Fig. 27. Portions of the margins of three barren disks, *t*, showing the ascending marginal bracts *t'*. Enlarged 15 diameters.

*Carboniferous Fungi.*

- Fig. 28. *Peronosporites antiquarius* from Halifax. *a*. Hyphæ. *b*. Oogonia. *c*. Cells of a fragment of bark. Enlarged 375 diameters.
- Figs. 29, 30, 31, 32, 33. Various fragments of the same from a specimen from Oldham. Enlarged 500 diameters.
- Fig. 34. Fragments of a Fungus with smaller hyphæ from Halifax. Enlarged 675 diameters.

PLATE 48.

- Fig. 35. Fragments of a Fungus with smaller hyphæ from Halifax. Enlarged 675 diameters.
- Fig. 36. *Peronosporites antiquarius*, Oldham specimen. Enlarged 320 diameters.
- Figs. 37, 38. *Peronosporites antiquarius*, Halifax specimens. Enlarged 320 diameters.

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During the progress of the investigations recorded in my eleven memoirs I have experienced some difficulties which would not have been felt if I could have examined the originals of the figures and descriptions left by my predecessors in this study. Those who may follow me in these enquiries may be preserved from similar difficulties by knowing that most of the specimens which I have described will find their permanent resting-place in the Geological Museum of the Owens College, Manchester, where they will be accessible to all who may require to consult them.

Fig. 1.





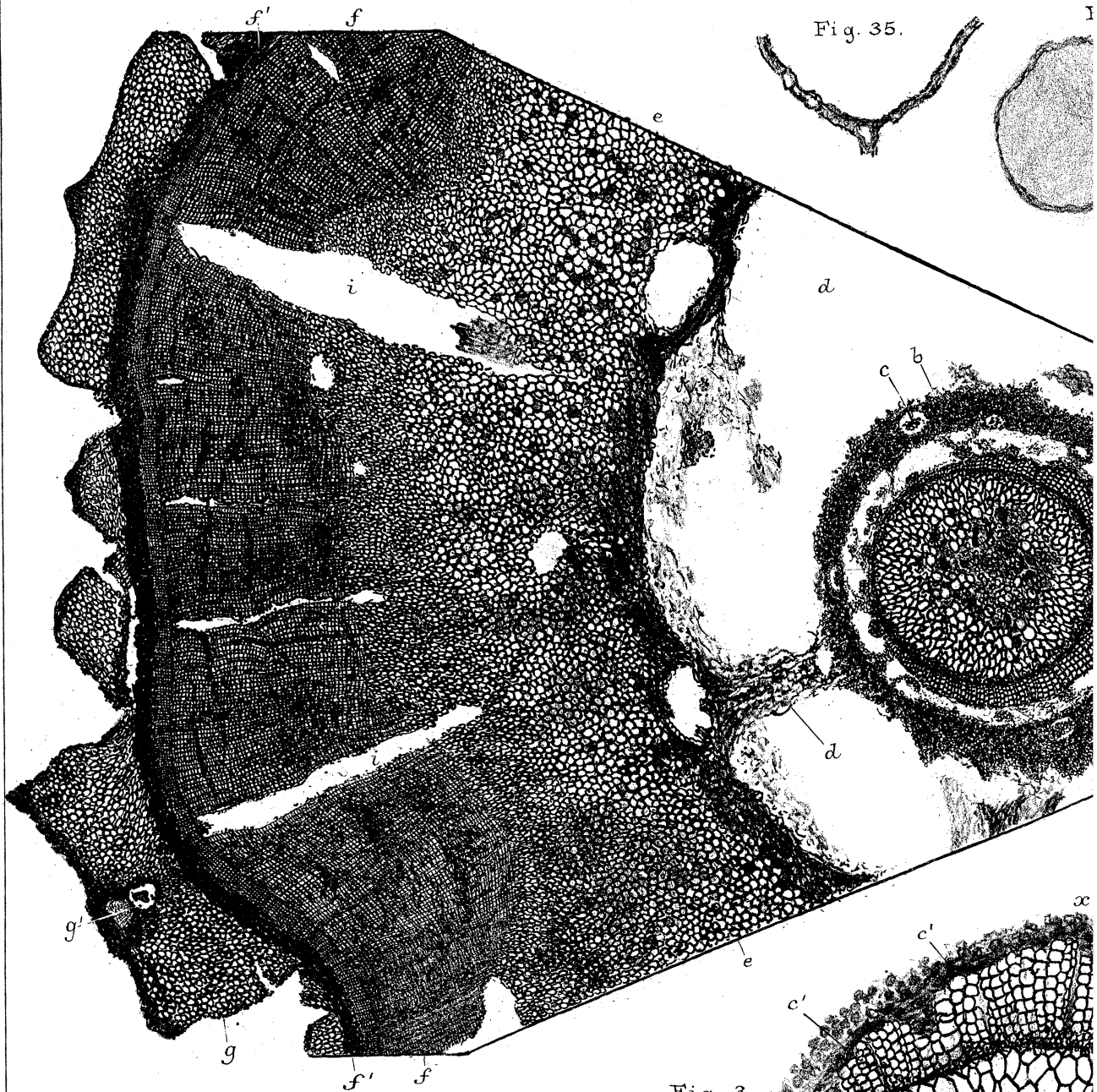


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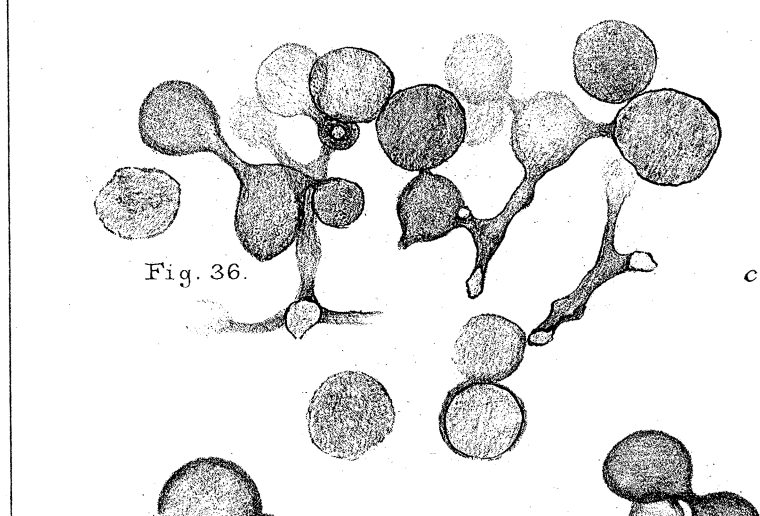


Fig. 36.

Fig. 3.

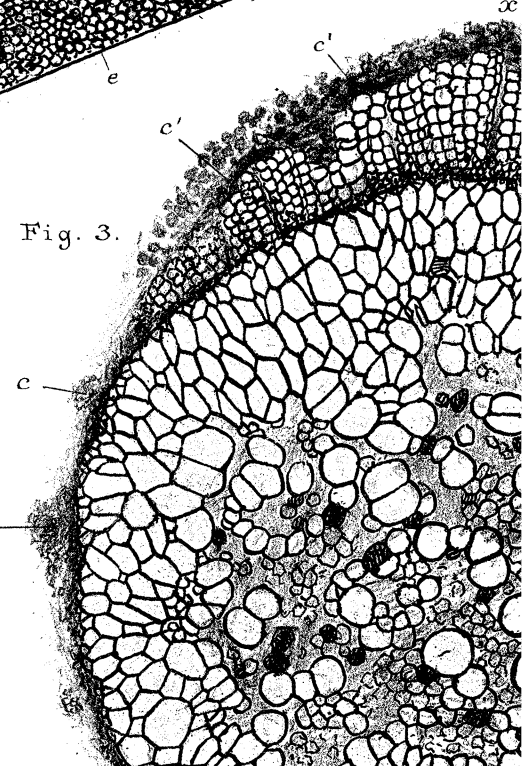


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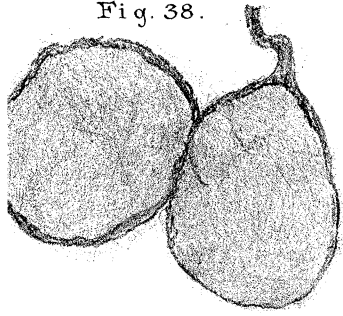
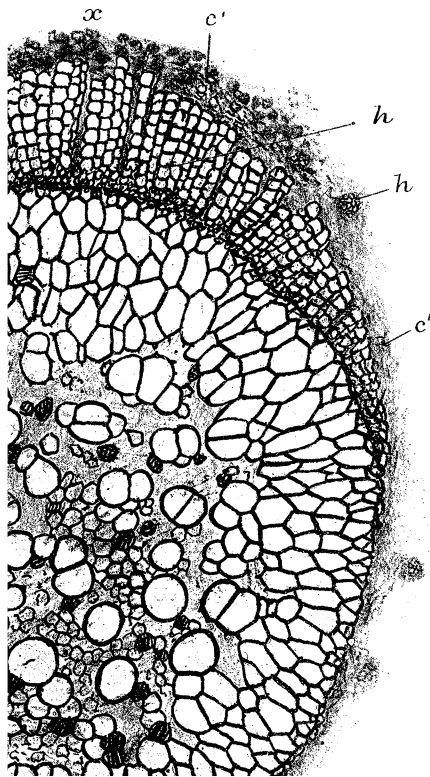


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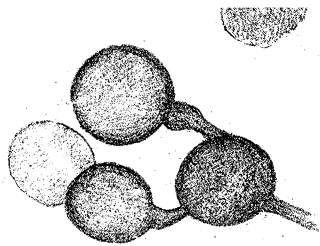


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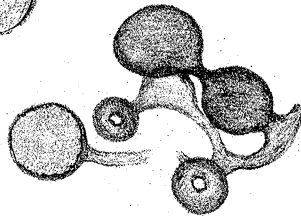
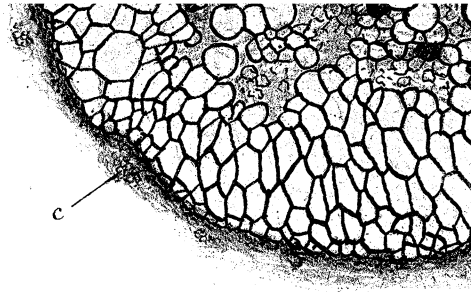
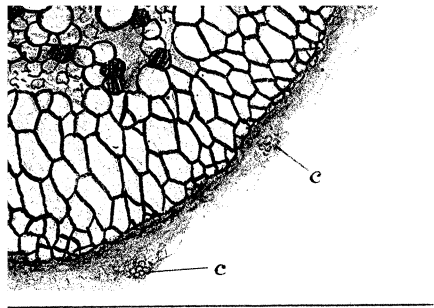


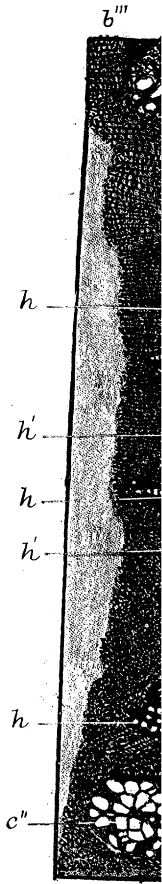
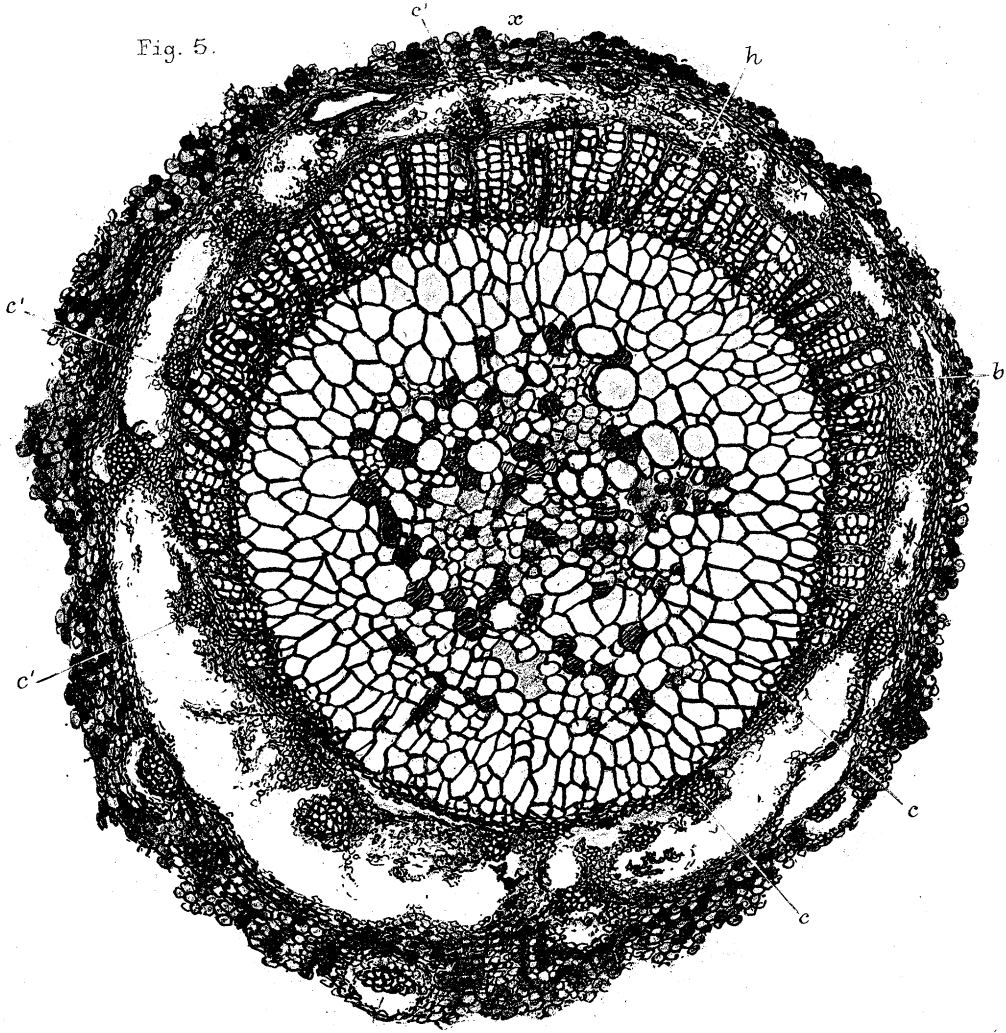
Fig. 37 A





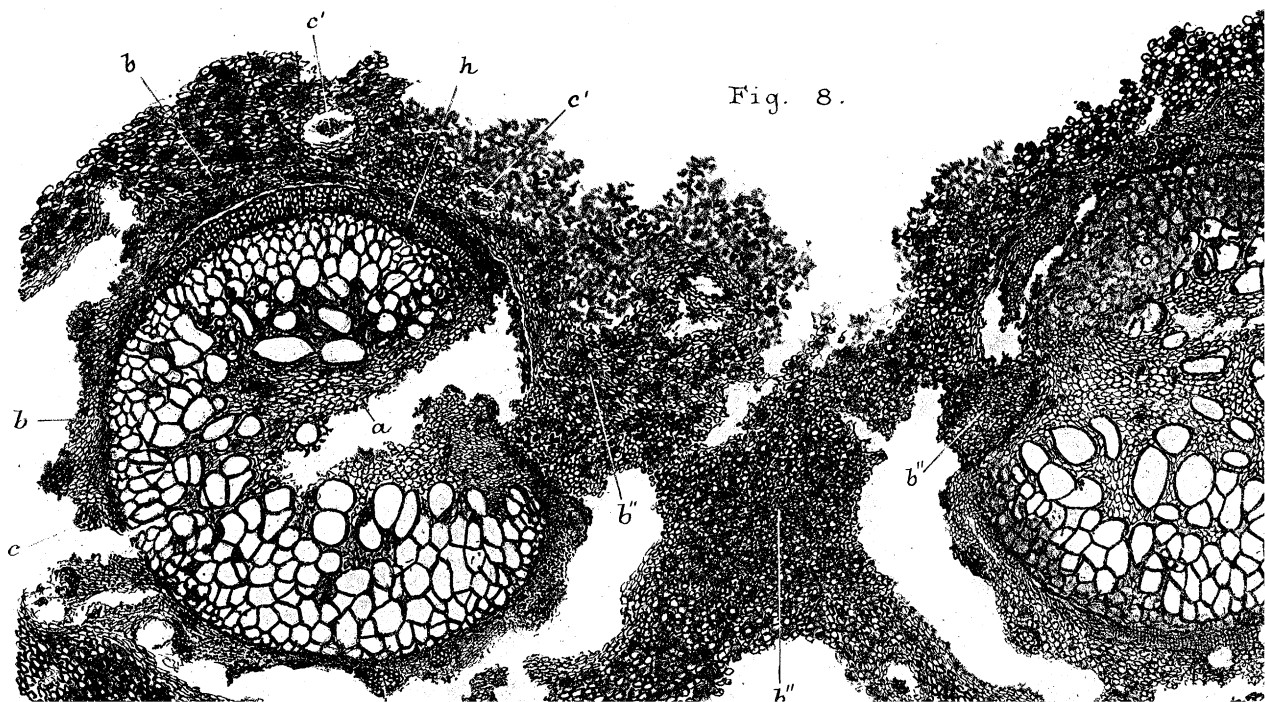
Whitman & Bass, *Photo-Litho*, London.

Fig. 5.



Fi

Fig. 8.



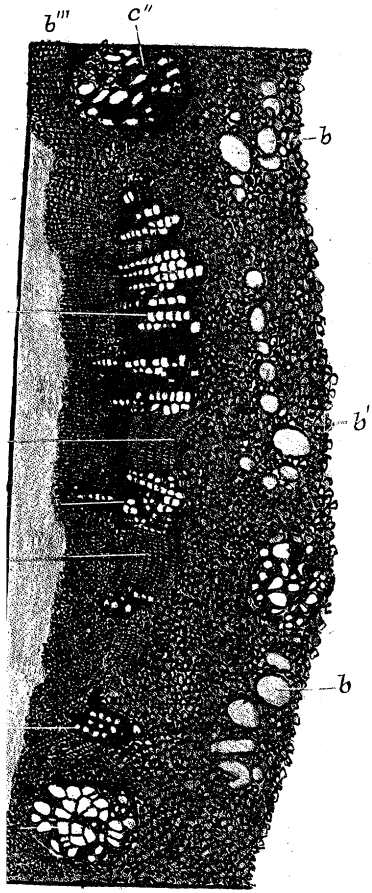
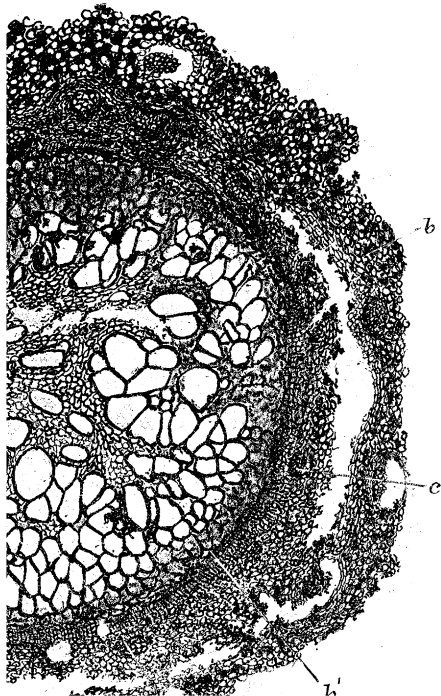
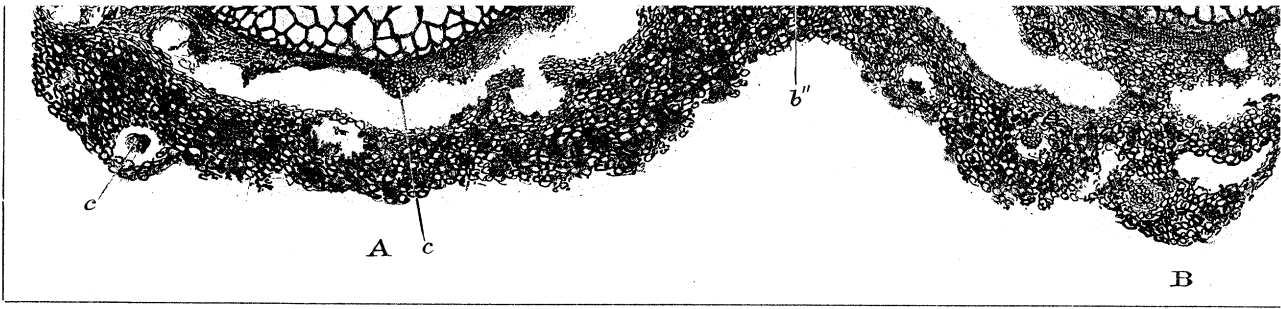
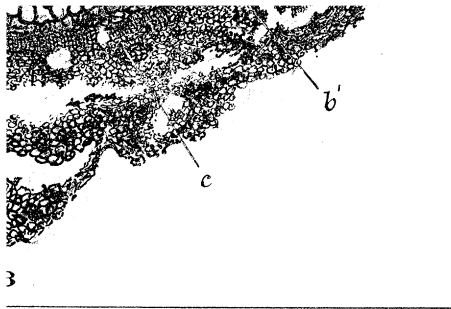


Fig. 11.





W. C. Williamson, Del.



Whitman & Barz. *Micro-Atlas*. London.



Fig. 6.

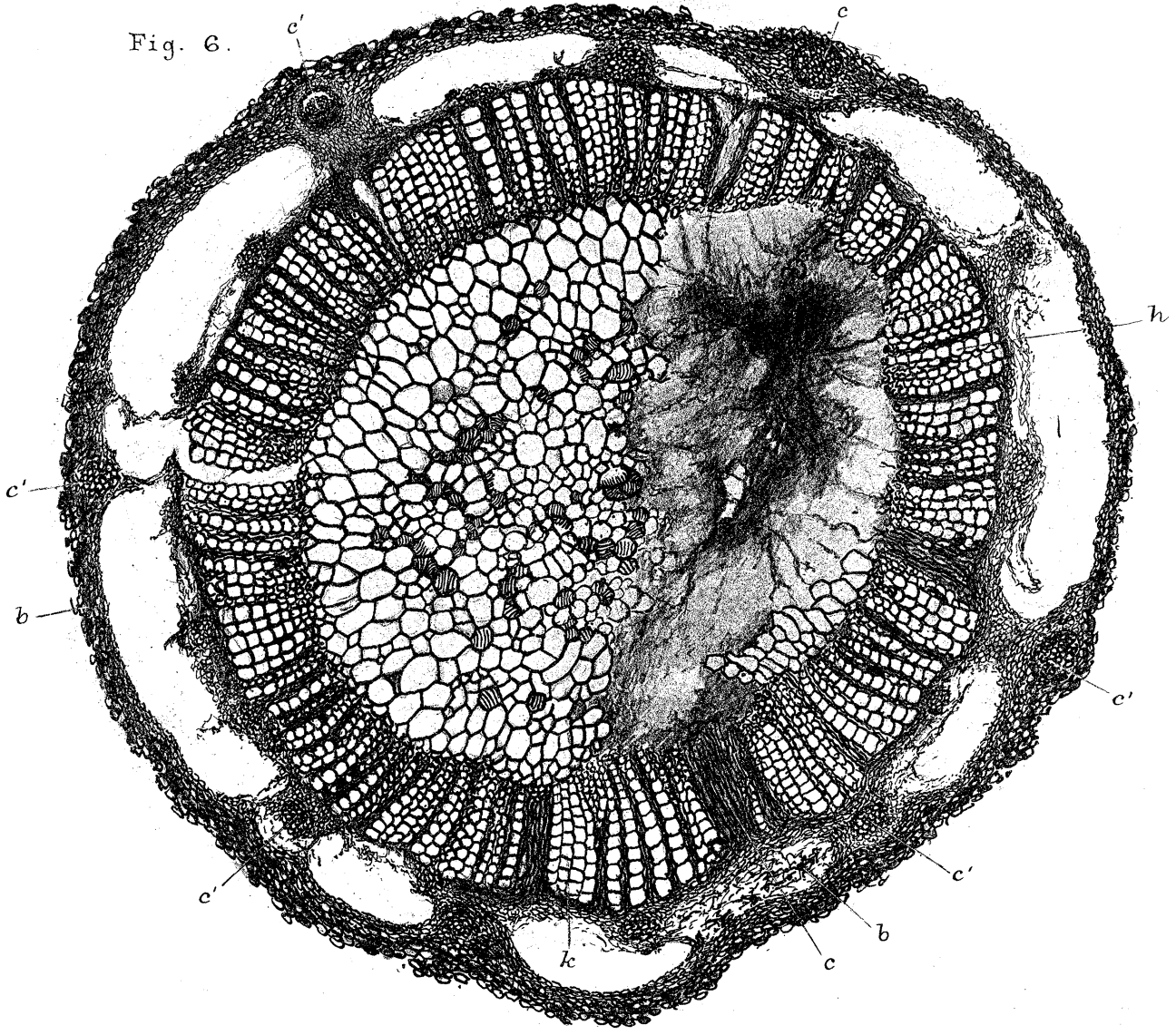
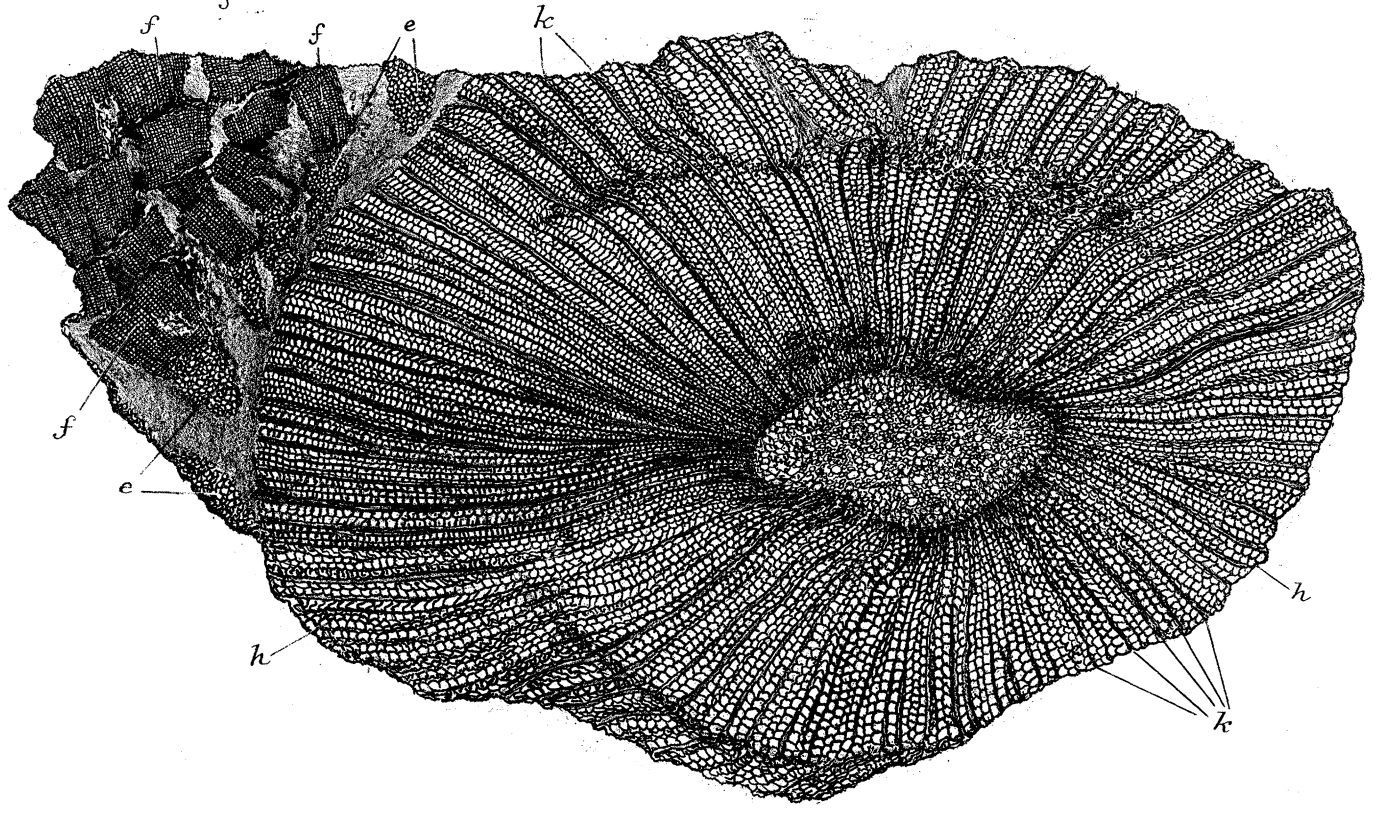


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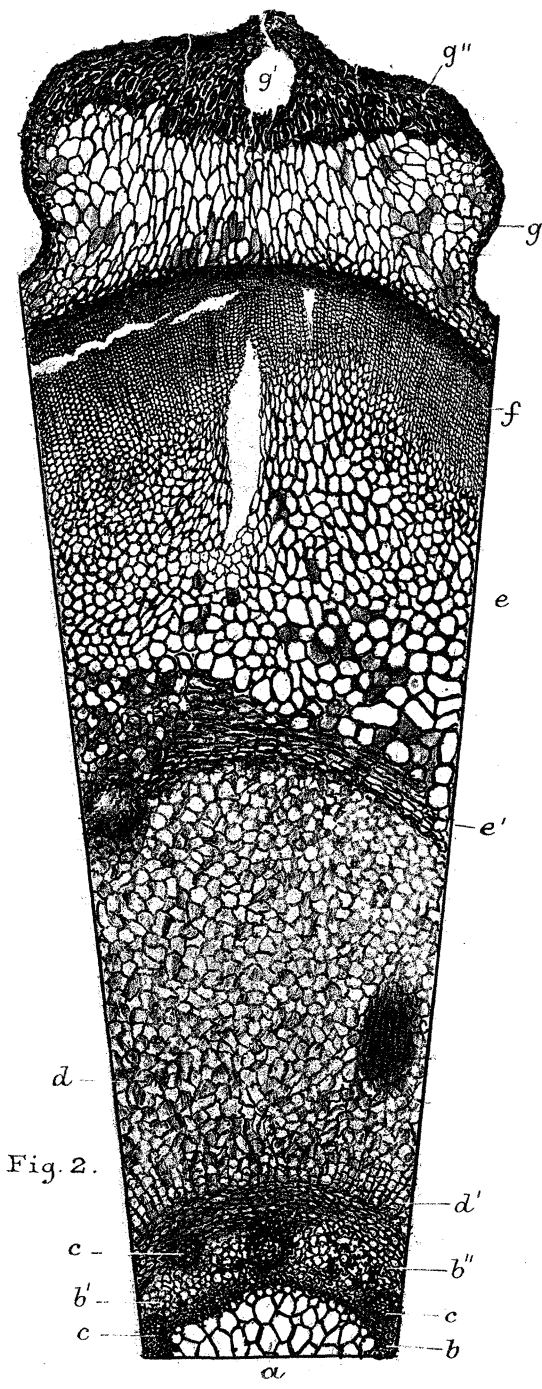


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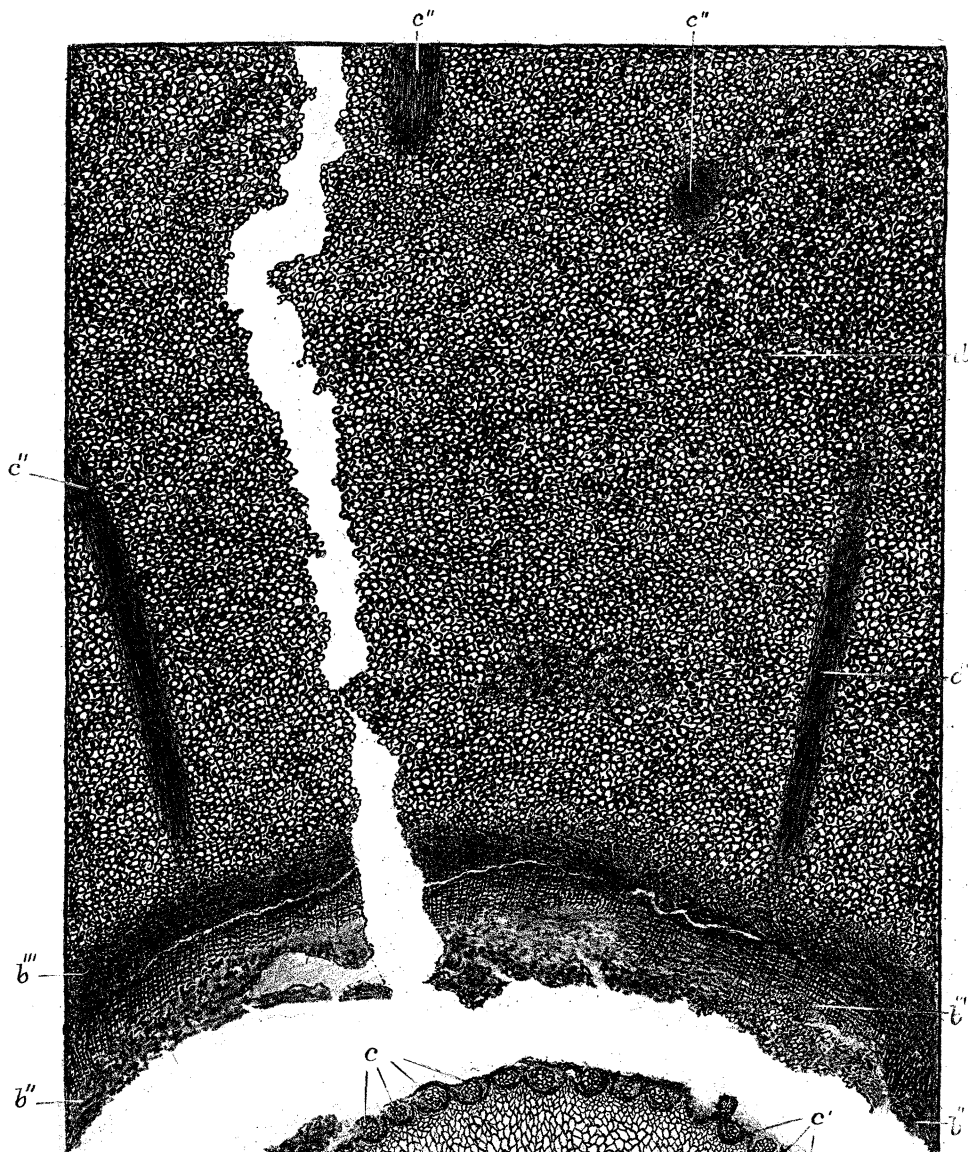


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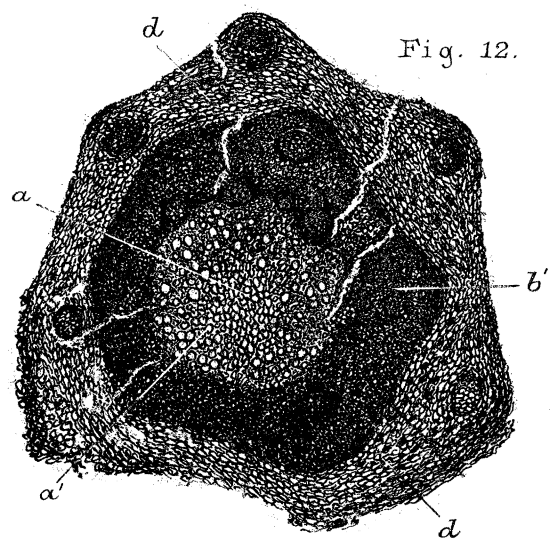


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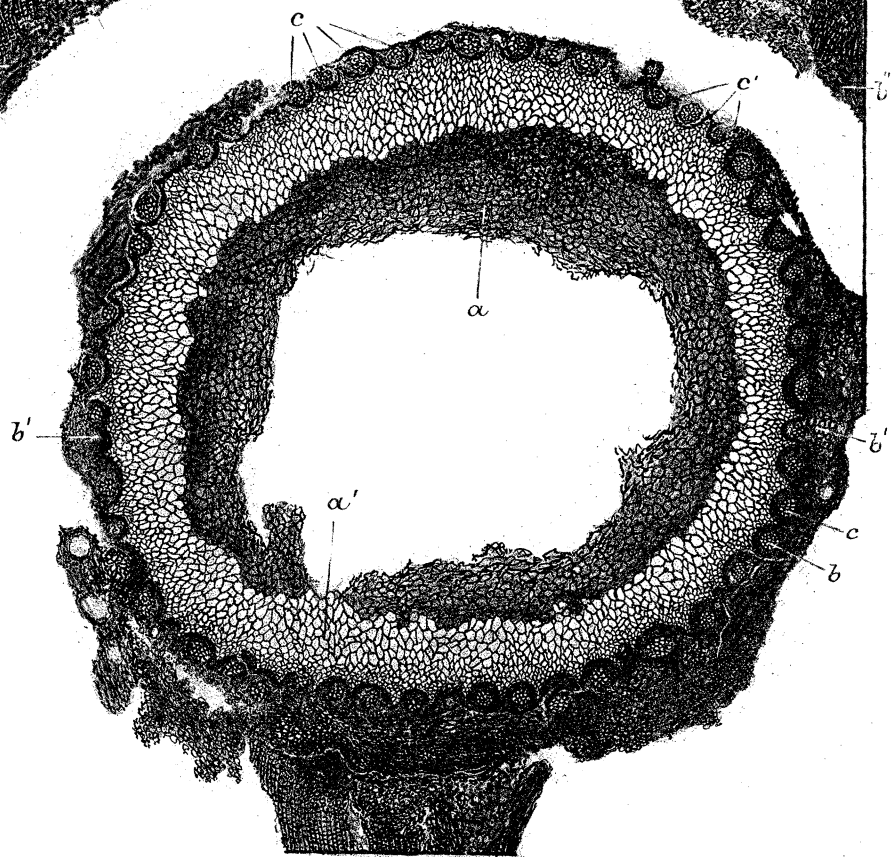


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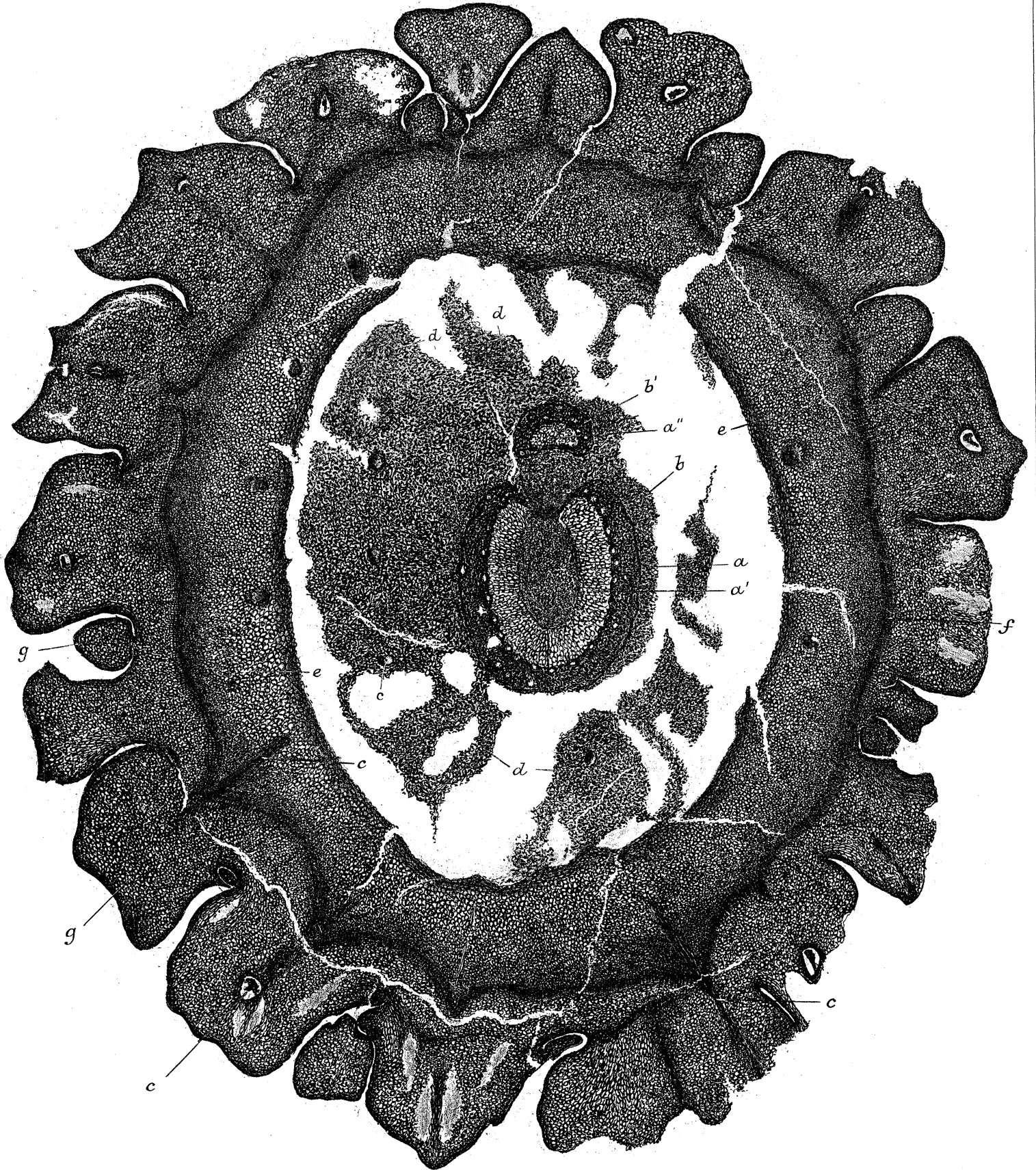




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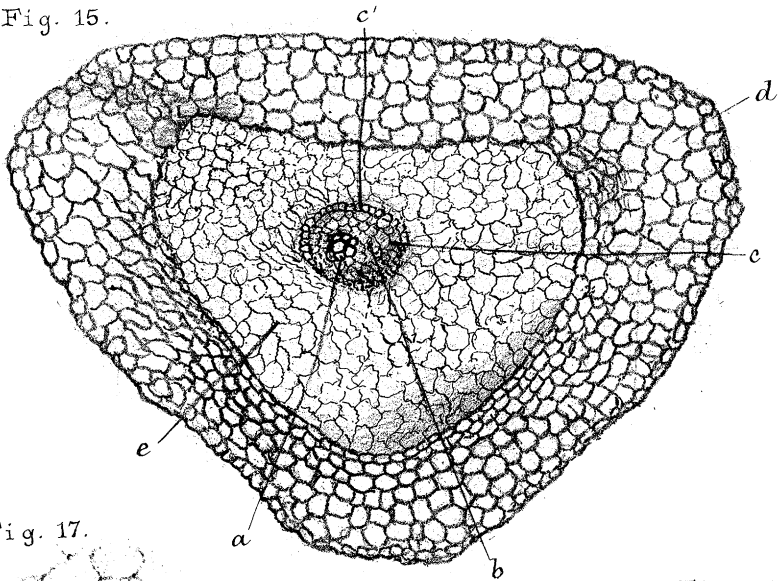


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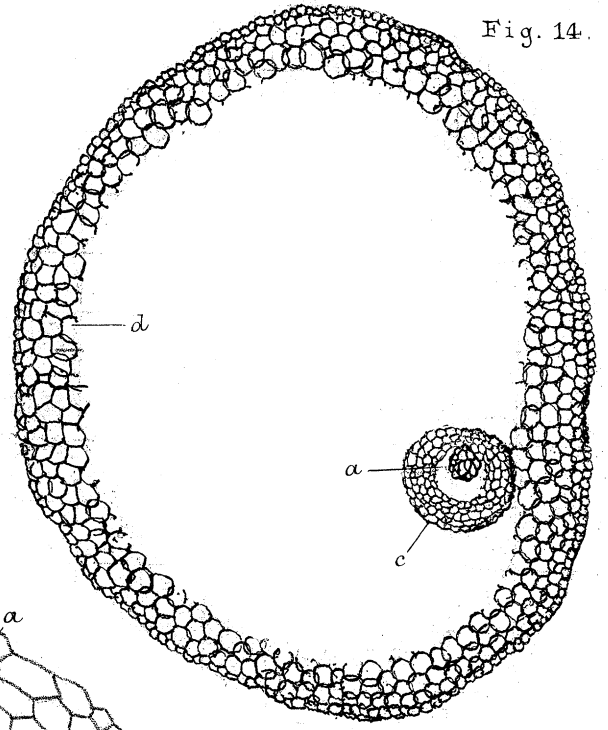


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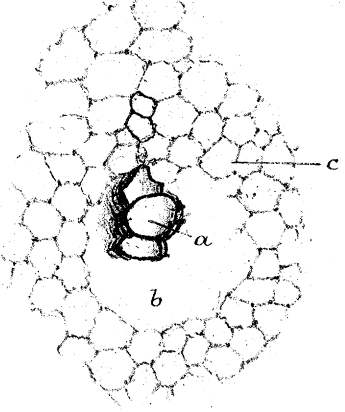


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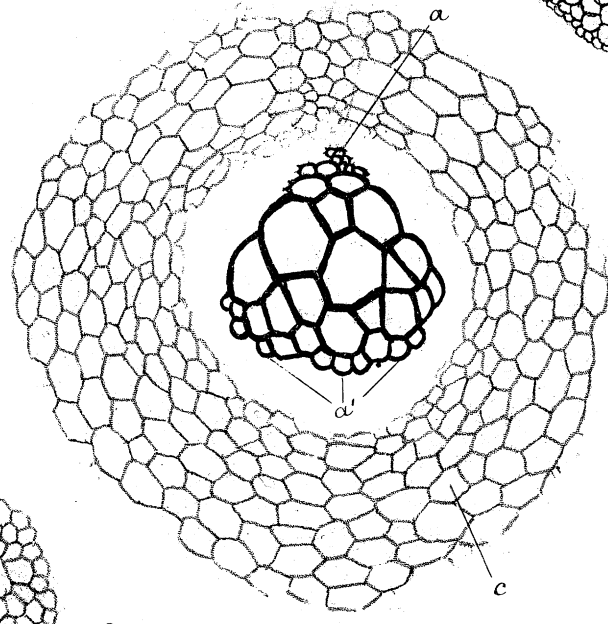


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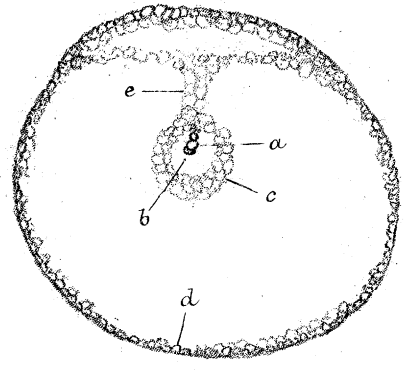


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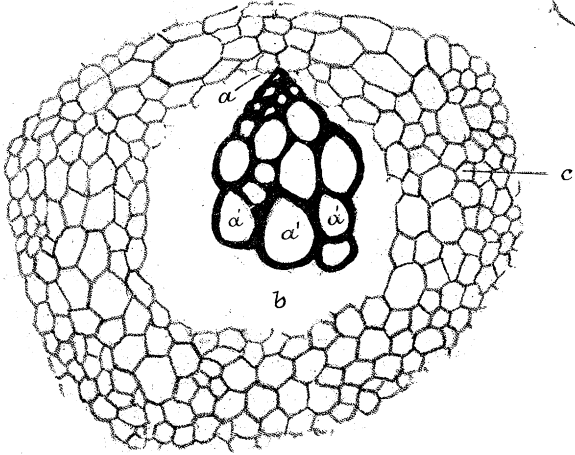


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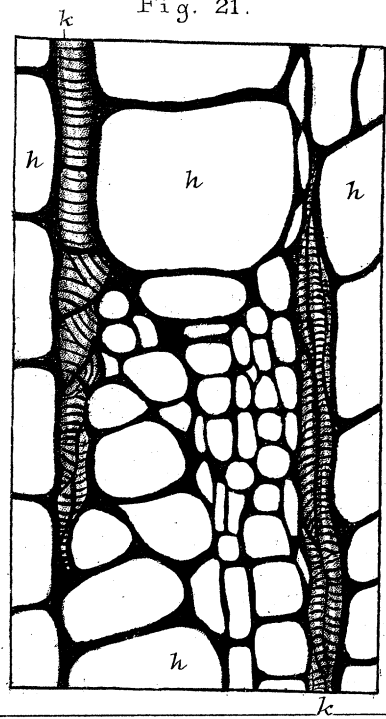


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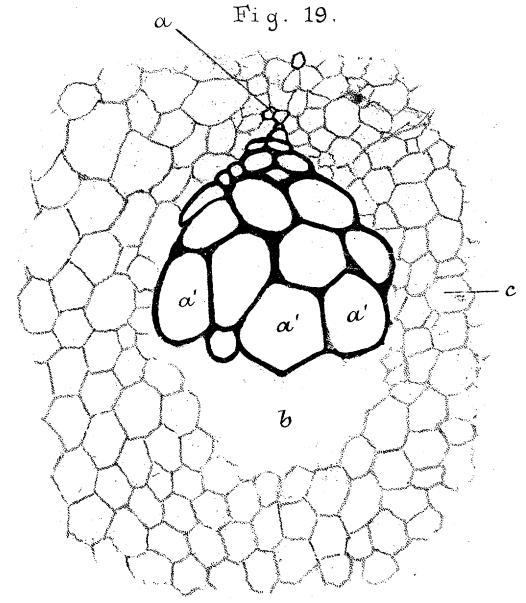


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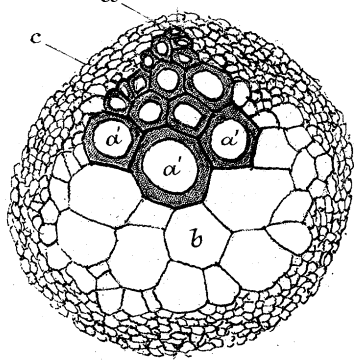


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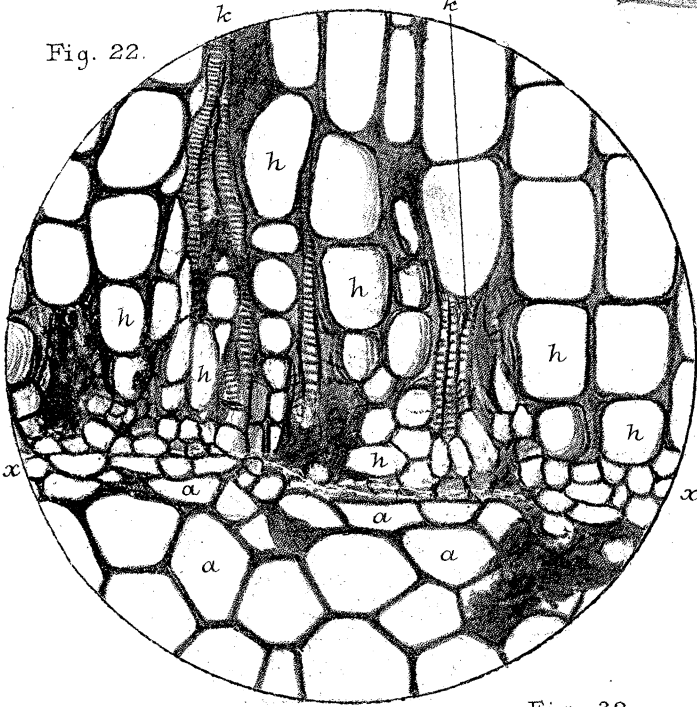


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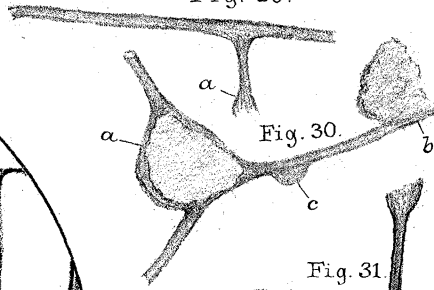


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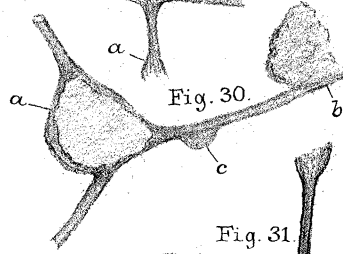


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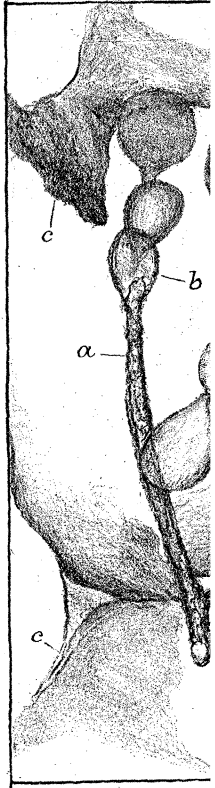
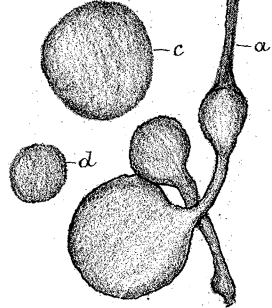


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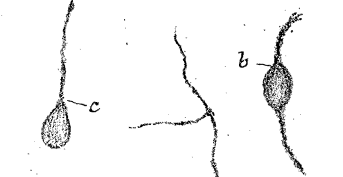


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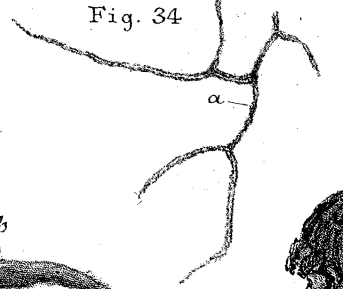


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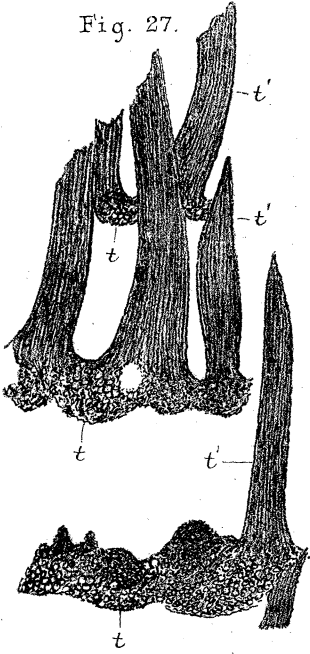


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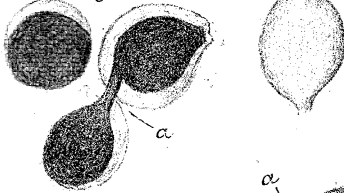


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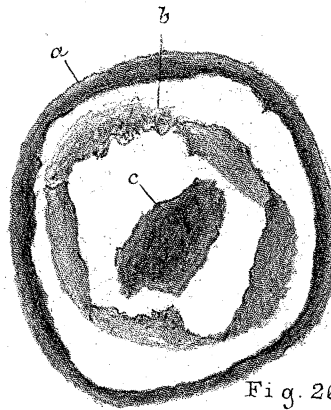
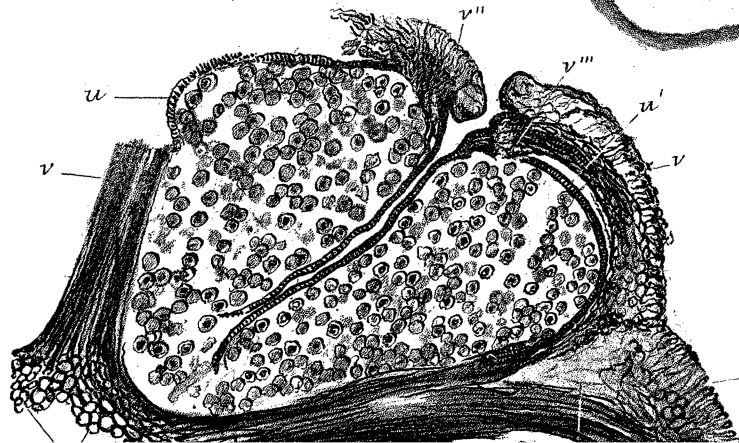
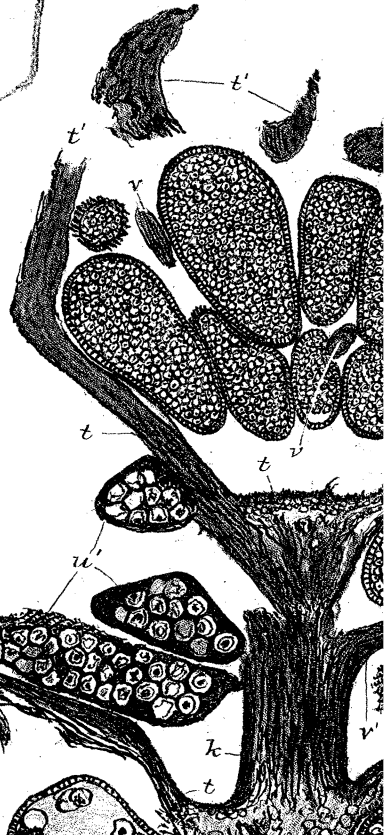


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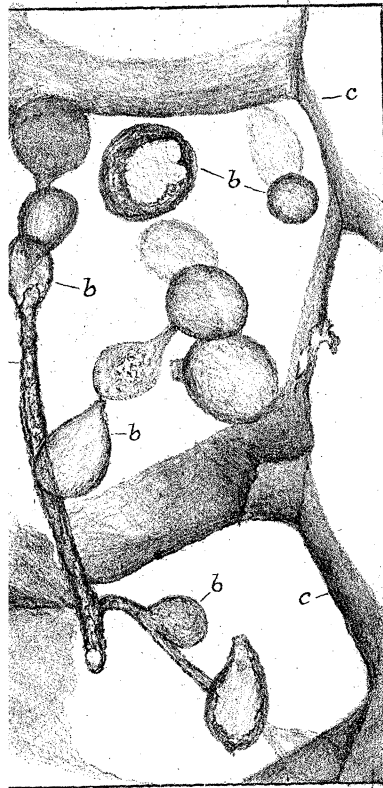
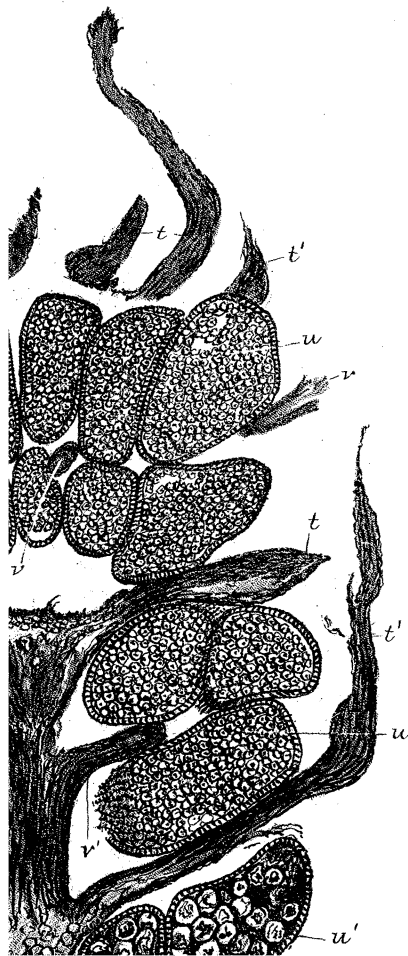


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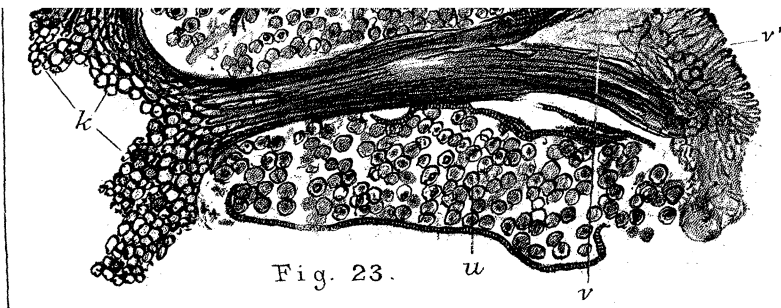


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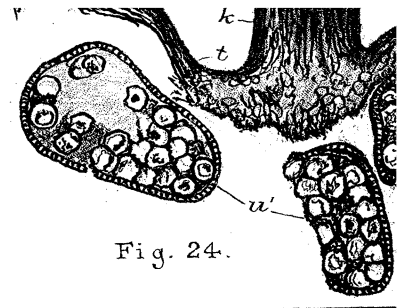
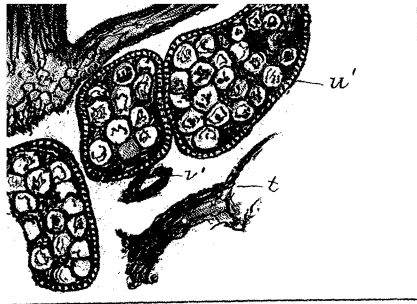
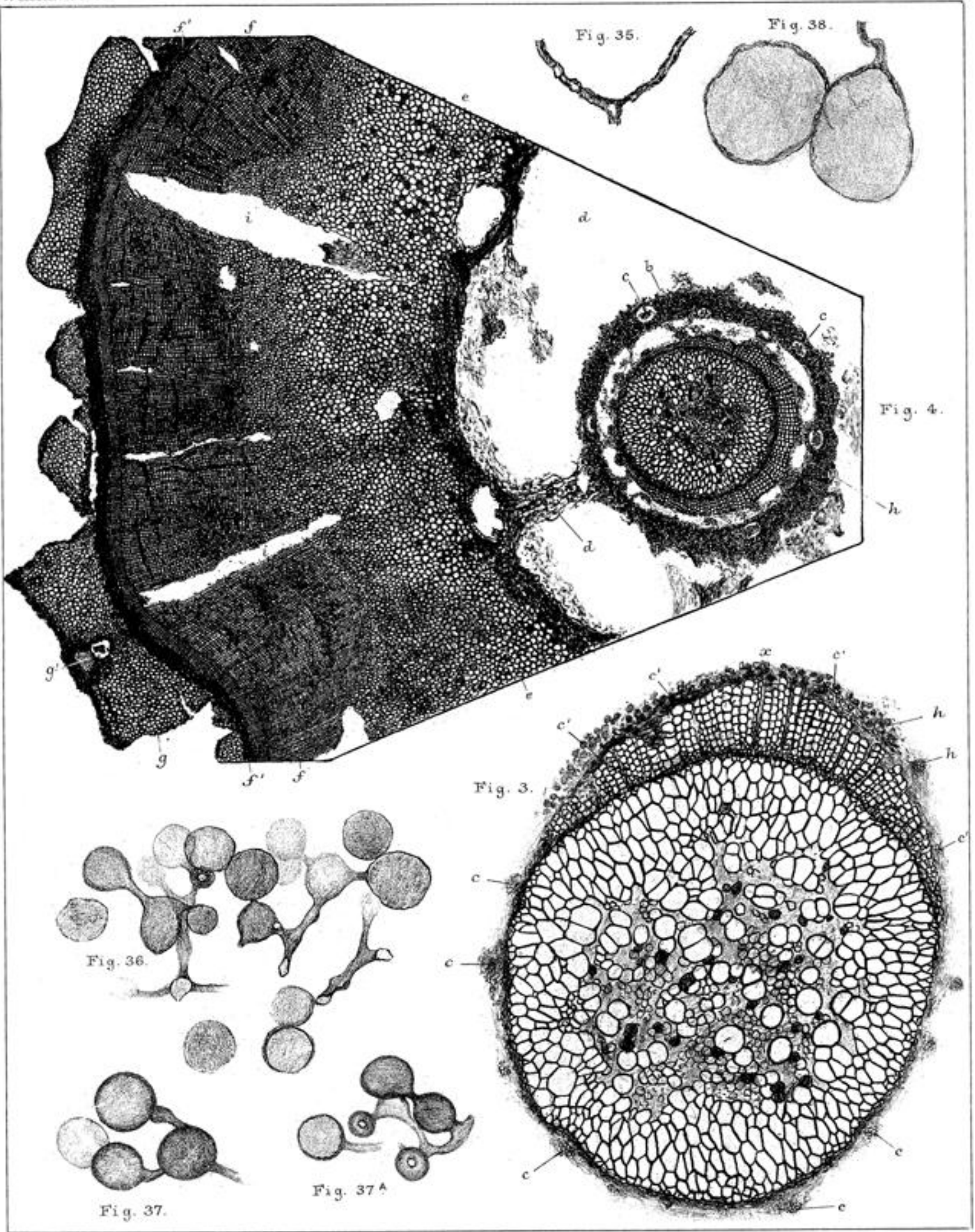


Fig. 24.



Wittmann & Bass, *Bevo-Litho* 1883/84.





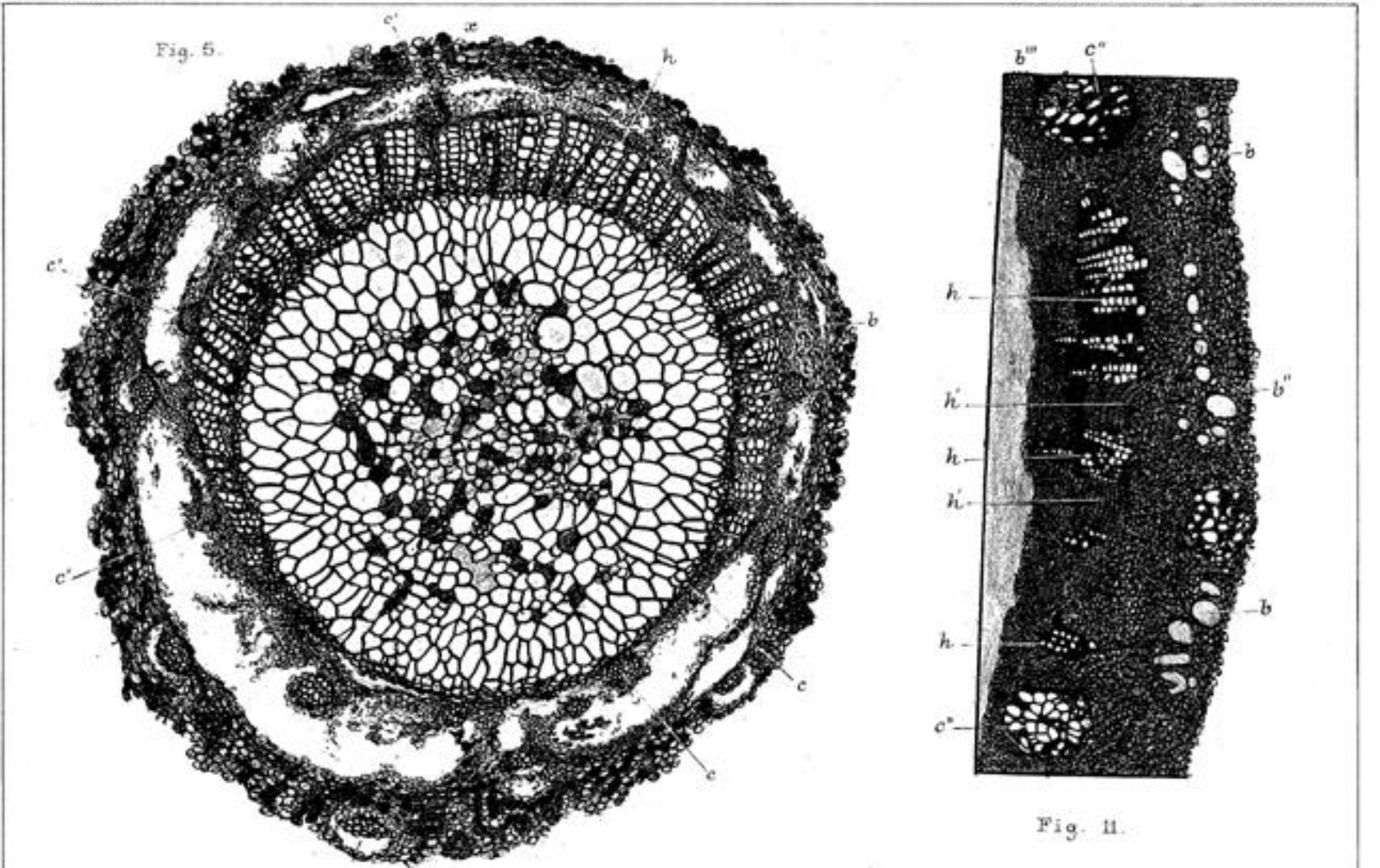


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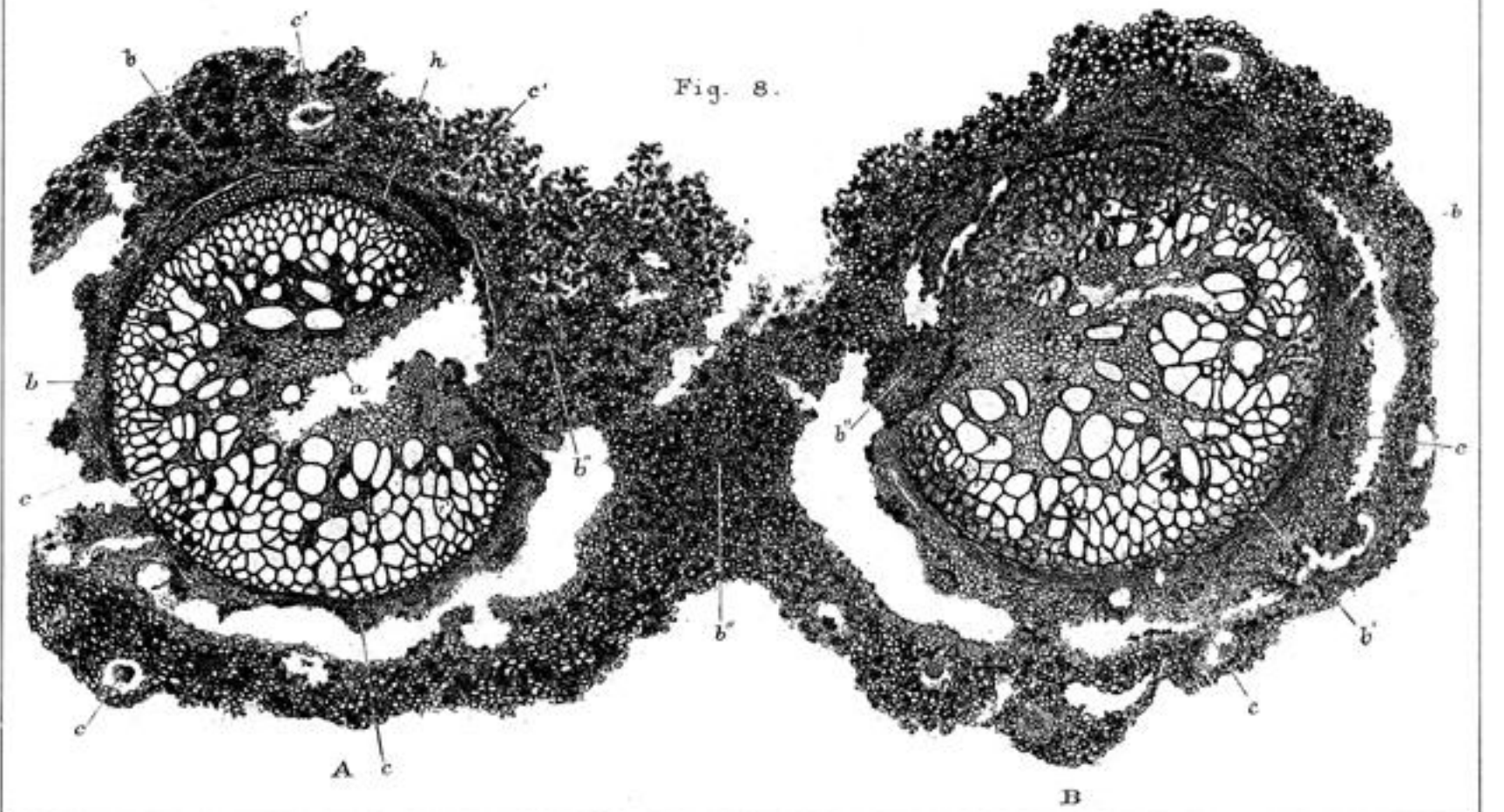


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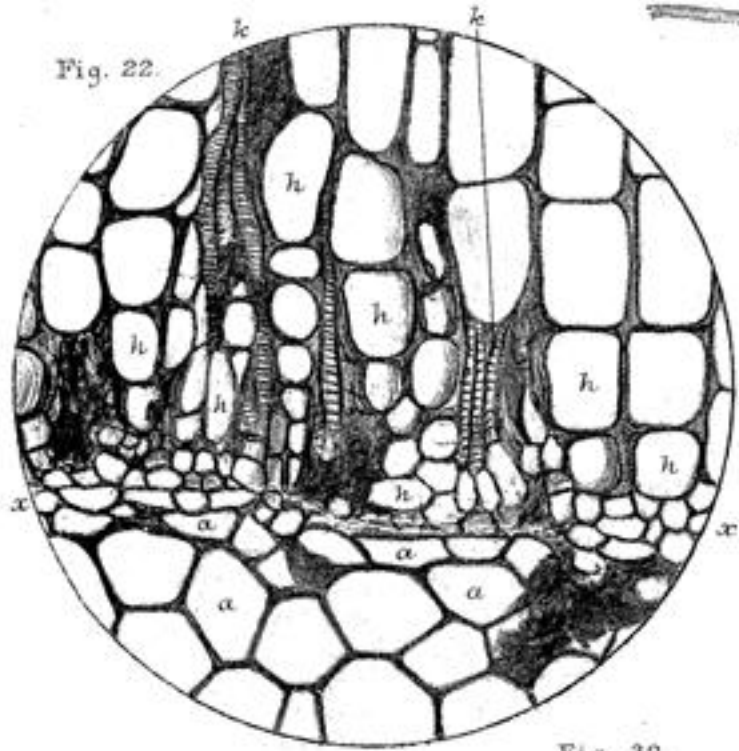


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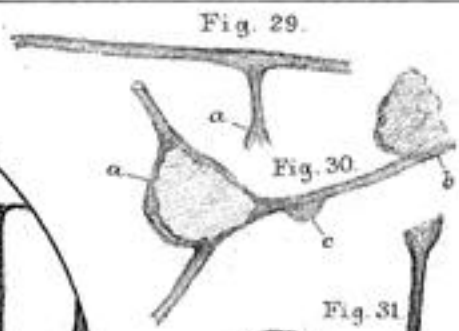


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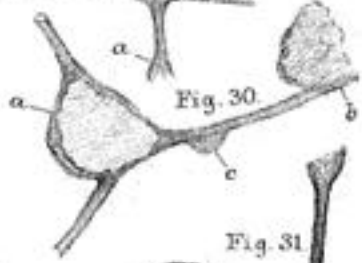


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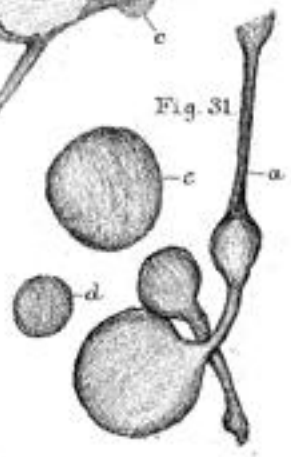


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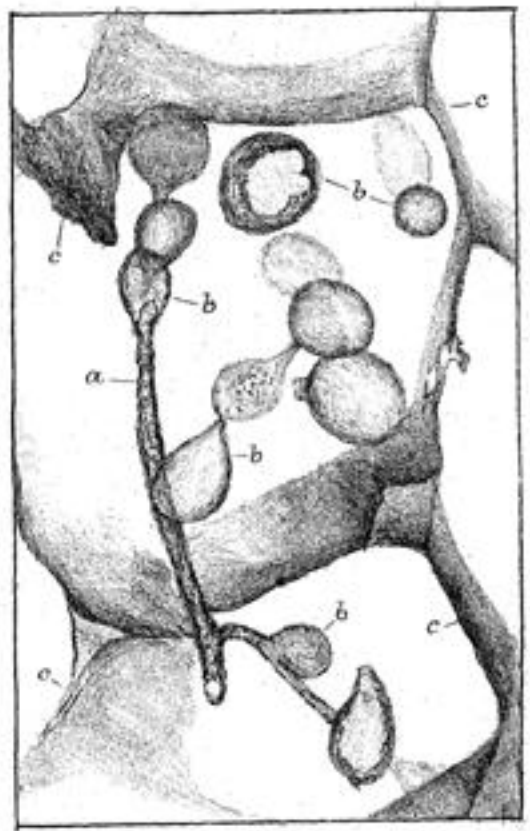


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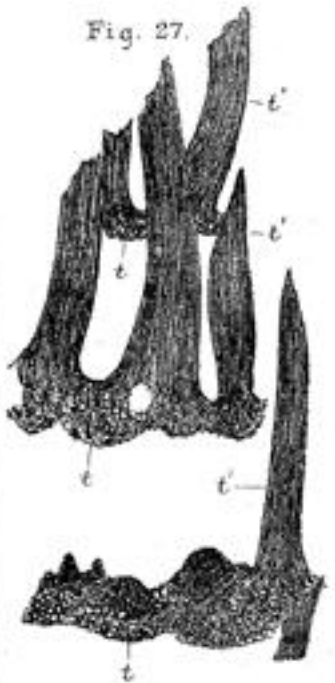


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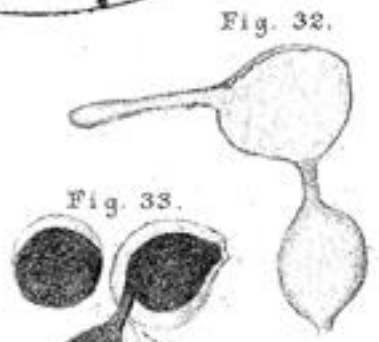


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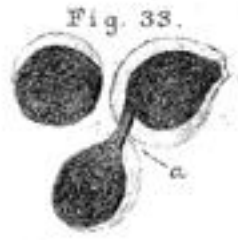


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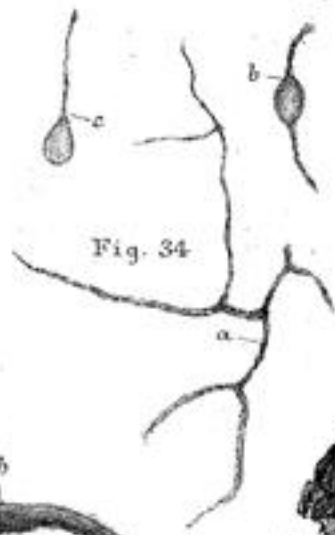


Fig. 34.



Fig. 25.

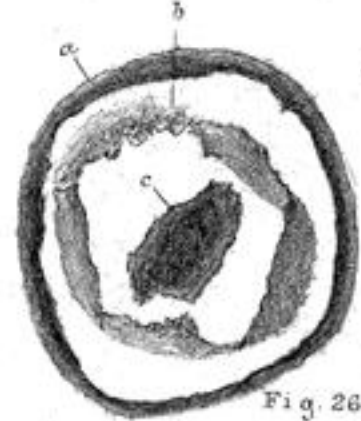


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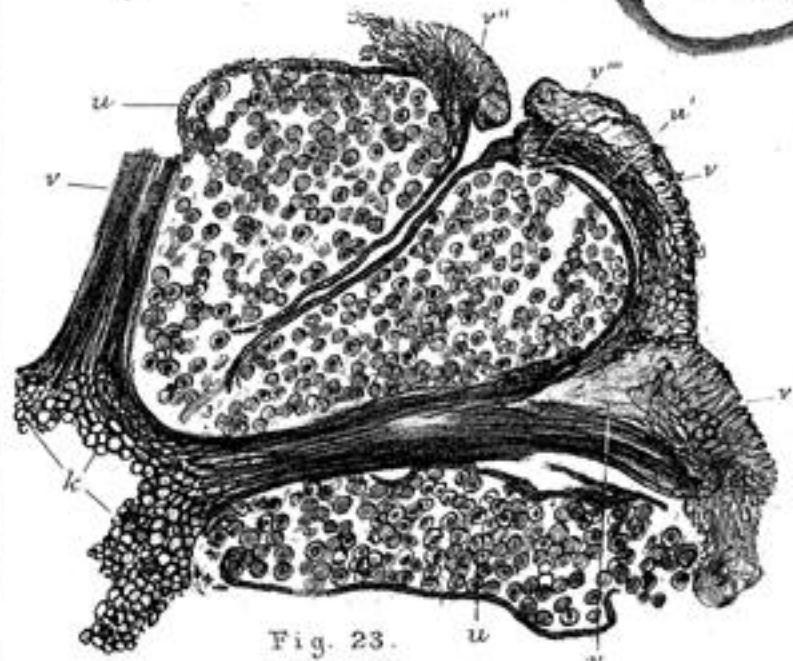


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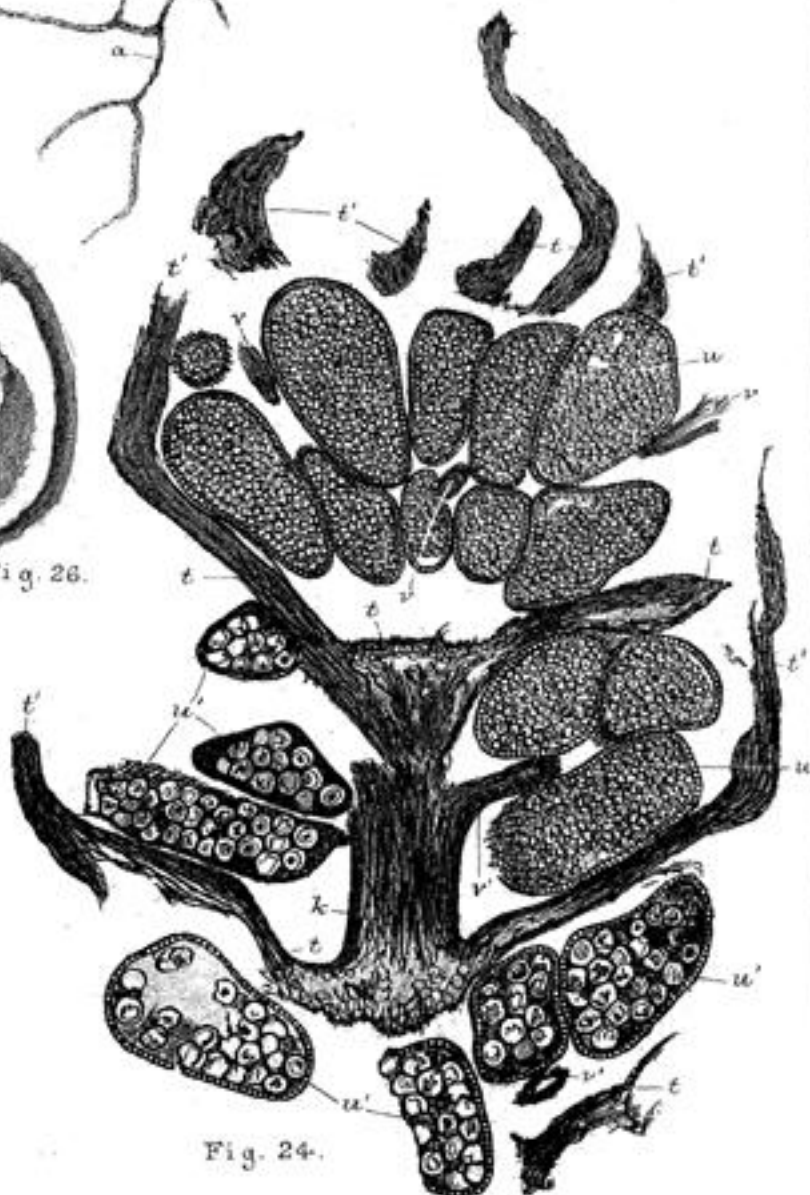


Fig. 24.