X. *On the Organization of the Fossil Plants of the Coal-measures.* — Part IV. Dictyoxylon, Lyginodendron, *and* Heterangium. *By* W. C. Williamson, *F.R.S.*, *Professor of Natural History in Owens College, Manchester.*

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On February 20th, 1866, Mr. Binney gave to the Literary and Philosophical Society of Manchester a brief description of a new plant from the Lower Carboniferous beds of the neighbourhood of Oldham. The following extracts from the 'Proceedings' of the Society embody some of the chief points of that description.

"It evidently belonged to the genus *Pinites* of Witham, since changed by Endlicher and Brongniart into *Dadoxylon*." It "has a medullary axis composed of irregular polygonal cells separated by intervening spaces vertically, and thus forming a kind of discoid pith." "This is separated from lunette-shaped bundles of hexagonal tubes arranged in a convex form from the pith inwards, and lessening in size as they pass outwards into wedge-shaped masses of four-sided subhexagonal cellules arranged in radiating series, and divided by large medullary rays or bundles, which appear to originate in the lunette-shaped masses. On the outside of this internal radiating cylinder are other lunette-shaped bundles similar to those in the inside." "Then comes a narrow zone of lax tissue, which has been a good deal disarranged. Outside this are some thin wedge-shaped bundles of cellules full of dark carbonaceous matter, and arranged in radiating series of varying sizes, separated by lax tissue, probably representing the bark of the tree."

"In the longitudinal section the cellules are seen to be greatly elongated and divided with oblique and transverse dissepiments placed at great distances. Two of the walls, viz. those facing the medullary rays, are regularly reticulated with six, seven, and eight series of hexagonal areolæ arranged regularly but not in a line."

"In the tangential section the walls of the cellules also show a reticulated appearance, something like that previously noticed, but not in so marked and distinct a manner; and the medullary rays or bundles, in their section, show numerous irregular series of small cellules of one to four, and more rarely much larger cellules."

"The areolæ on the walls of the cellules are more numerous than in any species of *Pinites* or *Dadoxylon* that have hitherto come under my notice, the *Pinites medullaris* of Witham having the walls of its elongated cellules with two, three, and four series of contiguous areolæ, and those only on the walls parallel to the medullary rays, whilst in my specimen they are reticulated with six, seven, or eight, and not only on such walls, but also on the walls at right angles to the medullary rays."

To the plant thus described Mr. BINNEY gave the name of *Dadoxylon Oldhamium*.

The above object came under my notice at an early period of my investigations amongst the plants of the Coal-measures, and I soon became convinced that it was *not* a *Dadoxylon*. In a brief memoir published in the 'Monthly Microscopic Journal' for August 1869, I pointed out that, since the appearance of ENDLICHER'S memoir on *Dadoxylon*, "numerous specimens of woody stems have been found, *transverse* sections of which exhibit a structure identical with that of living conifers; but longitudinal sections show that the vessels or fibres are altogether different from the coniferous or discigerous type. Instead of bearing rows of disks, and those only on the surfaces of the vessels parallel with the medullary rays, their entire walls are covered with reticulations formed by the deposition of lignine *in the interior* of the vessels." Then, after describing some figures, I proceeded to say, "These two figures represent reticulated fibres as seen in several distinct plants found in the Coal-measures. Whether these prove to be different species of one genus, or whether they will require more than one genus for their reception, remains to be seen. But certainly none of them can be regarded as Dadoxylons, since they belong to an altogether different type of structure."

"It appears necessary, therefore, to establish a new genus for all the plants whose woody cylinders consist of reticulated fibres, and the name of *Dictyoxylon* appears an appropriate one for it. I should propose for the present to include in this genus *all* the reticulated types, whether their medullary rays consist of one or of several vertical series of cells. At some future time their further separation into two or more genera may be requisite."

The memoir from which the above quotations are taken contains two errors—one of observation, and one due to a misprint. In some examples, in which the structure was imperfectly preserved, I found it difficult to distinguish the lenticular disks of the supposed conifer *Dadoxylon* from the reticulated areolæ of the Dictyoxylons. The two specimens numbered 7 and 11 in the Plate illustrating the memoir had their vessels in this imperfect condition, and I fell into the error of regarding them as Dictyoxylons. I have since ascertained, beyond doubt, that they are both Dadoxylons*. The second error is a misprint of *Dictyoxylon* for *Dadoxylon* in the eleventh line from the end of the memoir. As it stands, the supposed coniferous fruit known as *Trigonocarpon* is indicated as possibly belonging to the former genus, whereas I intended to suggest the possibility of its relation to the latter one.

At the Edinburgh Meeting of the British Association in 1871, I described yet more definitely the characteristics of my genus *Dictyoxylon*, especially as represented by three plants, viz. Mr. BINNEY'S *Dadoxylon Oldhamium*, a new species from Burntisland to which I gave the name of *Dictyoxylon Grievii*, and a third form from the Lancashire Coal-measures, to which I assigned the name of *D. radicans*. Further investigation into the history of the latter plant has led me to separate it from *Dictyoxylon*, under the

* The correction of this error is important, since fig. 11, especially, represents a plant with a Sternbergian pith, whereas no such pith occurs in any known true *Dictyoxylon*.

provisional generic name of *Amyelon**. My genus *Dictyoxylon*, therefore, is limited, for the present, to the two other species already mentioned, at least so far as this country is concerned. M. RENAULT recently brought before the Academy of Sciences at Paris a notice of some French examples of the genus from the Coal-measures of Autun; but as his memoir has not yet been published, I do not know what forms have been discovered by this excellent observer†. I may further observe I have recently found that other genera, *e. g. Asterophyllites*, sometimes possess reticulated vessels like those of *Dictyoxylon* and *Amyelon*.

Dictyoxylon Oldhamium proves to be one of the most common of the plants found in the calcareous nodules discovered in the lower Coal-measures near Oldham and other parts of Lancashire and Yorkshire having the same geological horizon. The vast majority of the specimens are young stems or branches, rarely exceeding an inch in their greatest diameter: nevertheless, as I shall show in the course of this memoir, the plant attained to an arborescent form. It was not an articulated plant, neither was it, in the usual sense of the word, a dichotomous one. It had terminal branches of small size compared with the dimensions of the main axis, but no traces of actual leaves have been discovered in connexion with any specimen that I have seen. The axis possesses the three distinctly marked divisions of pith, wood, and bark, each of which organs requires a detailed description.

The Pith.—As in the Lepidodendroid plants described in my last memoir‡, this structure was of very small size in young twigs, and gradually enlarged with the increasing dimensions of the stem, at least up to a certain stage of growth. Its average size, relatively to that of the entire stem, is seen in Plate XXII. fig. 1, which represents a transverse section made by Mr. BUTTERWORTH. Fig. 2 represents the medullary axis and innermost portion of the ligneous zone of a still younger stem; whilst fig. 4 represents a similar section of an entire ligneous cylinder, with its contained medullary axis and a little of the innermost bark. Fig. 3 is a segment of the ligneous zone and the adjacent part of the medullary axis of another transverse section; and fig. 5 exhibits a group of the cells of the true medulla, also intersected transversely.

The pith (*a*) is an undivided parenchymatous tissue of a very regular kind. The intervening spaces, described by Mr. BINNEY as separating the cells vertically, and converting the pith into a discoid one, have no existence in well-preserved specimens, but have been the result of desiccation or some other accidental cause. The individual cells vary in size, but they usually range between ·0025 and ·0033§: in the vertical section, and in perfect specimens, they often exhibit a very decided disposition to

* See 'Proceedings of the Royal Society,' vol. xx. p. 436 (1872). This plant proves to be the root of *Asterophyllites* (Proceedings, vol. xxi. p. 397, 1873).

† M. RENAULT has kindly supplied me with sections of the plant to which M. BRONGNIART had applied my generic name. It proves to be a Sigillarian plant.—Sept. 7, 1873.

‡ Philosophical Transactions, 1872, part ii. p. 283.

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

arrange themselves in perpendicular rows, as is so often the case amongst the Lepidodendroid plants; with this trifling exception the tissue is an ordinary form of parenchyma. I shall in the course of the memoir give my reasons for concluding that the history of this tissue in *Diploxylon Oldhamium* is similar to that of the Lepidodendroid plant described in Part III., viz. that it had scarcely any existence in the very young twigs, the central axis of each of which has been chiefly occupied by a mass of vascular tissue; but as the plant grew, the primitive cells which lurked amongst the vessels multiplied themselves, forming a true medulla, which pushed the vascular tissues outwards, where they permanently occupy a position analogous to, if not even physiologically identical with, that of the vascular medullary cylinder common to plants of the Lepidodendroid type. Thus in fig. 2 we have these medullary vessels at *c*, constituting an almost unbroken ring enclosing the true medulla. The large and but partially detached masses of vessels occupy the greater portion of the medullary area; but as we proceed to examine a series of larger and older examples, we discover that these vascular masses become widely separated from each other (Plate XXII. fig. 1, *c*, and opposite to *c c* in fig. 4). They now form irregularly triangular bundles of vessels, projecting into the medulla from ·0165 to ·02 in ordinary specimens, and adhering by their peripheral margins to the innermost surface of the ligneous zone, as represented in fig. 3, *c*, and in Plate XXIII. figs. 6, *c*, & 7, *c*. These masses do not appear to increase in size with the growth of the stem, since in a larger example of the latter, in which the ligneous zone alone has had a diameter of at least an inch, these vascular bundles do not project into the medulla more than from ·0166 to ·025. The component vessels of each bundle vary much in size. As in the Lepidodendroid medullary cylinders, they are arranged irregularly, and not in radiating series. They have all reticulated walls. In fig. 4 there are some conditions which I have not found in any other example, and which may have been the accidental results of partial desiccation or some similar disturbing cause: the continuity of the cellular medullary tissue is interrupted at the centre, and the cells exhibit a tendency to dispose themselves in irregular lines, radiating towards the periphery of the medulla.

The Ligneous Zone.—This is a cylinder of vessels arranged in radiating planes, which latter are really vertical laminæ separated by large and very remarkable medullary rays. In its normal state the cylinder has been an unbroken one, as represented in Plate XXII. fig. 4, *d*; but, owing to various causes, this continuity is frequently disturbed in the fossils, as seen in fig. 1. Each lamina commences, at its inner margin, either at the medullary cells or at one of the triangular medullary vascular bundles. The innermost vessels are usually the smallest ones, a gradual increase taking place in their diameter as we follow them towards the periphery. This enlargement, however, soon reaches definite limits. Their diameter in the smaller stems rarely exceeds ·0033, and in the largest ones I have found none more than ·005. In the young plants many of these laminæ consist of a single linear series of vessels, as shown in the several figures 2, 3, 6, and 7; and in such examples we have rarely more than four or five linear series in any undivided wedge.

In larger and older specimens I have counted as many as thirteen such laminæ in an apparently undivided series, though a tangential section of such wedges would probably show some thin medullary rays separating the laminæ, but which were not observable in the transverse section. The following Table gives the mean results of a series of measurements of the thicknesses of these compound wedges in a very large stem, beginning with those in which each wedge consists of a single linear series of vessels, and ascending to those in which I have found as many as thirteen.

Number of laminæ in each wedge.	Entire thickness of wedge.	Mean thickness of the component laminæ.
One row of vessels . . .	·0023	·0023
Two rows " . . .	·0041	·0020
Three " " . . .	·0058	·0029
Four " " . . .	·007	·0017
Five " " . . .	·007	·0014
Seven " " . . .	·0094	·0013
Eleven " " . . .	·015	·0013
Thirteen rows of vessels . .	·015	·0011

The second column of figures shows that as the wedges increased in size there was a gradual diminution in the thickness of their component laminæ—the result partly of their mutual pressure impeding the expansion of the vessels to their normal dimensions, and partly of the fact that these larger wedges contain more than the average of young laminæ which have been intercalated, and which may not have reached their full development. In young stems we find that the dimensions of the wedges are somewhat larger than those recorded in the above Table.

On tracing these wedges in such sections as Plate XXII. fig. 3, from their medullary to their peripheral margins, we find that many of them consist of a single lamina of vessels throughout their entire course; but such limited examples rarely, if ever, occur in the larger stems. As shown in fig. 3, *e*, after proceeding outwards for a little distance, the single row of vessels divides into two smaller ones, which in turn become yet further multiplied in the thicker stems.

These vascular laminæ are divided from one another by large medullary rays (*f*), which are very conspicuous, even in the transverse sections, in which they are usually composed of several rows of cells with thin walls running in a radial direction, their square-ended cells being elongated in the same direction. In tangential sections (Plate XXIII. fig. 8) we see that the ligneous zone exhibits the appearance of a network, of which the woody laminæ (*e*) represent the threads, and the medullary rays (*f*) vertically elongated lenticular meshes. Two things strike us on regarding such a section, viz. the immense number of these rays and their large size. In large stems they frequently have a vertical length of a quarter of an inch, and sometimes even more, whilst in such specimens ·125 is a common size; their diameter ranges from a thin column of single cells up to dense cellular masses (fig. 8, *f'*), with a diameter of from ·0016 up to ·01, the cells of which exhibit the aspect of ordinary parenchyma. On turning to radial sections (Plate XXIII. fig. 9), we see that these rays (*f*) present as perfect an example of mural arrangement as could be found in any Dicotyledonous plant. In whatsoever direction we make sections of the woody zone of this plant, we equally obtain clear proof that the cellular tissues of the medullary rays constitute fully half of its substance. Occasionally, as at Plate XXIII. fig. 8, f'', we find individual rays consisting of but three or four cells, but such restricted examples are rare.

The Bark.—This consists of three very conspicuously distinct layers—an inner parenchyma, a prosenchymatous layer, and an outer parenchyma; but practically four such may be distinguished, since the surface of the innermost one of the three, which is in immediate contact with the wood, becomes differentiated into a cambium-layer.

Inner Parenchyma.—This innermost division is not always to be found in a distinctly marked form. When present, it consists of a uniform series of exceedingly delicate cells (Plate XXII. fig. 1, *g*, & Plate XXIII. fig. 6, *g*), which have a somewhat constant diameter of from ·001 to ·002. In the transverse section they present the ordinary parenchymatous form; in the longitudinal one they exhibit a tendency to arrange themselves in vertical lines. At its outer boundary this stratum merges in an almost equally delicate parenchyma, but composed of somewhat larger cells (Plate XXII. fig. 1, *h*, Plate XXIII. fig. 7, *h*, & Plate XXIV. figs. 10, *h*, & 11, *h*). Both the inner and outer portions of this double parenchymatous layer are characterized by the presence of large, irregularly star-shaped patches (Plate XXIV. fig. 11, h') of cells of a dark colour. These might at first be supposed to be accidental discolorations due to local mineralization; but I am satisfied that such is not the case. These cells are rather larger and have denser walls than those amongst which they are imbedded; and they form so constant an element in this portion of the plant, that I can have little doubt as to their having constituted a feature of the living structure, resembling possibly the dark-coloured cells so common in the rootlets of Ferns and of some *Lycopodiaceæ*. Those in the inner parenchyma are much larger than those of the outer parenchyma, the latter often consisting of but one or two well-marked dark-coloured cells. In studying the Dictyoxylons, these pigment-patches supply an excellent guide, enabling us to distinguish between the parenchyma of the inner bark and that of the medullary rays*. In the fossil specimens this cortical parenchyma frequently appears as if trailed about in a remarkably irregular manner; but this is probably a result of partial desiccation prior to fossilization.

* Whilst describing this part of the bark, a specimen now under my microscope reminds me once more of the necessity of guarding against the misleading influence of Stigmarian rootlets, the great enemies of the young palæophytologist who studies the organization of these coal-plants. In the specimen referred to, a long narrow strip of clearly defined cellular tissue of peculiar aspect runs longitudinally through the portion of the bark just described, imbedded amongst the true cortical tissues in a way that would inevitably mislead an observer whose eye was not thoroughly familiar with the aspect of these rootlets. In a previous memoir I have called attention to the universal diffusion and marvellous penetrating power of these intruders; but I think the latter attribute has reached its acme in one specimen which I have recently met with, in which a large rootlet has been penetrated longitudinally by a smaller one; and the latter, in its turn, contains a third within its

In the innermost layer just described we find large longitudinally disposed vascular bundles, the presence of which, under various conditions, constitutes one of the characteristics of the genus *Dictyoxylon*. These bundles sometimes, though rarely, occur singly; but even when they do so we can generally trace a radial line, indicating a division of the bundle into two lateral halves. An example of this latter condition is seen in Plate XXIII. fig. 7, *z*. More ordinarily we find two such bundles (Plate XXV. fig. 17, *z*), evidently resulting from the vertical division of a cluster, like that just referred to, into two nearly equal parts. The transverse section of each bundle is now somewhat of a rounded triangle in form, the semiovoid form being due to the same vertical division of an oval double bundle.

Such undivided bundles as that of Plate XXIII. fig. 7 have a longer diameter of ·033. When the two halves become separated, as in Plate XXV. fig. 17, by a decided and sometimes considerable interval, each half attains to about the same dimensions as the undivided whole, making it clear that as the division progresses the component vessels increase in size. The diameters of these vessels vary from ·003 to ·0015. On examining the bundles in a longitudinal section (Plate XXIV. fig. 11, *z*), we observe that they preserve their parallelism with the exterior of the ligneous zone, and do *not* seem to take their rise in, or diverge from, the latter structure, as is the case with the foliar bundles of the Lepidodendroid plants, with which, at the first glance, we should be tempted to compare them. Their component vessels are chiefly reticulated ones, like those of the woody zone; but along with these are other and usually smaller ones, which are distinctly of the barred type. Such barred vessels are, as I have already shown, entirely absent from the true ligneous zone.

In the great majority of cases I have counted four of these double bundles in each transverse section of the entire stem. In Plate XXII. fig. 1, I only discover three pairs, whilst in Plate XXII. fig. 4, I have reason to believe that there were as many as five. The positions of these double bundles bear a remarkable relation to those of the separate masses of the original medullary cylinder (Plate XXII. figs. 2, 3, & 4, & Plate XXIII. figs. 6 & 7, *c*), which remain attached to the medullary surface of the ligneous zone. Where the relative positions of the organs have not been disturbed by mechanical pressure, as is often the case, these cortical bundles are disposed externally to the woody zone at points intermediate between those of the medullary clusters of vessels. I have seen no exception to this rule. Of course, this alternation is less obvious in young stems, in which, like Plate XXII. fig. 2, the medullary cylinder is not yet broken up into distinctly separated portions, than in older ones, though even here, as seen in Plate XXIII. fig. 7, the evidence of this relationship is not wanting; but where, as in Plate XXII. figs. 1 & 4,

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cylinder. Whilst referring to the necessity for incessant vigilance against this source of error, I may express my absolute conviction that the vascular bundles which Mr. Binney has figured as belonging to the medullary tissues of *Halonia* ("Observations on the Structure of Fossil Plants, &c." (Palæontographical Society, 1871), plate xvi. figs. 2 & 5, and plate xvii. fig. 5) are merely examples of these intrusive rootlets.

the growth of the stem has distinctly separated the medullary vascular buttresses widely apart, we distinctly see the intermediate arrangement of the peripheral bundles. Examination of a large series of these transverse sections further shows that the undulating outline of the ligneous zone, best seen in Plate XXII. fig. 4, and which is always more or less present in uncompressed stems, is due to the relationships just pointed out. That outline is centrifugal opposite to where the medullary bundles are located (*c*), and bulges inwards or becomes centripetal where the cortical bundles are placed (*z*). The latter might have been introduced to compensate for the absence of the former for the purpose of equalizing the resisting power of the walls of the entire, combined, vascular cylinder. I shall shortly point out the existence of a peculiar series of exogenous additions made to many of these cortical bundles.

Prosenchymatous Layer.—Transverse sections of the stem at once arrest the attention of even casual observers by the remarkable aspect of this layer, which is well represented in Plate XXII. fig. 1, *k*. It bears a strong resemblance to a clock-face, upon which the figures have been inscribed in Roman numerals. On magnifying more highly the dark bands which give this aspect to the section, as is done to three of them in Plate XXIV. fig. 10, *k*′, we discover that they are due to irregularly defined radiating laminæ of prosenchyma, the walls of the component cells of which are thickened by internal deposits, converting them into true fibres. These fibrous bands alternate with lenticular masses of ordinary cellular tissue, which displays different forms of cells, not only in different plants, but in different parts of the same plant. On making tangential sections of this portion of the bark (Plate XXIV. figs. 13 & 15, & Plate XXV. fig. 14, *k*′), we learn that these fibrous laminæ not only undulate as they ascend vertically through the stem, but bundles of fibres regularly detach themselves obliquely from one lamina to unite themselves with those of a contiguous one, thus mapping out the section, by dark continuous lines, into a series of lenticular spaces (*k*″). At the first glance these lenticular or rhomboidal areolæ might be mistaken for those characterizing the bark of a *Lepidodendron*; but closer examination shows that there is no real identity between the two structures. The fibrous laminæ bear a much closer resemblance to the structure of the liber in Dicotyledonous plants, especially as seen in the lace-bark tree (*Lagetta lintearia*) and other Thymelaceæ. In tangential sections of young stems, the areolæ described by these fibrous layers are longer in proportion to their breadth (Plate XXV. fig. 14, *k*″, & Plate XXIV. fig. 15, *k*″) and also less regular in their arrangement than is the case with older ones. Plate XXIV. fig. 13 represents part of the bark of a stem, the ligneous cylinder of which, apart from its bark-bundles, has been rather more than two inches in circumference. We here see that the areolæ (*k*″) have not only become less lenticular and more rhomboid in their form, but have also arranged themselves with greater regularity in pseudo-spiral lines than is the case with many other stems. In these respects, however, individual specimens vary very greatly.

The thickness of this prosenchymatous layer of the bark, as a whole, is usually, in young stems, from ·1 to ·145: in some very young ones it did not exceed ·033. The fibres of the radiating laminæ have a diameter varying from ·0023 to ·0006, their more usual dimensions being from ·0012 to ·0008. It is very difficult to measure their length, because, owing to its amount, which is considerable, and to their interlacing freely within their respective bundles, it is almost impossible to see the two extremities of each fibre; it is, however, sufficiently great to give them an almost vascular character. Practically they are bast-fibres. When we do see their extremities, as in Plate XXIV. fig. 15, k', we observe distinctly the fusiform terminations of the cells; but where they come in contact with the parenchyma enclosed within the areolæ, we sometimes notice a very rapid transition from the one type to the other, through some elongated square-ended modifications of cellular tissue.

I have referred to the cellular tissue filling up the lenticular or rhomboidal areolæ as parenchymatous, but it varies immensely in the same plant. Thus in the transverse section (Plate XXII. fig. 1) we find these spaces occupied throughout the greater part of the section by ordinary parenchyma, as seen in Plate XXIV. fig. 10, k''; but on the extreme right of fig. 1 they are filled with transversely elongated prismatic cells, which often almost extend from one fibrous lamina to another, their long axes being parallel with the circumference of the bark. We see similar differences in the tangential sections: thus, in Plate XXIV. fig. 15, k'', these cells are parenchymatous, whereas in the greater part of fig. 13, k'', & Plate XXV. fig. 14, k'', they are prismatic, or even mural, their long axes being transverse to that of the stem. In the radial vertical section (Plate XXIV. fig. 11, k') we see the prosenchymatous layer forming an irregular wavy line. The cells occupying the areolæ vary much in their dimensions; but when they assume the parenchymatous form they have a somewhat larger diameter than characterizes the contiguous fibres, or from ·0033 to ·0015. The internal cavities of the fibres are usually more or less filled with carbonaceous matter (Plate XXIV. fig. 10, k'), their ligneous walls having evidently possessed some peculiar osmotic properties not possessed by the ordinary cellulose of the parenchyma.

In the large majority of my specimens I detect no tissue external to the remarkable one just described; but in some young stems, more perfect than the rest, the parenchyma of the rhomboidal areolæ spreads out into a thin parenchymatous subepidermal layer (Plate XXII. fig. 1, l, & Plate XXIV. fig. 10, l), at the outer surface of which we often see small irregular projections. Nothing approaching a true epiderm has yet been found*. The thin layer just named seems to have disappeared during growth, as if it were an epiderm and was not renewed.

In no instance has a trace of a foliar vascular bundle, like those of the *Lepidodendra*, been found in the cellular areolæ of the bark. This fact alone demonstrates one difference between these rhomboidal areolæ and the leaf-scars of *Lepidodendron* and *Sigillaria*;

* At the Meeting of the British Association in 1871, Mr. BINNEY stated that he had found a yet more peripheral layer. I have examined some hundreds of these stems, but have seen no trace of any thing like what he there described.

and it further stands related to the equally remarkable fact that no trace of a true leaf has yet been met with connected with these stems: and in but one solitary instance have I seen any of the cortical vascular bundles within the area of the prosenchymatous zone; they are limited to the inner bark. To these points, however, I shall shortly return.

Having thus examined the ordinary structure of the *Dictyoxylon Oldhamium*, we may now turn to some special points connected with its growth. I have already pointed out that whilst in some specimens the ligneous zone is thin, consisting of but a very limited number of vessels, as in Plate XXII. fig. 4 (which condition is still more obvious in the case of the older woody layer, *e*, of Plate XXIII. fig. 6), I have obtained from Mr. Nield one magnificent axis in which the woody cylinder and its contained medulla has been at least eighteen inches in circumference. The thickness of the wall of this vascular cylinder has been at least $2\frac{1}{2}$ inches; and since the specimen is weathered and water-worn*, it may have been of even larger dimensions. In this specimen, assigning to each vessel a mean diameter of ·004 would give us between six and seven hundred vessels in the linear series of each radiating lamina of the wood. Dimensions like these at once suggest the existence of some exogenous mode of growth. But fortunately we are not left to mere inference on this point. As in the case of the Diploxyloid stems described in my last memoir, I have obtained several specimens which unmistakably demonstrate the operation of this exogenous development of the Dictyoxylons. Of these, Plate XXII. fig. 4 represents one in which there are three distinct rings of vessels; and Plate XXIII. fig. 6 is a still more enlarged figure of a second example, drawn with great care, in which there are but two concentric growths. In the former example the boundary line between the innermost and middle ring is but faint, because the vessels of the latter have already expanded to their normal dimensions. The outermost ring (Plate XXII. fig. 4, *e'*) is less completely developed; hence the vessels have not attained to much more than half their size. In Plate XXIII. fig. 6 the distinction between the vessels belonging to the inner and older ring (*e*) of the ligneous zone and those of the newer one (*e'*) is very marked: the latter are of very small size; not larger, indeed, in many examples, than the inner bark-cells (*g'*) in which they have developed themselves. The specimen from which this figure was taken puts beyond the possibility of doubt the existence of exogenous growth amongst these plants.

But there remains another curious evidence of the pseudocambial action of the innermost bark. I have already depicted the usual forms of the cortical vascular bundles in Plate XXIII. fig. 7, *z*, & Plate XXV. fig. 17, *z*. A similar bundle, copied from the specimen shown in Plate XXII. fig. 1, is seen in Plate XXVI. fig. 18. In this example the bundle is less sharply defined than in those already described; and some of the vessels in its central portion have the appearance of being intervascular cellular tissue. I presume that at least some of this appearance is but the result of imperfect minerali-

* It was found in a watercourse intersecting the Lower Coal-measures at a locality near Oldham, known as Har Culver (Higher Culvert).

zation. In Plate XXV. figs. 19, *z*, & 20, *z*, we have the two bundles belonging to another of the clusters of Plate XXII. fig. 1, and which are enclosed within the innermost bark-layer: their relative positions in the bark were similar to those which they occupy upon the Plate. On the outer or cortical side of each we find several diverging lines or laminæ of vessels (z'), of which those nearest the space separating the two bundles are the longer ones, whilst the others become successively shorter as we diverge from that space. We have here unmistakable growths superadded to the exterior margins of the two bundles, similar, in all essential respect, to those added by the pseudocambium to the exterior of the ligneous zone, and apparently through the action of the same pseudocambial cells. Though I do not by any means find these conditions of the cortical bundles repeated in all the specimens of *Dictyoxylon*, they are frequently met with. Plate XXV. fig. 21 exhibits a yet more remarkable modification of these bundles that I have occasionally observed. In this instance the original bundle of non-radiating vessels has become firmly incorporated with the periphery of the ligneous zone (*e*), and the exogenous additions have been made to its exterior in such a manner as to form a wedge-shaped buttress (z'), running vertically down the ligneous cylinder. I have dissected several of these buttresses, and find that when radial sections of the ligneous zone pass directly through them they exhibit all the ordinary appearances of, and are scarcely distinguishable from, that zone; indeed, as seen in such sections, they only appear to be outward prolongations of it. In some of the examples, as is the case with the one figured, the central non-radiating bundle of vessels has its details less clear than in others. Where these *are* distinct, I think they show that the bundle is in the same state as that represented in Plate XXIII. fig 7, *z*, viz. in its undivided condition. This explains why, in these wedge-shaped growths, we never find the twin bundle. The exogenous growth, which now binds the vessels together, has commenced before the separation of the cluster into two parts was effected. These details are trivial, but they help to throw light upon the nature of the objects in question.

Another remarkable feature of these organisms yet remains to be examined. So far as outward appearances are concerned, *Dictyoxylon* might be declared to have been a simple, unbranched stem. In no one instance have I found an example which exhibits any obvious division or bifurcation of the stem, such as is common amongst the *Lepidodendra*. Nevertheless several examples have come into my hands in which branches of some kind have existed. The first trace which I met with of this character was in a tangential section of the bark made by Mr. BUTTERWORTH, and represented in Plate XXV. fig. 14. One of the cellular areolæ of the prosenchymatous layer of the bark has evidently been modified and enlarged to allow the branch (*y*) to escape through it. The cellular parenchyma of the middle bark has been condensed into an oval ring, through which the bundle has emerged. This ring is seen further enlarged in Plate XXVI. fig. 22, *h*; within it is a space (*g*) which was, I have no doubt, originally occupied by the delicate parenchyma of the innermost bark, prolonged as an investing layer from the central cylinder of that tissue, but the cells of which have now disappeared. The centre is occupied by a round and well-defined mass of vessels of two kinds, which the section, though made tangentially to the parent bark, has divided transversely, showing that the bundle passed out of the original stem at right angles to its vertical axis. The greater portion of the section consists of a cluster of vessels (*c*) not arranged in radiating series, larger ones occupying the centre and smaller ones the periphery of the cluster. In the former portion some of the vessels have almost disappeared; but I have no doubt that originally there was an almost solid mass of them interspersed with some delicate cellular tissue. The periphery exhibits a narrow ring (*d*) of small vessels which are arranged in radiating series, the radiating lines being separated by medullary rays. Here we have obviously the first growth of an exogenous ligneous zone.

Plate XXV. fig. 16 represents a second and yet more beautiful example, from one of the larger specimens to which reference has already been made. The cellular tissue (*h*), in which the branch-section is imbedded, is the central parenchyma of the bark of the parent stem, intersected tangentially: we have here, as before, the condensed ring of this latter tissue (*h'*) enclosing the vacant space which I presume to have been occupied by a prolongation of the innermost bark-layer. The section of the branch, which is as perfect as possible, exhibits the same general arrangement of the tissues as that which appears in the previous example. The medullary axis is occupied, as in Lepidodendroid twigs, by a cylindrical bundle of vessels; this, again, is surrounded by a well-developed ligneous zone, consisting of about twenty-three clearly defined, radiating vascular wedges, separated by equally distinct medullary rays. The exogenous development of this branch has advanced further before it emerged from the bark than in that just described. Tracing these branches inwards in order to ascertain their origin, we must return to Plate XXII. fig. 1, *x*, in the interior of which we discover a section similar in all respects to the last one, save that it has attained to a yet more remarkable degree of development before escaping from the pseudocambial and inner parenchymatous bark-layers. Plate XXVI. fig. 23 is a carefully drawn enlargement of a portion of this branch-section. Here, again, we have at *c* the compact mass of vessels forming the medullary axis, radiating from which we have a series of vascular wedges (*d*), which, in the perfect section, are nearly forty in number; these, again, are separated by clearly defined medullary rays (*f*) of relatively large size, especially on the left and lower sides of the figure. As the section has traversed this part of the branch somewhat obliquely, we readily trace the mural arrangement of the cells constituting these rays; whilst at their outer extremities we also see, with similar distinctness, how the cells merge in the equally delicate ones (*g*) of the pseudocambium of the parent axis (Plate XXII. fig. 1, *g*). Approaching nearer to the central axis of the stem, we find in Plate XXIV. fig. 11, *x*, another of these branches penetrating the ligneous zone (*e*). As already stated, this figure represents part of a tangential section of a ligneous cylinder made midway between the medulla and the bark; but whilst the *wood* is intersected *tangentially* on the left-hand of the figure, the *bark* on the right is cut through almost *radially*—results due to the cylindrical form of the branch. The woody zone displays the usual innumerable medullary rays separating the woody wedges; but at the lower part of the figure the latter tissues are yet further deflected right and left, to allow a large vascular bundle to pass out between them. This bundle and the surrounding tissues are shown, still further enlarged, in Plate XXIV. fig. 12. The section has divided the vessels in the centre of the bundle transversely; but the more peripheral ones trail across the field of view in irregularly radiating lines, which, at their peripheral ends, appear to merge with the curving vessels of the parent axis. Having obtained another specimen similar to that just described, I made a series of tangential sections of it, and found that the divergent bundle of vessels diminished rapidly in size as I approached the medullary axis, and became almost, if not wholly, wanting before reaching the inner surface of the ligneous zone, affording an additional illustration of the exogenous development of both stem and branch. The section Plate XXVI. fig. 24 throws additional light upon these arrangements: this is part of a transverse section of a stem, but the section has passed somewhat obliquely through one of these branches; besides which, owing to the curvilinear direction followed by the branch, the section has divided its upper half almost transversely, whilst its lower or inner portion is intersected more longitudinally. The peripheral portion of the section shows clearly that this branch consisted of laminæ arranged in radiating order; whilst the more central part demonstrates that these laminæ consist of true vessels, which are derived from the exogenous ligneous zone.

But there is yet another peculiar lateral appendage found in this plant, as seen in a transverse section of a stem represented in Plate XXIII. fig. 7. In the centre of this figure we observe that the vascular laminæ bounding two of the medullary rays are forced asunder, to permit the escape of a large mass of tissue (*n*), some of which emanates from the left-hand ray, but the greater portion of it comes from the one to the right. It will be observed that in this instance there is no disturbance of the regular order of the vascular laminæ of the exogenous zone beyond their being thrust asunder at their peripheral margins; neither is there the slightest indication of what appears obvious in Plate XXVI. fig. 24, viz. a direct connexion between the vascular tissues of the parent axis and those of the branch. As the latter proceeds outwards, it passes through the parenchymatous (*h*) and prosenchymatous (*k*) layers of the bark, contracting rapidly in diameter as it does so, and terminates abruptly at the circumference of the outer bark (*n'*).

Unlike the previous examples, this divergent structure consists of a mass of cells, many of which are so elongated and fusiform as to assume a pseudo-vascular aspect. But each cell and pseudo-vessel, unlike the cells of the parent medulla and medullary rays, is beautifully reticulated like the true vessels of the central axis—an important feature to be borne in mind on endeavouring to assign a probable function to this organ. Equally important is it to remember that the tissues composing this appendage, instead of being derived from the vascular laminæ forming the two lateral boundaries of one medullary ray, have every appearance of originating in some metamorphosis of the mural cells of two such rays. We can clearly trace the pseudocambial layer of the parent axis accompanying the above structure in its outward course in the shape of an investing cylinder.

It thus becomes clear, not only from the specimens described, but from other similar ones in my cabinet, that though we discover no true dichotomization or *externally* conspicuous branching of the *Dictyoxylon*-stems, they gave off distinct lateral appendages almost at right angles to the axis of the parent stem. What were these diverticula? whither did they go? and why do they terminate so invariably at the circumference of the parent bark?

I think we must separate Plate XXIII. fig. 7, *n*, from the other examples; it differs alike in its structure and origin. My impression is that it may have supplied an adventitious or aërial root, which impression is confirmed by the history of a similar appendage which I find in *Dictyoxylon Grievii.* The other examples in which we have a distinct central axis surrounded by a regularly constructed exogenous zone are manifestly young branches; but whether they were prolonged into ordinary leaf-bearing branches, or whether they were half-abortive fruit-bearing ones, I am unable to determine. The invariable absence of any outward prolongation of them beyond the periphery of the parent stem, certainly seems to indicate a connexion with some deciduous appendage. Had they been prolonged into such persistent organs as true branches, it is difficult to believe that clear proof of the existence of such organs would not have been met with in some example amongst the hundreds of these stems which I have examined.

That they were not the vascular axes of leaf-petioles seems clear from their exogenous organization. I know of no leaf, however large, in which such an organization exists. Hence, as already suggested, I am inclined to believe that they may have nourished spikes of fructification, which, being modified branches, might be expected to retain a branch-structure in their central axes. I have shown in my last memoir the existence of exogenous layers in the axis of a *Lepidostrobus,* and I have in my cabinet specimens of *Volkmannia Binneyi* which have a similar radiating external woody cylinder. Hence there is no impossibility involved in the supposition that similar conditions may have prevailed in *Dictyoxylon.* These, however, are purely hypothetical suggestions; and the further fact remains, that we have hitherto discovered no fruits that could, with reasonable probability, be correlated with the stems in question.

Whatever may have been their functions, these branches throw a clear light upon the origin of the irregular vascular medullary cylinder seen even in very young Dictyoxylons, and which only remain, in a fragmentary state, as detached buttresses supporting the inner surfaces of the exogenous woody zones. But we must further study this subject in the light of the facts described in my last memoir on Lepidodendroid plants. I there showed that the compact central vascular axis of each young Lepidodendroid twig first expanded into a vascular cylinder, through the rapid fusion and multiplication of some of the more central cells located amongst the vessels, and which thus developed into a true cellular medulla, the growth of which was synchronous with that of the vascular cylinder. I further demonstrated that this compound axis became invested, at a still later period, by a true exogenous ligneous zone. It appears to me that corresponding phenomena reappear in the Dictyoxylons, but with some characteristic differences. In the Lepidodendroid plants each vasculo-medullary axis expanded into a regular cylinder, whose walls were of almost uniform thickness throughout its entire circumference, and which permanently retained its integrity throughout the life of the plant. In *Dictyoxylon* the solid vascular axes of Plate XXV. fig. 16 & Plate XXVI. fig. 23 expanded in like manner, and also had a cellular medulla developed within each cylinder; but the thickness of the latter was not only unequal in its various parts, but, at a very early period, it broke up into several detached and irregular masses, which no longer effected a complete separation of the pith from the exogenous layers throughout the entire circumference of the former organ. In the intervals between these detached vascular masses the cells of the medulla, and those of the medullary rays, become continuous with one another. In the first instance each radiating exogenous lamina had its inner margin in direct contact with the medullary vessels: this is indicated clearly in such specimens as that represented in Plate XXII. fig. 3. But though the disruption of the cylinder ultimately limited this direct cohesion of the exogenous with the medullary vessels to certain well-marked clusters of the former, evidence of similar but earlier relations of the entire ligneous zone is retained in the curvilinear forms of many of the woody wedges, whose inner margins are now in direct contact with the medulla; as in fig. 3, their several medullary extremities still bend towards the nearest cluster of medullary vessels with which they were, at an earlier period of their growth, in direct contact.

I have already called attention (in page 383) to the relations which these detached medullary bundles sustained to those lodged in the inner bark, and pointed out the way in which the latter helped to equalize the resisting power of the compound vascular cylinder, by strengthening those parts of the woody zone which were weakened by the breaking up of the medullary cylinder. This idea receives confirmation from the fact that, so long as the central axis is occupied by an undivided vascular bundle, these cortical buttresses are invariably wanting. In no one of the lateral diverticula which I have just described, and in which the *solid* axis invariably existed, did I find a trace of these cortical bundles: all the facts indicate that they were growths developed in the bark at a later date; at the same time such specimens as the original of Plate XXII. fig. 2 showed that they became fully grown before the disruption of the medullary cylinder had proceeded to any considerable extent.

The large size of the medullary rays, and the simple and conspicuous organization of the woody wedges in *Dictyoxylon*, enable us easily to compare its growth with that of living Dicotyledonous stems. As in the latter instances, we find that, as the wedges extended themselves in the peripheral direction, they became enlarged transversely by the addition of new laminæ. This was sometimes the result of two meristem-cells occupying the place previously filled by one, the consequences of which are seen in the conversion of the single lamina into a double one, as in Plate XXII. fig. 3, *e*. In other instances new and very small laminæ were either intercalated into the substance or added to the external surface of each wedge. Examples of all these methods of growth abound. If not antagonized, the continuance of this process would have given the peripheral portions of the wedges very different dimensions to those described in the preceding pages. I have already pointed out that we rarely find a dozen laminæ in any one wedge. The constant intercalation of new secondary medullary rays which took place here, as in living exogens, produced the result described. We thus see that in many of its minute details, as well as in its more general aspects, the growth of these stems has been a truly exogenous one.

The bark of one specimen, but which stands alone amongst the number of those that I have examined, exhibits conditions requiring further elucidation: I am as yet unable fully to understand its significance, but it is suggestive of additional facts belonging to the history of *Dictyoxylon* that have not yet been worked out. In this specimen, part of which is represented by Plate XXVI. fig. 25, we have the exterior of the ligneous zone at *d*. Some very slight traces of the parenchymatous layer of the bark are to be seen investing the woody zone. On the other hand, the prosenchymatous layer (*k*) is very thick: this thickness is due to the appearance of a large double vascular bundle, surrounded by a considerable mass of parenchyma, which is lodged in the substance of the prosenchymatous layer. Two of the vertical prosenchymatous laminæ, seen at k', k', have obviously been pushed aside to make room for the above intrusive structure. I have already mentioned the fact that I have never seen any of the cortical bundles located in the prosenchymatous zone of the bark, save in one solitary instance, the latter reference being to the example now under consideration. The double vascular mass (*z*) bears so striking a resemblance to these bundles when but partially divided, as to leave little doubt that it is really one of them. At the first glance we might suppose that it had been accidentally displaced from its normal position and forced, by pressure, into the outer bark; but such is certainly not the case. The parenchyma with which it is surrounded is identical with that separating all the prosenchymatous laminæ, leaving little reason to question that one of the parenchymatous areolæ of the outer bark has been specially enlarged to admit of the outward transmission of the vascular bundle and its thick parenchymatous investment, the vertical prosenchymatous layers (k', k) having been thrust apart to make room for this enlargement and transmission.

These conditions suggest the possibility that others of the cortical bundles may finally leave the woody zone and pass outwards to supply foliar appendages with vascular tissue. The large size of these bundles indicates (supposing the above suggestion to be correct) that the missing appendages have been of corresponding dimensions. They suggest fronds rather than leaves. It is impossible to reason upon such limited data with any confidence; but I shall recall attention to the facts just described when I proceed, on some future occasion, to examine the stems or petioles to which I have proposed to assign the provisional name of *Edraxylon* *.

* Proceedings of the Royal Society, vol. xx. p. 438 (1872).

Our history of what is known of this remarkable plant is not yet exhausted. On examining the fine series of coal-plants in the Liverpool Museum, which owes so much to the ever-vigilant energy of the Rev. H. H. Higgins, of Rainhill, I detected a series of cortical impressions which evidently belonged to an arborescent tree, and which I at once identified as having a probable relationship to my Dictyoxylons. On naming this circumstance to Mr. Carruthers, he called my attention to the fact that a specimen similar to the Liverpool ones had been described by the late Mr. Gourlie, of Glasgow, under the generic name of *Lyginodendron*. Dr. Bryce, of Glasgow, kindly furnished me with Mr. Gourlie's memoir, which at once satisfied me that the Liverpool specimens were varied forms of the *Lyginodendron Landsburghii* of the Scotch author. Mr. Gourlie gave a characteristic figure of his fragment in the 'Proceedings of the Philosophical Society of Glasgow' for February 15th, 1843, but he made no attempt to describe it scientifically, or to correlate it with any other known fossil plants. He obtained the fragment from the Rev. David Landsborough, and having recognized that it was undescribed, he contented himself with figuring it and giving to it the above name. On turning to Corda's 'Beiträge zur Flora der Vorwelt,' published two years later, I found a fragment of the same kind figured under the name of *Sagenaria fusiformis* (*loc. cit.* Taf. vi. fig. 4). Corda brought together in his plate, along with this specimen, fragments of a true Lepidodendroid bark, with some other plants showing internal organization; but I am perfectly satisfied that fig. 4 of his plate, the *Lyginodendron* of Gourlie, has no relationship whatever to the objects associated with it.

Plate XXVII. fig. 26, which bears the closest resemblance to Mr. Gourlie's specimen, consists of a slab of sandstone whose surface is covered with oblong-fusiform elevations of variable dimensions; the largest of these are fully three inches in length and nearly half an inch in diameter. As shown in the figure, these elevated areolations are in close contact with each other, being merely separated by a sharply defined groove, their surfaces being rounded or slightly flattened. Plate XXVII. fig. 27 represents a similar specimen, only in this example the largest areolæ are rarely more than 2 inches in length and ·18 in breadth; they are more uniform in size and regular in their arrangement than in fig. 26, exhibiting a greater tendency to dispose themselves in the oblique spiral lines of the Lepidodendroid plants than in the other specimen; the surface of each areola also projects in a sharp, central, longitudinal ridge. In Plate XXVII. fig. 28 we have a third modification. In this example the areolæ rarely exceed 1·5 in length and ·12 in diameter, whilst they are separated from each other by flat spaces from ·2 to ·1 in breadth. Their surfaces in this instance likewise are more or less rounded. Plate XXVII. fig. 29 is a small specimen, also with convex areolæ, which are very uniform in size and contour, as well as regular in their Lepidodendroid arrangement; as in the last figure, flat areas intervene between the fusiform areolæ.

In a fifth specimen of this instructive series the areolæ are not more than an inch in length, whilst in a sixth they are reduced to about half that size. Plate XXVII. fig. 28 is a flat fragment fully 7 inches in diameter; and even the sixth example just referred to is nearly $2\frac{1}{2}$ inches in breadth and perfectly flat. Hence it is obvious that all these specimens belonged to stems or branches of arborescent dimensions, whilst the successive gradations in the size of their areolæ clearly indicate that their differences are merely those of age and growth. Specimens in my own cabinet, and a sharply defined one in that of Mr. BOYD DAWKINS, link the above series with those described in the preceding pages, leaving no room for doubting that the whole belong to one form of vegetation, of which the larger examples were casts of the bark of the arborescent stems, and the smaller ones, in which the entire organization is preserved, the peripheral extremities or branches. The explanation of these casts is sufficiently obvious. The fibrous bands, forming a coarse network in Plate XXIV. figs. 13 & 15, have constituted a firm framework, alike resisting atmospheric abrasion and contraction through desiccation. The enclosed cellular areolæ have been characterized by precisely opposite features. Hence, where the latter reached the surface of the bark, deep lenticular depressions presented themselves, whilst the surrounding fibrous bands stood up in bold relief. That these results were partly due to the shrinking of the cellular areolæ is shown by two specimens in my cabinet: they both consist of the usual prosenchymatous bark of branches in which the inner or parenchymatous layer has been replaced by inorganic matter; but the *inner* surface of the *outer* bark exhibits precisely the same areolation, save that the concavities of the areolæ are now directed *inwards* instead of *outwards*, that I have just described as characterizing the periphery of the same bark-layer. The difference in the relative size of the areolations and of the intervening flat spaces in Plate XXVII. figs. 26 & 28 has obviously been due to corresponding differences in the thickness of the raised fibrous bands in relation to the size of the cellular areolæ which they enclosed. We thus learn that whilst *Lyginodendron* is undoubtedly an inorganic cast of the prosenchymatous layer of the bark of *Dictyoxylon*, it may either represent its exterior surface, which has impressed its contour upon the surrounding mud or sand, or it may represent its inner surface, to which the inorganic material has obtained access through the accidental destruction of the inner parenchyma of the bark. Combining these observations with the evidence derived from Mr. NIELD'S large specimen of the ligneous zone of *Dictyoxylon Oldhamium*, described on page 386, we are irresistibly brought to the conclusion that *Dictyoxylon Oldhamium* was an arborescent tree, which, from the comparative abundance of its fragments preserved in the Lower Coal-measures of Lancashire, must have formed one of the most conspicuous features of the forests of the Carboniferous age.

The bearing of the facts just recorded upon nomenclature will be considered after describing the next subject of this memoir.

In the spring of 1871, Dr. DAWSON, of Montreal, conferred upon me the double favour of directing my attention to the plants of Burntisland, and of introducing to me their energetic discoverer, G. GRIEVE, Esq. I soon found amongst the rich treasures which that gentleman had brought to light a most remarkable plant, closely allied in many points of its structure to *Dictyoxylon Oldhamium*. I gave a very brief and hasty description of this plant at the Edinburgh Meeting of the British Association, assigning to it the name of *Dictyoxylon Grievii*, after its discoverer. Since that period I have made numerous additional sections of the plant, some of which I will now proceed to describe. At the first glance no two plants could well appear to be more distinct than the two just named; it is only when we compare the details of their organization that we learn how numerous and strong are their points of affinity, and how great the amount of light which each throws upon the other. The example now under consideration always appears in the form of straight, slender, unbranched stems; but we also find associated with it much smaller twigs, having the characteristic structure of the larger ones, but with distinctive features in their central vascular axes, similar to those which distinguish a twig of a Lepidodendroid plant from its matured Diploxyloid stem.

Plate XXVIII. fig. 30 represents one half of a transverse section of one of the more matured of the stems that have hitherto been met with. We here readily discern a large vasculo-cellular medullary axis (*a*), a very thin investing ligneous cylinder (*d*), a thin and delicate inner layer of bark (*g*), a thick parenchymatous bark-layer (*h*), and a well-defined outer or prosenchymatous layer of the same (*k*).

The central axis consists of a mass of medullary parenchymatous cells, dispersed throughout which are numerous well-defined bundles of reticulated vessels, unprovided with any special sheaths. The cells have thin walls, and are devoid of all fibrous deposits in their interiors. Plate XXVIII. fig. 31 represents an enlarged portion of this medullary axis: the cells (*b*) are at once distinguished from the vessels (*c*) by their smaller size, their thinner walls, and their brown colour. The last distinction is an evidence, were such needed, of their cellular character: however thin the section, owing to their small size, we always look through one or more of their carbonized cell-walls; whereas the long tubular vessels, being filled by infiltration with pure carbonate of lime, and having their oblique transverse divisions only at long distances from each other, their transverse sections transmit pure white light. The relations of the cells and vessels are further shown in the longitudinal sections (Plate XXIX. figs. 32 & 33, *b* & *c*). Fig. 33, *b*, especially exhibits the aspect of these cells in vertical sections. The largest of them rarely exceeds ·0025 to ·0028 in diameter, and many of them are much smaller. The vessels are arranged in clusters, transverse sections of no two of which exhibit the same shape; and they are equally variable in the number of their component vessels. They are of large size, many of them being ·0052 in diameter; but they are frequently much smaller than this, and at the peripheral portion of the medullary axis they are invariably so. In the latter case, in the transverse sections, they are only distinguishable from the surrounding cellular tissue by their colour and their thicker walls. The clusters of the periphery also contain a larger number of vessels, as well as display a greater tendency to an irregular coalescence of the groups, than is the case nearer the centre of the axis. Plate XXVIII. fig. 34 exhibits the lateral aspect of one of these vessels, enlarged 200 diameters. The entire diameter of the medullary axis in the larger specimens is about ·13. This axis is invested by an exogenous layer of vessels (*d*), disposed in radiating lines widely separated by large medullary rays. The entire thickness of this zone is small, rarely exceeding

·025, which is its thickness on the upper side of the specimen figured, whilst on the lower one it contracts to ·008. This inequality in the thickness of the ligneous zone on opposite sides of the stem is an almost invariable characteristic of this plant. In some specimens the zone is of such small dimensions as to be easily overlooked by observers ignorant of its aspect in more developed examples; where such is the case, the vessels are also of much smaller size than elsewhere. The largest vessels are always found in the thickest part of the zone: here they frequently reach a diameter of ·0032; but in those parts where the zone is dwarfed their diameter does not usually exceed ·0017. In the case of the thicker laminæ, one or two of the innermost vessels are always smaller than the more peripheral ones. Whilst many of these vessels are reticulated, like those of the medullary axis, others are frequently scalariform: the latter is especially the case with those nearest the medullary axis. The radial section, Plate XXIX. fig. 33, partly traverses the outer part of the medullary axis (*b* and *c*), and partly the ligneous zone (*d*). The vessels (*d*) belong to the latter; and at *f*, *f* we have two medullary rays, the cells of which are of the mural type of parenchyma, being repetitions of what we found in *D. Oldhamium*, except that the transverse diameter of each ray is less in the present case than in the Lancashire species, though relatively large in proportion to the thickness of the entire ligneous zone. The latter has evidently been of a very lax character, differing materially in this respect from that of *D. Oldhamium*: I have never counted more than a dozen vessels in each of its radial series. At their inner margins the laminæ are usually connected with some one of the numerous peripheral clusters of medullary vessels; they very rarely, if ever, commence amongst the medullary cells. I shall shortly call attention to some curious clusters of vessels that occasionally interrupt the continuity of this ligneous zone. Plate XXIX. fig. 33 *a* represents a tangential section of this radiating zone. The medullary rays (*f*) are here seen to consist chiefly of a single vertical series of cells, and are further remarkable for the long vertical range of each ray. The figures and descriptions already given apply to the stems of this plant in their normal state; but it is only in rare examples that we meet with them in this undisturbed condition. The physical circumstances that have attended their mineralization have usually compressed and displaced the tissues in so great a measure that it becomes almost impossible to make out the structure of such specimens. The vessels have lost their cylindrical character, and the entire vascular axis is distorted into a confused mass of cells and vessels.

The bark of this plant is as interesting as it is remarkable; but I have found the minute interpretation of its varying aspects a difficult task, owing to the effects of the pressure alluded to in the last paragraph. The general outline of the plant is never the same either in different stems, nor even, as shown on Plate XXX., in different sections of the same stem; and I have found it no easy matter to determine how much of this irregularity was due to pressure and how much to the original peculiarities of the plant. The broad features of the bark are sufficiently obvious: it consists of three very distinct layers, the innermost two of which contain a few large, vertically disposed vascular bundles. These layers present very different appearances when viewed in transverse and in vertical sections: in the former the outermost layer exhibits the greatest peculiarities of structure; in the latter the peculiarities are the most striking in the middle one. The innermost layer exhibits the same appearances in both sections. The latter (Plate XXVIII. fig. 30, *g*, & Plate XXIX. fig. 35, *g*) exhibits so close a general resemblance to the innermost bark-layer of the Lepidodendroid plants, that I do not hesitate to assign to both the same functions. It has a rather uniform thickness of ·008, occasionally swelling out to as much as ·025. It consists of delicate parenchyma, the largest cells of which range between ·0023 and ·0028, their size being moderately uniform: sometimes they are arranged in radiating lines; at others they appear as regular parenchyma. This layer is a very distinct one, both in the definiteness of its boundaries, in the delicacy of its texture, and in the general uniformity of its aspect: in Plate XXVIII. fig. 30 it is seen describing a semicircle at *g g*, and in the vertical section at Plate XXIX. fig. 32, *g*. In every one of the numerous examples which I have examined, this inner bark appears too large for the cellulo-vascular axis which it invests. Sometimes the excess projects at one or both ends of the compressed axis, enclosing a vacant space, as in Plate XXVIII. fig. 30 & Plate XXX. fig. 36; at others it appears in the transverse section as a caudate appendage, occupying the same position as in most of the figures on Plate XXX. This condition has doubtless resulted from a contraction of the central axis that had no existence during the life of the plant. The layer has evidently been at once flexible and firm; since, though compressed into innumerable forms and detached from the central axis in a variety of ways, I have rarely seen its continuity interrupted, save where some vascular bundle passed through its tissues to reach the periphery of the stem.

The middle bark-layer (Plate XXVIII. fig. 30, *h*, & Plate XXIX. figs. 32, *h*, & 35, *h*) is a much more variable one. It consists of masses of very regular parenchyma, intermingled with horizontal layers of darker-coloured cells, which latter constitute the characteristic feature of this tissue. In transverse sections we only detect these darker layers in the form of dark isolated patches (Plate XXVIII. fig. 30, *h'*) and wavy lines (Plate XXIX. fig. 35, *h'*), surrounded by or enclosing clearer spaces occupied by regular parenchyma (Plate XXIX. fig. 35, *h''*); but in the vertical section the former appear in the shape of very regular, parallel, horizontally disposed bars (Plate XXIX. fig. 32, *h'*). The ordinary parenchyma consists of cells having a maximum diameter of from ·0028 to ·004. In Plate XXXI. fig. 45, which represents this tissue in a vertical section of the two outermost layers of the bark of a very young stem, each cell has been drawn with scrupulous accuracy, the dark-coloured transverse bars being represented at *h' h'*, and the intervening parenchyma at *h''*. In vertical sections of this tissue in older stems the latter cells constantly exhibit a disposition to arrange themselves in vertical and often slightly curved lines (Plate XXIX. fig. 32, *h''*), approaching, in the former respect, to the condition of the tissue so common in the medullæ of the Lepidodendroid plants*.

* Mr. Binney has proposed ("Observations on the Structure of Fossil Plants found in the Carboniferous Strata.—Part III. *Lepidodendron*") to assign to this tissue the name of "orthosenchyma." It is but one of the

Plate XXXI. fig. 45 exhibits correctly the general aspect of the dark coloured horizontal bands, and their relations to the intervening layers of ordinary parenchyma. The cells of the former are smaller and more uniform in size, as well as less lax in their arrangement, than the latter. The bands are arranged at uniform distances, which vary little in different specimens, there being generally about forty-six of these in each vertical inch. They do not appear to form absolutely continuous rings in matured examples, encompassing the entire stem, though they do so in young shoots. In the former case they are frequently interrupted by the vicinity of cortical vascular bundles; but, in addition to this, we observe often in vertical sections the faintly defined margin of one of these bands intercalated between two sharply defined ones, indicating that some of them at least become merged laterally in the surrounding parenchymatous tissue: tangential sections of the same structure also frequently indicate that where a cortical vascular bundle approaches the outer bark, the dark bands of the parenchyma right and left of the bundle are alternate in their arrangement rather than continuous.

The "orthenchymous" disposition of the parenchymatous cells is sometimes seen in transverse sections, as in Plate XXVIII. fig. 30, *h''*; but in these instances I have no doubt that the section has passed somewhat obliquely through the tissue in question.

I shall call attention to some further peculiarities in this parenchymatous layer when describing the vascular bundles (*m*) which traverse it.

The outermost layer of the bark (Plate XXIX. fig. 35, *k*) is also a well-defined one, which scarcely differs in its essential features from the prosenchymatous layer of *Dictyoxylon Oldhamium*. Its usual thickness is about ·021; but, as we shall immediately see, it is liable to undergo a sudden enlargement at special points. In the horizontal sections (Plate XXVIII. fig. 30, *k*, & Plate XXIX. fig. 35, *k*) it exhibits a radiating series of alternating bands of parenchyma and prosenchyma, the former being light-coloured and semitransparent, and the latter of a denser texture and a darker hue—conditions which are identical with those seen in the corresponding layer of *D. Oldhamium* (Plate XXIV. fig. 10). The prosenchymatous fibres have a diameter of about ·0005, occasionally expanding to ·001.

In radial vertical sections (Plate XXIX. fig. 32, *k''*, & Plate XXXI. fig. 45, *k*) the cells of this layer appear in the two forms of prosenchyma and of elongated parenchyma of the prismatic cylindrical variety with square ends. In tangential sections these tissues are arranged in the same way as in *D. Oldhamium*, viz. the prosenchymatous bands form a network enclosing vertically elongated parenchymatous areolæ of a lenticular form. But the plant under consideration differs from the Oldham one, so far as this portion of the bark is concerned:—1st, in the greater relative thickness of the prosenchymatous bands; and, 2nd, in the smaller size and almost linear vertical form of the enclosed areolæ. A

innumerable modifications of parenchyma and frequently seen amongst living Cryptogams; but if we do give it a special name it must be "orthenchyma." Mr. BINNEY's term involves an impossible, *i. e.* an ungrammatical, combination of noun and adjective; besides which mine is shorter, and accords better with its similar modifications of Bothrenchyma, Orthanthera, &c.

further difference is seen in the entire absence from *D. Grievii* of all trace of the thin outermost or subepidermal layer of parenchyma which occurs in young shoots of *D. Oldhamium*.

Vascular bundles.—I have already alluded to the existence in the bark of large bundles of vascular tissue, which ascend vertically through the stem. In transverse sections these bundles exhibit a more or less oval section (Plate XXVIII. fig. 30, *m m′* & *m″*, & Plate XXIX. fig. 35, *m* & *m′*), the longer axes of which are parallel to radial sections, or to the circumference, of the bark. Most of these bundles exhibit some tendency towards a division into two lateral halves, either in a median constriction of their peripheral outline (Plate XXIX. fig. 35, *m′*), in a disposition of the component vessels to group themselves round two determinate centres (Plate XXVIII. fig. 30, *m′*), or in an actual line of demarcation dividing the bundle into two parts. These bundles chiefly consist of barred vessels, with some reticulated ones, imbedded in a mass of small cells identical in size, colour, and general aspect with those of the medullary axis. Under a high magnifier these cells can generally be traced between the two divisions of the vascular bundle. No part of this investigation has caused me such serious trouble as that relating to these bundles. It was easy to see that they *most probably* originated somehow in the vascular axis, and that they proceeded outwards towards the periphery to supply leaves or fronds. The difficulty was to obtain proof of all this, owing to the circumstance that a large number of longitudinal sections threw little light upon the matter. The bundles were present in the sections; but, owing to their small size and want of perfect straightness in their course, I could not trace that course over any considerable area; whilst, so far as I was able to do so, I obtained but few and faint evidences of divergence from parallelism with the central vascular axis. At last, having obtained a favourable specimen, nearly two inches in length, I made, at measured intervals, the series of eight transverse sections represented in Plate XXX. figs. 37–44. These sections gave me the key to the history of this portion of the plant.

We sometimes find these bundles inside the innermost cylinder of bark-cells, as in Plate XXVIII. fig. 30, *m*, and partially in Plate XXIX. fig. 35, *m*. In the latter instance the bundle is almost imbedded *in* this bark-tissue, a condition not unfrequently met with. They further occur in all parts of the middle parenchymatous layer, but never in the prosenchymatous one. So far as I can ascertain, the number of these bundles, in a perfectly free state, in any one transverse section is usually seven or eight, the latter being the largest number that I have yet seen. In the sections represented on Plate XXX. we find only six; but the specimen was imperfect at one side, and one or two bundles doubtless disappeared in the missing portion. Of these sections, I believe fig. 37 to belong to the lower, and fig. 44 to the upper extremity of the fragment; at all events such has been the case if, as I expect, the bundles have supplied leaves and not roots.

In the figures of these sections I have not filled in the details of their organization, but the outlines of the various structures have been drawn to the same scale and with the utmost attention to accuracy of measurement. In each of them *a* represents the medullary vasculo-cellular axis, *g* the pseudocambium or innermost bark, *h* the parenchymatous bark, and the dark shaded outline, *k*, the peripheral prosenchyma. Six vascular bundles are indicated by corresponding numerals, the same numeral being attached to the same bundle in each section. We thus see that in Plate XXX. fig. 37 there is one bundle (3) enclosed *within* the innermost bark; 1, 4, and 6 are external to, but in almost immediate contact with, its outer surface; whilst 2 and 5 are in the parenchymatous layer at a little distance from the pseudocambium. Bundle 1 retains its unchanged position in all the sections up to fig. 42; in each of the remaining two the section is imperfect, and this bundle has been lost. Bundle 2, on the other hand, is seen in all the sections; but it also occupies nearly the same position in fig. 44 that it does in fig. 37, as well as in the intermediate ones. Bundle 3 first appears in fig. 37 enclosed within the pseudocambium layer, but entirely separated from the vasculo-cellular medullary axis: in fig. 38 it is imbedded in the substance of the inner bark; in fig. 39 it has escaped through that innermost bark-layer, and now rests upon the outer surface of it; which position it retains undisturbed up to the uppermost section, fig. 44. Bundle 4 occupies the same unaltered position throughout the entire series. The same remark applies to bundle 6 in the first six sections, in which it is present, it having disappeared from figs. 43 & 44, from the same cause as that which has removed bundle 1. Bundle 5, on the other hand, not only appears in all the series, but has undergone important alterations of position in the interval separating figs. 37 & 44. Following these sections in their numerical order, we see that this latter bundle has moved steadily outwards, until in fig. 43 it only appears as a semidisorganized mass external to the prosenchymatous layer of the bark.

We further learn that the changes in the position of the latter bundle have been accompanied by some correlate changes in the bark itself. In Plate XXX. fig. 37 the prosenchymatous layer of the bark external to bundle 5 is rather thinner than usual, forming a conical protuberance which projects slightly beyond the general peripheral outline of the stem; at the base of the conical portion a prolongation of the prosenchyma extends obliquely inwards to the right, whilst the same layer is also somewhat thickened on the left hand of the apex of the cone. As we proceed towards fig. 40 we find that the prosenchyma to the left hand of the bundle gradually thickens, until it forms a prominence which projects inwards, precisely like that already noticed as existing to the right of the bundle in fig. 37. In fig. 41 we discover that the bundle is fairly within a circumscribed area, which resembles in form a section of the base of a Lepidodendroid leaf. In fig. 42 the bundle has reached the centre of this area, besides which the outermost bark (*k*) immediately external to the bundle is now becoming disintegrated. In fig. 43 the process has gone still further. The half-decomposed bundle can now scarcely be identified, encompassed as it is, in the original section, by the foreign vegetable *débris* which surrounded the entire stem. The thin bark-layer (*k*) seen in fig. 42, has wholly disappeared, and the two projections of the outer bark (k' k') are rapidly converging to produce that complete closure of the interruption to its continuity which is seen in fig. 44.

If we now turn to bundle 2 and interpret it by the light afforded by the preceding description, we shall see that it is about to undergo similar changes. The bundle itself exhibits little change of position in the several sections, but the prosenchymatous bark has altered its form so that the bundle is in nearly the same condition in fig. 44 that bundle 1 exhibits in figs. 38, 39, & 40. We here learn several important facts. The first is that whilst the vascular bundles retain the same unchanged positions throughout a considerable length of the stem, they each in turn move outwards and disappear at the periphery of the bark: the second is that the irregularities in the outline of the bark are not wholly due to external pressure, but to the successive development of a series of peripheral appendages, the bases of which have risen from the bark in the form of sharp, projecting, longitudinally disposed ridges with broad bases. During the progress of these changes we always find that, immediately external to each vascular bundle, the parenchymatous layer of the bark consists of a large mass of very regular and translucent parenchymatous cells, as represented in Plate XXIX. fig. 35, *h''*, and an expansion of which tissue has evidently constituted the great bulk of the appendicular organ, whatever it was, since similar masses of parenchyma retain the same position in the enclosed areas external to bundle 5 in Plate XXX. figs. 41 & 42. I do not doubt that all the lenticular areas of regular parenchyma (Plate XXX. figs. 37, *h'*, & 41, *h'*) enclosed within lines of more condensed cellular tissue were destined in turn to receive new bundles of vessels at points higher up in the stem.

I have no difficulty in determining whence these bundles were derived. I have called attention to the coalesced clusters of small vessels which occupy the peripheral portion of the vasculo-cellular medullary axis immediately within the exogenous layer. Small masses of these clusters, consisting of vessels intermingled with medullary cells, first become isolated, and then tend outwards, emerging through the exogenous zone, as in Plate XXVIII. fig. 30, *m'''*, the exogenous radiating laminæ becoming separated to allow of their escape. On the opposite side of the figure just quoted, we observe a break in the continuity of the exogenous ring, from which vacant space a similar bundle has obviously emerged. Nearly every transverse section in my cabinet exhibits similar evidences that the bundles originated as I have just described. Before considering the probable significance of these growths, there remains to be noticed another peculiar, cylindrical, divergent appendage of a different kind, and which is represented in Plate XXX. fig. 36, *n*. It consists of a mass of cells and vessels, or rather pseudo-vessels, both equally reticulated, which appear to take their rise in the cellular portion of the vasculo-cellular medullary axis. I have not been able to trace any of the true vessels of that axis within the diverging appendage, though I cannot affirm that there is no connexion between the two tissues. At its base this large bundle has been about ·25 in diameter, but it soon contracts to ·12. The section having cut through it somewhat obliquely, its more central portion is seen in the specimen figured, and its peripheral extremity appears in a contiguous section made from the same specimen. By combining the two portions, we obtain a length of nearly half an inch. Arising, as described, in the central axis, it proceeds outwards, penetrating in succession the parenchymatous and prosenchymatous layers of the bark, but carrying the innermost pseudocambial layer (*g*) along with it in the form of an investing sheath (*g'*). At its outer extremity it terminates in a disorganized carbonaceous mass, which I am unable to interpret. The tissues of which this organ is composed remind us of the elongated scalariform cells or incipient vessels which form in the developing roots of Ferns and Lycopods. In this respect they also correspond with the similar appendage of *Dictyoxylon Oldhamium*, shown in Plate XXIII. fig 7, *n'*. The above is the only clearly defined example of this growth which I have seen in *D. Grievii*, but unmistakable indications of a similar structure appear in Plate XXVIII. fig. 30, *n*.

Associated with the ordinary stems of *D. Grievii*, I find abundance of small twigs of the same plant, a transverse section of one of which is shown in Plate XXVIII. fig. 46, and a longitudinal section of the same specimen is given in Plate XXXI. fig. 47. The former of these is precisely what the bundle 5 of Plate XXX. figs. 41 & 42 would be, supposing it could be prolonged upwards, with its investments of parenchyma and prosenchyma, until it projected clear of the parent axis. In the transverse section of each of these twigs we have a more or less triangular figure with prolonged lateral angles. The greater portion of this area consists of a mass of parenchyma (*h*), surrounding a vascular bundle (*m*): the latter consists of an intermingled cluster of barred and reticulated vessels—often separable into two groups, and imbedded in medullary parenchyma. This bundle is not placed in the centre of the twig, but excentrically, or nearer the slightly heart-shaped base than the apex of the triangular outline seen in the transverse section, the peripheral margin opposite to it being either rounded or projecting in an obtuse angle. The entire structure is invested by a thin layer of outermost bark (*k*), consisting of alternating bands of prosenchyma and parenchyma, like those of the parent stem. The thin lateral expansions of the twig are often doubled back upon the thicker central portion, as in Plate XXVIII. fig. 46. The position is an accidental result of pressure, but it indicates that these angles of the twigs projected like those of a petiole with decurrent leaflets.

On turning to the vertical section (Plate XXXI. fig. 47) we find a single central bundle (*m*) invested with a bark which presents, in an uncomplicated form, the essential features of that of the parent stem. We have here the three typical layers of the bark, only the inner bark is very feebly represented. It appears as a thin layer of delicate, vertically elongated cells, immediately surrounding the bundle; it is closely attached to the central vascular bundle opposite to each of the dark transverse bands of the parenchymatous layer, but bulges outwards in the intermediate spaces. The moulding effect of contact with this innermost layer is seen in the undulating outline of the left side of fig. 45, which only represents the parenchymatous and prosenchymatous layers of one of these young twigs. The parenchymatous layer corresponds with that of the larger stems, only each of the dark horizontal bands of cells (*h'*) now extends continuously, in a quoit-like form, across the twig. The prosenchyma, *k*, is in all respects, except its thinner dimensions, like that already described.

Whatever these twigs may be, homologically, I have no doubt that they are the free prolongations of the lateral diverticula from the parent axis, described in pages 400 & 401. There can, I think, be little question that they are petioles rather than branches; but as yet I have not succeeded in connecting them with any thing resembling leaves. They bear so close a general resemblance to corresponding sections of the petioles of the *Lepidodendra* as to leave little room for doubting their petiolar character. If this be a correct interpretation, it follows that *Dictyoxylon Grievii* has been a stem giving off large foliar appendages, at somewhat distant intervals and from its entire circumference. That these appendages have been of considerable dimensions relatively to the diameter of the main stem, is indicated by the large size of each of the petiolar bundles of vessels. Whether it was an erect stem or a creeping rhizome is doubtful; but the circumstance that the exogenous zone is always so much thicker on one side than on the other, suggests the possibility of an excess of vital action on that side, due to the stimulus of light upon the upper surface of a creeping stem. Supposing this inference to be correct, the question recurs, What is the large divergent vascular bundle of fig. 36? Most probably the vascular bundle of a large adventitious root rather than a true branch. It bears a most striking resemblance to the bundles seen in corresponding sections of recent Lycopodiaceæ, which supply the roots or root-bearers; only in the latter case the vessels originate in the vascular bundles of the main axis. It bears a still closer resemblance to that of *D. Oldhamium*, seen in Plate XXIII. fig. 7, *n*. In both plants the reticulated vasculo-cellular mass appears to be projected from cellular tissues; only in *D. Oldhamium* the intervention of a thick ligneous zone shuts out the root-like organ from direct association with the pith, and compels it to spring from it indirectly through the cells of the medullary rays, whilst in *D. Grievii* it starts directly from the axial medullary cells.

The supposed petioles just described, whether we regard their structure or their probable origin as illustrated by Plate XXX. figs. 37–44, help to throw some light upon the very similar portion of *Dictyoxylon Oldhamium* represented in Plate XXVI. fig. 25. The latter bears strong indications of having been one of the double vascular bundles seen in the inner and middle layers of the bark, but which is here moving outwards to form, with its surrounding parenchyma, the base of a petiole. But if this has been the case, why are such examples so seldom met with? and where are the petioles which, considering how abundant *Dictyoxylon Oldhamium* is, cannot have been rare objects?

In the 'Proceedings of the Royal Society' (xx. p. 438) I have pointed out the existence, in the Lancashire nodules, of abundance of small stems or petioles, to which I gave the provisional name of *Edraxylon*. I have since succeeded in connecting these petioles with the leaflets of a *Pecopteris*. I think it far from impossible that these may prove to belong to *Dictyoxylon Oldhamium*; but since I have not yet succeeded in correlating them with any certainty, I shall add no more respecting them at present; the details of their curious organization will be made the subject of a future memoir. It follows from the previous determinations that the bark of *D. Grievii* is essentially a mass of coalesced petioles. The final question to be asked is difficult to answer. What are the mutual relations and botanical affinities of the two plants which I have described? That they possess many points of close mutual resemblance is obvious from the preceding descriptions, especially in their reticulated vessels, in the general aspects and arrangement of their cortical vascular bundles, in their root-like appendages, and especially in the structure of the parenchymatous portions of the bark. On the other hand, they exhibit some equally obvious differences, especially in the composition of the vasculo-cellular medullary axis and in the very different dimensions attained by their exogenous ligneous zones. There is now no room whatever for doubting that the *Lyginodendron* of Mr. GOURLIE is a sandstone impression of the exterior of the bark of a plant like *Dictyoxylon Oldhamium*, if it does not, as I think exceedingly possible, represent the arborescent condition of the same species; but since the latter point is not clearly established, it will be more prudent to retain, for the present, Mr. BINNEY'S specific name. On the other hand, my generic name of *Dictyoxylon* must clearly be abandoned for that of Mr. GOURLIE, so that the plant in question may henceforth be recognized as *Lyginodendron Oldhamium*. If at any future period specimens having the internal organization of our Oldham plant should be found at the Ayrshire district, whence the Rev. DAVID LANDSBOROUGH obtained his casts, it may then become necessary to adopt Mr. GOURLIE'S name of *Lyginodendron Landsburghii* in its totality.

In plate xvii. of his 'Flora der Vorwelt,' CORDA published sections of a fragment of a plant which he obtained from the Bohemian Coal-measures, and to which he gave the name of *Heterangium paradoxum*. This specimen only exhibited a small portion of the vasculo-medullary axis; but, so far as it goes, the structure which he figures and describes appears identical with the corresponding portion of my *Dictyoxylon Grievii*. Since no trace of the bark exists in his specimen, we cannot identify the species of the German botanist with the Burntisland plant. But I think there can be no doubt that the two objects are generically identical. This circumstance in some degree affects the question whether the two plants which I have just described should be united in one genus or separated into two. On this point I entertain serious doubts; but if the latter plan be adopted, then my *Dictyoxylon Grievii* must be recognized as *Heterangium Grievii*. By acting thus we not only create no new genus, but, by the extinction of my new term *Dictyoxylon*, actually reduce the existing number; hence, for the present, it may be desirable to adopt this plan. If further research should bring the two plants yet closer together, then Mr. GOURLIE'S, being the oldest of all these generic terms, must be adopted for both. The accident of CORDA'S introduction of a fragment of *Lyginodendron* amongst his figures, under the name of *Sagenaria fusiformis*, is so obviously a blunder, that this still more ancient generic term may be excluded from our consideration.

We must not forget that all these names are merely provisional ones. These and numerous other stems that are the subject of research doubtless belong, in most cases, to leaves that are already well known, and that have long ago received appropriate names, which names must be those permanently adopted whenever we ascertain the correlation of these *disjuncta membra*.

The question of the botanical position of both the above plants remains undecided, and I confess I shrink from arriving at a decision in the present state of our knowledge respecting them. If I succeed in establishing a connexion between the common Oldham plant and the equally common *Edraxylon*, then, strange as it may appear, the former will become an undoubted arborescent fern; at the same time it has many features of affinity with the Lycopodiaceæ that must not be overlooked. On the other hand, the Burntisland species looks more Lycopodiaceous than fern-like; yet it is very different from all the other Lycopodiaceæ of the Carboniferous age with which we are familiar. I confess I find an increasing difficulty in distinguishing between the fossil stems of Lycopods and of Ferns—a difficulty that increases rather than the reverse the more extensive my acquaintance with these fossil forms becomes. These objects differ from their diminutive recent allies in so many features of their internal organization, that structural differences, of which we avail ourselves amongst the living plants, wholly fail to help us in discriminating the fossil ones. Until we obtain more decisive evidence respecting the foliage of the two subjects of this memoir, I fear we must locate them amongst the miscellaneous objects which BRONGNIART brings together under the heading of "*Sedes incertæ*"*.

The two figures Plate XXXI. figs. 48 & 49 are scarcely restorations, because little is introduced into either of them the presence of which is not absolutely demonstrated in the preceding figures. They are therefore diagrams showing the bird's-eye view of the actual structure of these plants, rather than restorations. The various letters of reference attached to them respectively indicate the same structures and tissues as those employed in all the other figures.

I have again to acknowledge my obligations to my Oldham friends, Mr. BUTTERWORTH, Mr. NIELD, Mr. WHITTAKER, and Mr. ISAAC EARNSHAW, for the aid they have afforded me in keeping me supplied with an abundance of specimens for examination. Through Mr. NIELD's invaluable aid I have obtained large supplies of the calcareous nodules in which the fossil plants are found; and every one of these nodules has been subjected to an exhaustive examination, lest any available fact of importance should escape my eye. In reference to the Burntisland specimens, all my great obligations are centered in GEORGE GRIEVE, Esq., whose persevering energy and kindness I have already recorded in previous memoirs, and who has continued to lay me under fresh obligations. I must also record kind assistance from the Messrs. PATTESON, the well-known marble merchants of Manchester, who have allowed me the gratuitous use of their labourers and mechanical appliances on several occasions, when such help has been of material

* More recent researches have rendered it increasingly probable that *Heterangium Grievii* is a true fern. If so, the exhibition in its vascular axis of a very rudimentary form of exogenous growth becomes a physiological feature of great interest.—Manchester, September 15th, 1873.

value. To all these friends I can only return my cordial thanks for the aid they have so kindly rendered.

Description of the Plates.

Lyginodendron Oldhamium.

Plate XXII. fig. 1. Transverse section of a young stem with an exogenous branch emerging through the bark, magnified $4\frac{1}{2}$ diameters.

„ fig. 2. Medullary axis and inner part of the ligneous zone of a very young stem, magnified 40 diameters.

„ fig. 3. Segment of a ligneous zone with one of the detached vascular masses of the medullary axis, magnified 50 diameters.

„ fig. 4. Transverse section of the entire vascular axis of a young stem, with an external young and half-developed vascular layer; magnified 6 diameters.

„ fig. 4*. Reticulated vessel of the ligneous zone, magnified 200 diameters.

„ fig. 5. Transverse section of the cellular tissue of the medulla, magnified 150 diameters.

Plate XXIII. fig. 6. Segment of a transverse section of a young stem with a young exogenous layer of half-developed vessels, magnified 50 diameters.

„ fig. 7. Segment of a transverse section of a young stem, giving off a supposed root-bundle, magnified 50 diameters.

„ fig. 8. Tangential section of the ligneous zone, composed of a network of vessels and numerous medullary rays, magnified 70 diameters.

„ fig. 9. Radial section of part of a ligneous zone, with portions of two vascular laminæ (*e*), and one medullary ray composed of mural cells (*f*), magnified 70 diameters.

Plate XXIV. fig. 10. Transverse section of part of the bark, with its several divisions of innermost layer (*g*), parenchymatous layer (*h*), prosenchymatous layer (*k*), and subepidermal layer (*l*), magnified 50 diameters.

„ fig. 11. Tangential section of the ligneous zone, giving off a lateral branch: the section intersects the bark (*g*, *h*, and *k*) almost radially; *h′*, frequent patches of dark-coloured cells: magnified 6 diameters.

„ fig. 12. Portion of fig. 11, magnified 18 diameters.

„ fig. 13. Tangential section of the prosenchymatous layer of the bark, with its prosenchymatous bands and cellular areolæ, magnified 5 diameters.

Plate XXV. fig. 14. Tangential section of the prosenchymatous layer of the bark of a young stem, with a branch emerging through it, magnified 6 diameters.

Plate XXIV. fig. 15. Tangential section of the prosenchymatous layer of the bark, showing the tubular fibres of the prosenchymatous bands, magnified 28 diameters.

Plate XXV. fig. 16. Tangential section of the middle cortical parenchyma of a large stem, giving off an exogenous branch, magnified nearly 20 diameters.

„ fig. 17. Double cortical bundle of vessels imbedded in the innermost bark-layer with the exterior of the ligneous zone, magnified 30 diameters.

Plate XXVI. fig. 18. Cortical bundle of vessels from fig. 1, magnified 80 diameters.

Plate XXV. figs. 19 & 20. Cortical bundles of vessels, with peripheral exogenous growths, from the innermost bark-layer of fig. 1, magnified 80 diameters.

„ fig. 21. Cortical bundle of vessels with wedge-shaped exogenous additions to its exterior surface and adherent to the ligneous zone, magnified 24 diameters.

Plate XXVI. fig. 22. The branch (*y*) of fig. 14, enlarged 60 diameters.

„ fig. 23. Central vascular bundle, with some of the exogenous laminæ and medullary rays of the branch (*x*) of fig. 1, enlarged 100 diameters.

„ fig. 24. Transverse section of part of a young stem, the ligneous zone of which is giving off an exogenous branch.

„ fig. 25. Transverse section of the bark of a young stem, with a double vascular bundle escaping through the prosenchymatous bark, as if to reach a petiole; magnified 75 diameters.

Plate XXVII. fig. 26. Cast of the exterior of the bark of an arborescent stem.

„ fig. 27. Cast of the exterior of the bark of an arborescent stem.

„ fig. 28. Cast of the exterior of the bark of an arborescent stem.

„ fig. 29. Cast of the exterior of the bark of an arborescent stem.

Heterangium Grievii.

Plate XXVIII. fig. 30. One half of the transverse section of a stem, magnified 22 diameters.

„ fig. 31. Portion of the medullary axis of fig. 30, magnified 70 diameters.

Plate XXIX. fig. 32. Longitudinal section of the stem, magnified 24 diameters.

„ fig. 33. Radial longitudinal section of the exogenous zone of fig. 30, with mural medullary rays, magnified 72 diameters.

„ fig. 33 *a*. Tangential section of the exogenous zone, showing the medullary rays, magnified 75 diameters.

Plate XXVIII. fig. 34. Reticulated vessel, enlarged 200 diameters.

Plate XXIX. fig. 35. Segment of a transverse section of the bark, magnified 24 diameters.

Plate XXX. fig. 36. Transverse section of a stem, giving off a lateral pseudo-vascular bundle, probably supplying an adventitious root, magnified 6 diameters.

„ fig. 37.
„ fig. 38.
„ fig. 39.
„ fig. 40.
„ fig. 41.
„ fig. 42.
„ fig. 43.
„ fig. 44.

(figs. 37–44) Successive series of transverse sections of one stem, about 2 inches long, showing the changes in the relative positions of the vascular bundles at various heights of the stem: magfied 10 diameters.

Plate XXXI. fig. 45. Vertical section of the middle and outer layers of the bark of a young twig, magnified 96 diameters.

Plate XXVIII. fig. 46. Transverse section of a young twig, magnified 24 diameters.

Plate XXXI. fig. 47. Longitudinal section of the twig fig. 46, magnified 24 diameters.

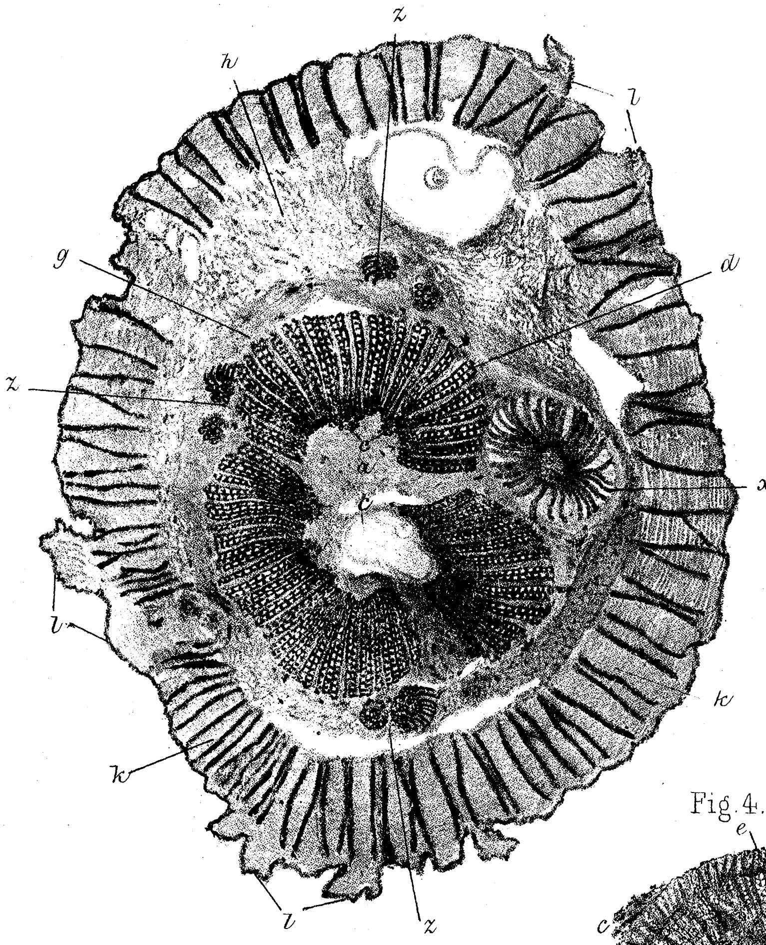
„ fig. 48. Restoration of the young stem of *Lyginodendron Oldhamium*, cut open to show the several structures.

„ fig. 49. Restoration of the stem of *Heterangium Grievii*, cut open as in fig. 48.

Throughout the entire series of the preceding figures, the same letters are employed to indicate what appear to be homologous tissues and organs. They are also employed, as far as possible, in the same way as in my preceding memoirs of this series.

a. Medullary axis.
b. Medullary cells.
c. Medullary vessels.
d. Ligneous zone.
e. Ligneous zone, vessels of.
f. Medullary rays of ligneous zone.
g. Innermost bark-layer, parenchymatous.
h. Middle bark-layer, parenchymatous.
k. Prosenchymatous bark.
l. Subepidermal parenchyma.
m. Foliar (?) bundles of vessels.
n. Root-bundles ?
x & *y.* Branches.
z. Stem-bundles.

Fig. 1.



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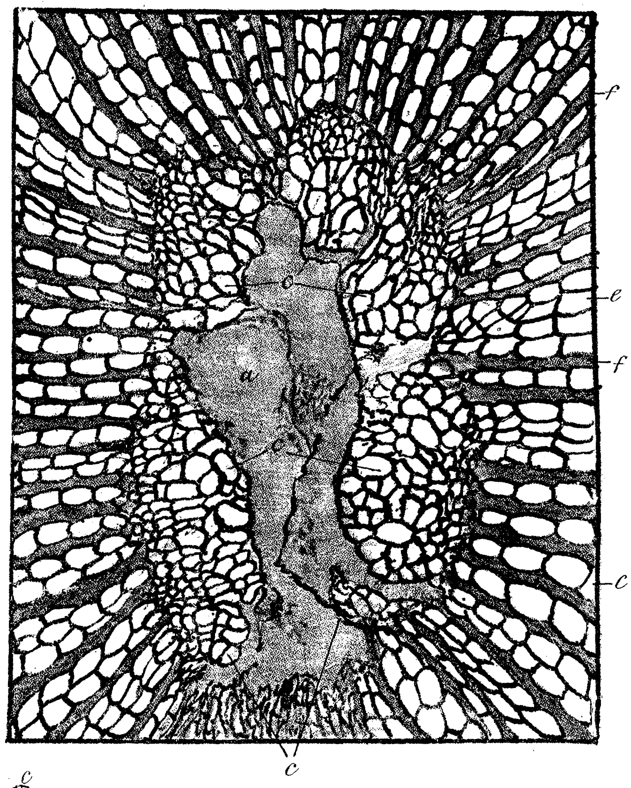

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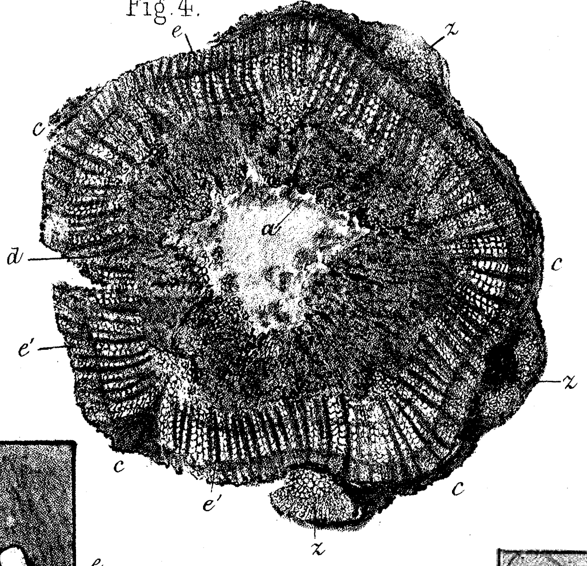

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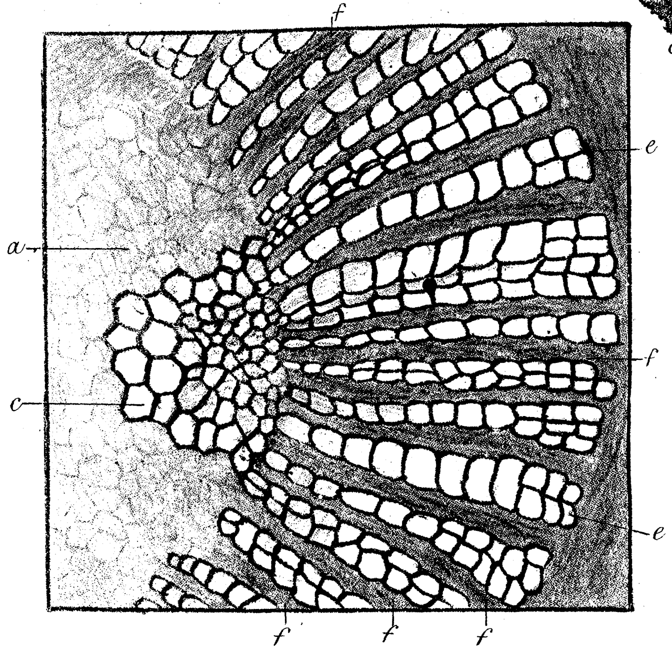

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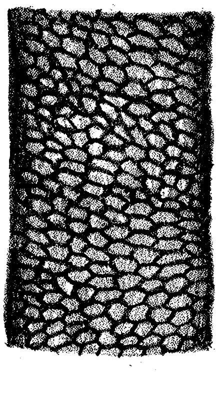

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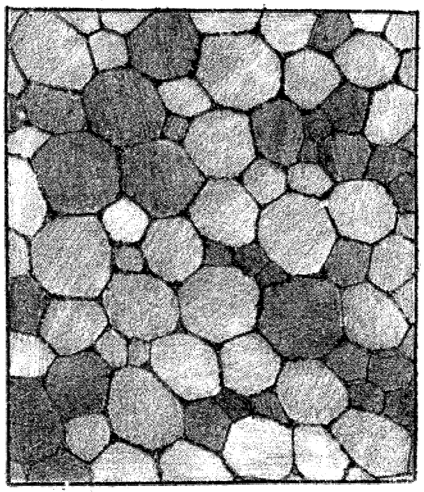

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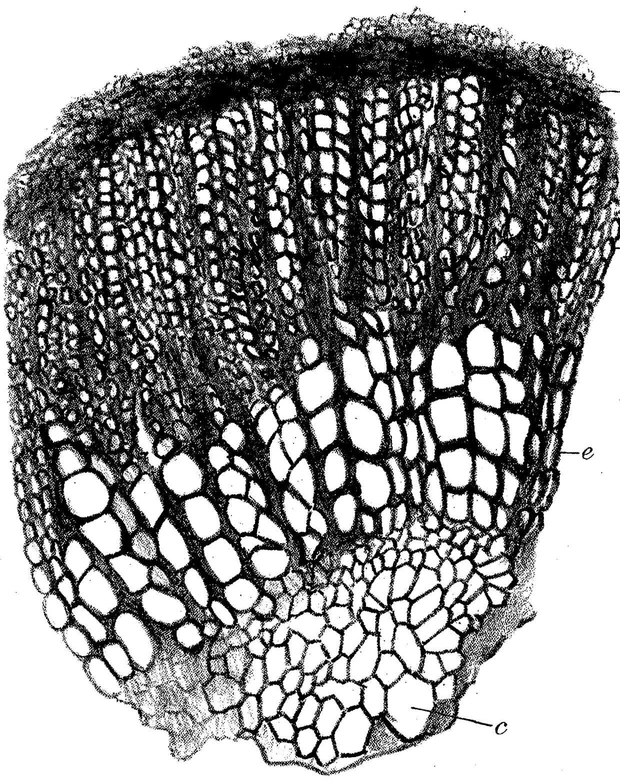

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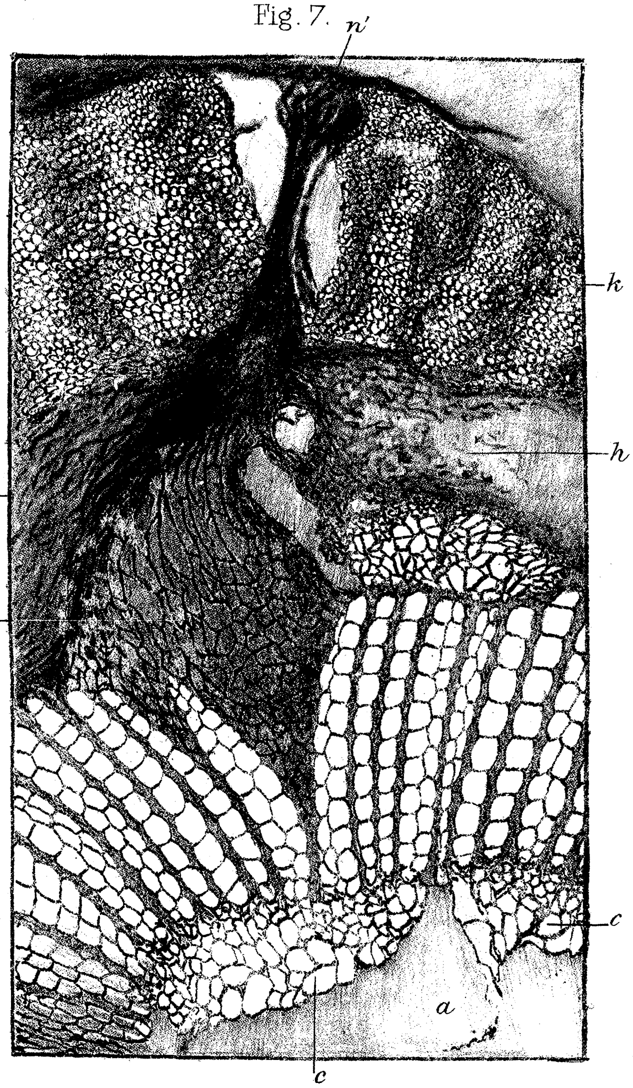

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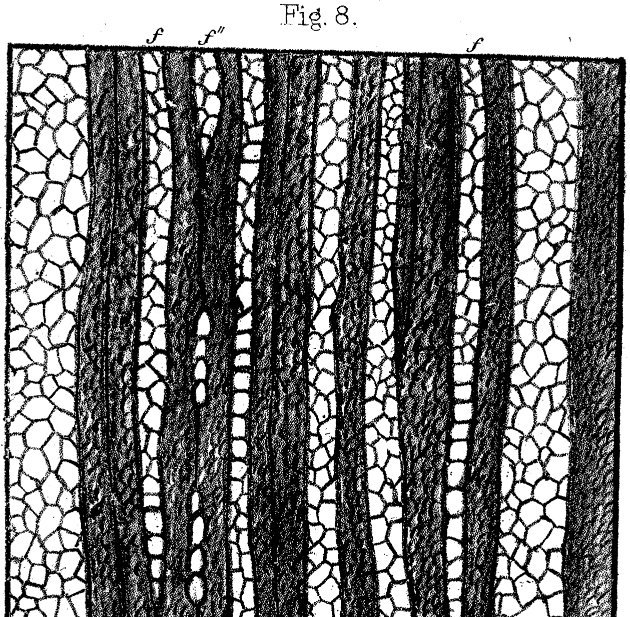

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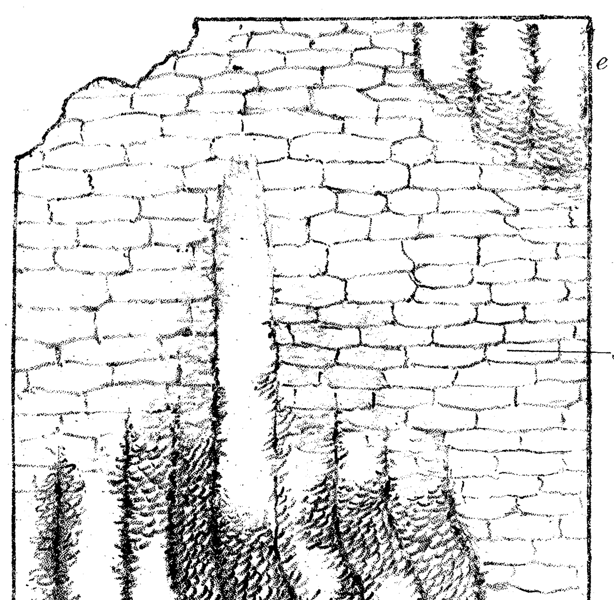

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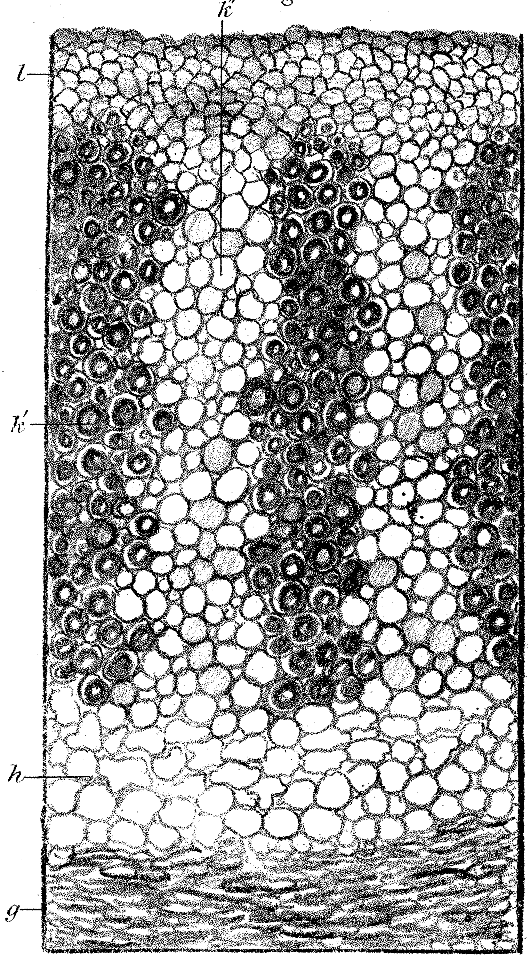

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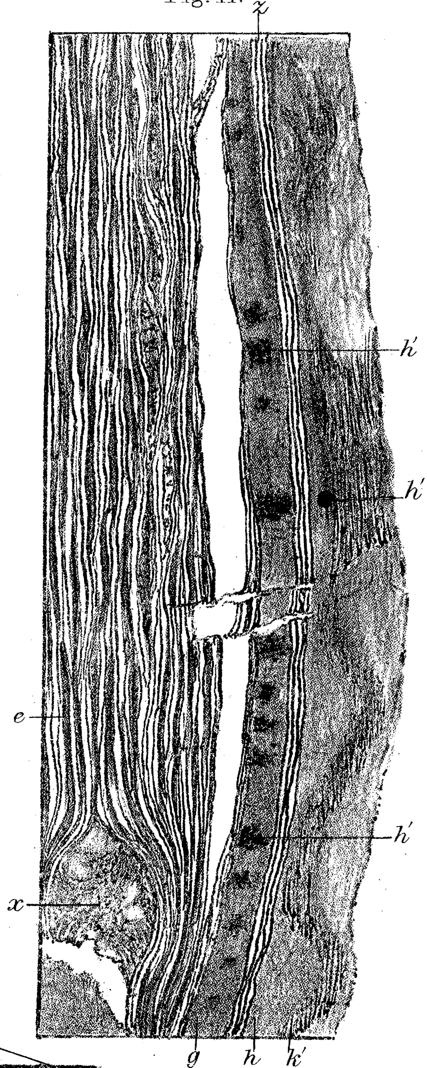

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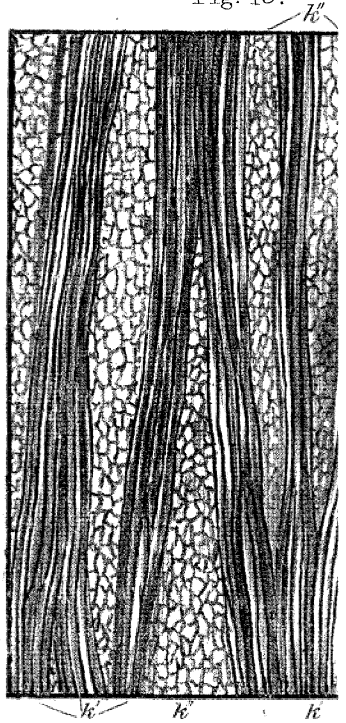

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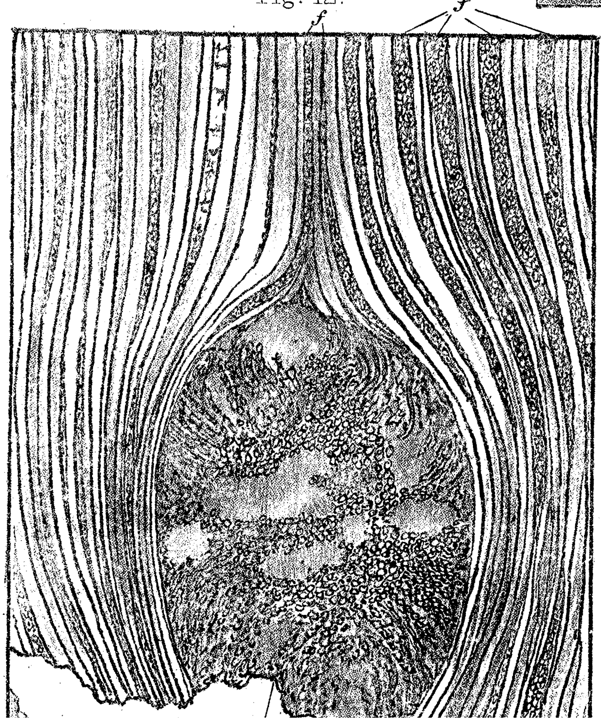

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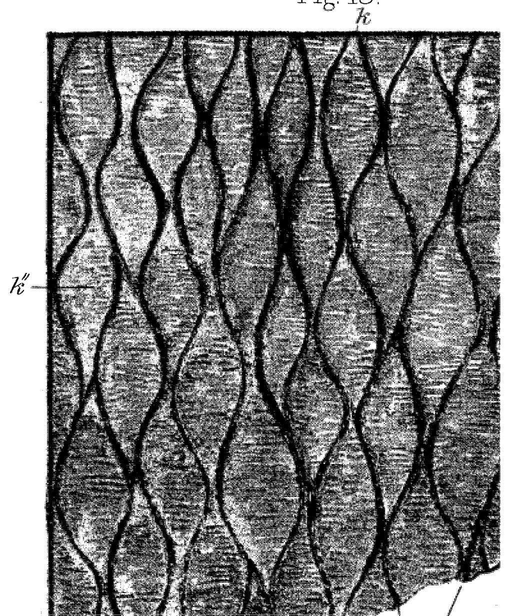

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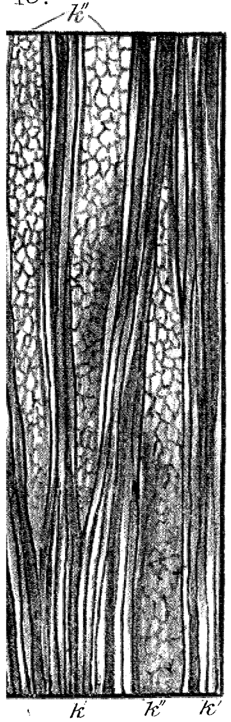

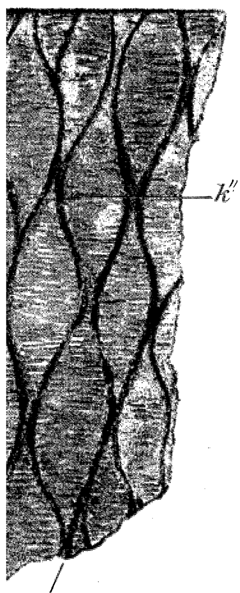

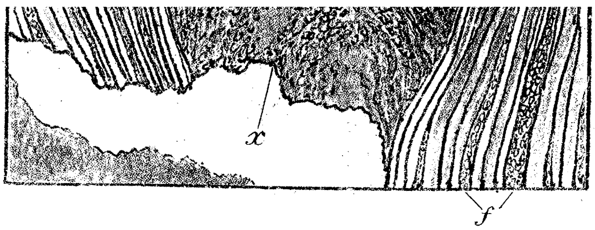

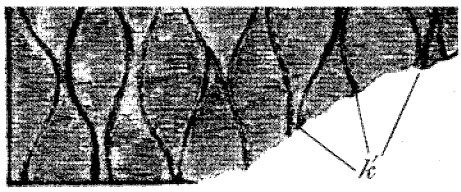

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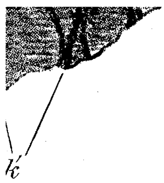

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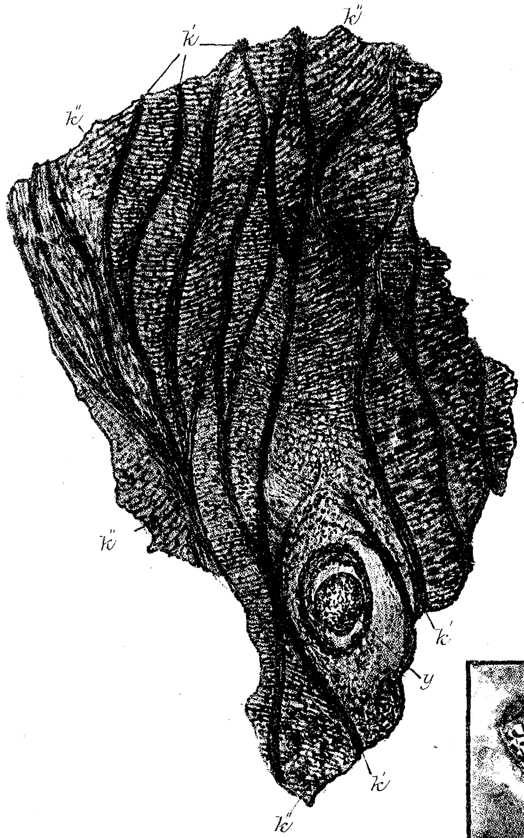

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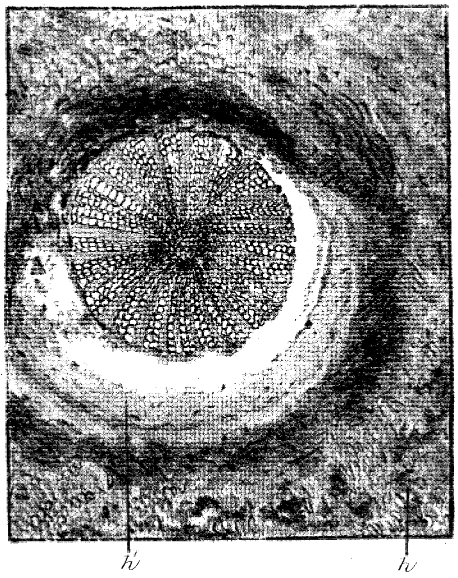

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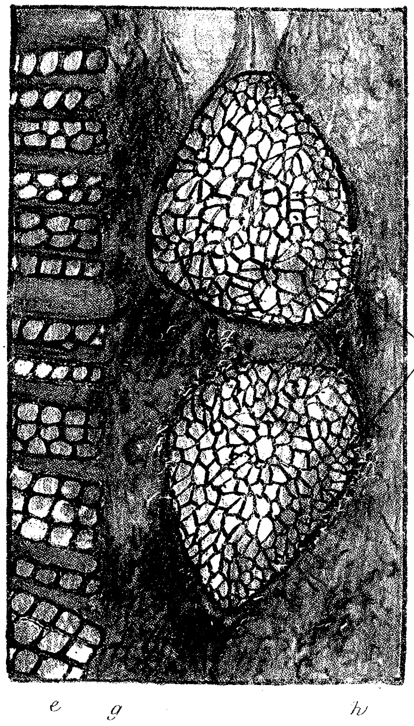

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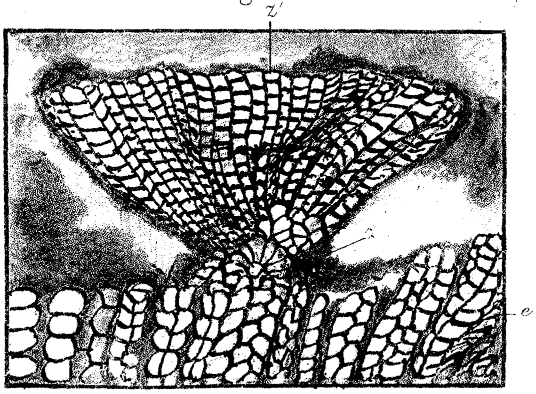

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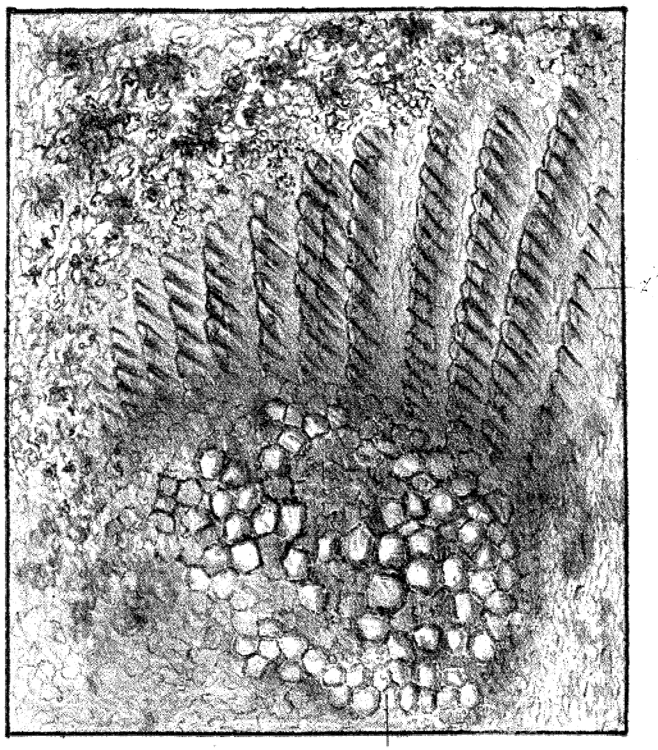

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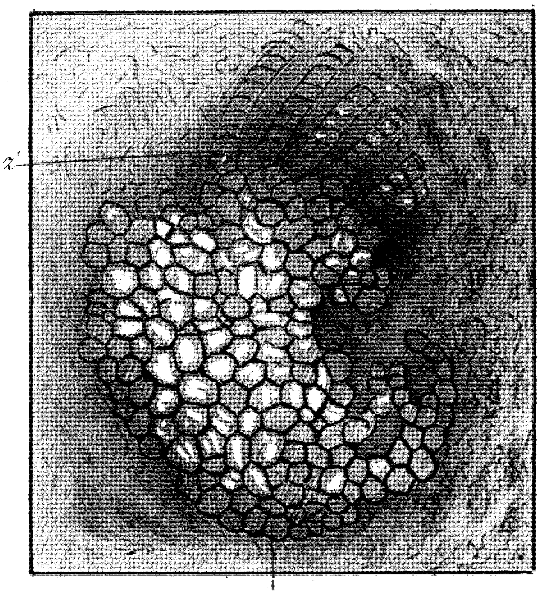

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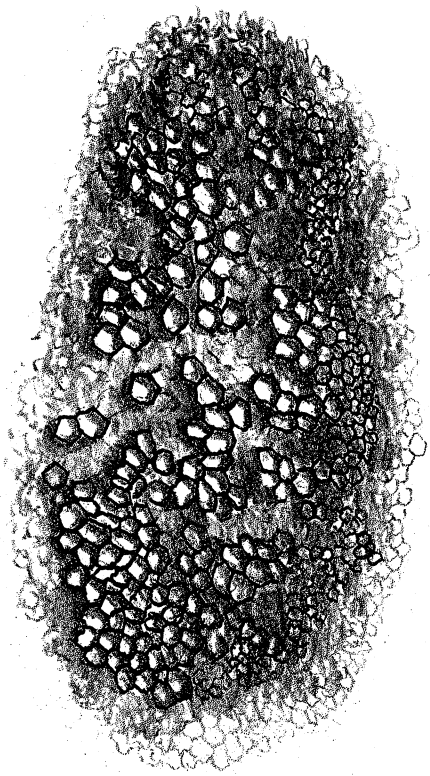

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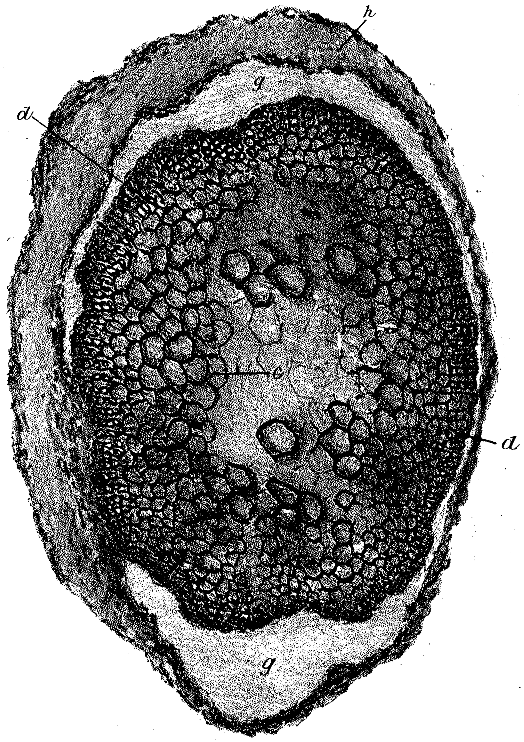

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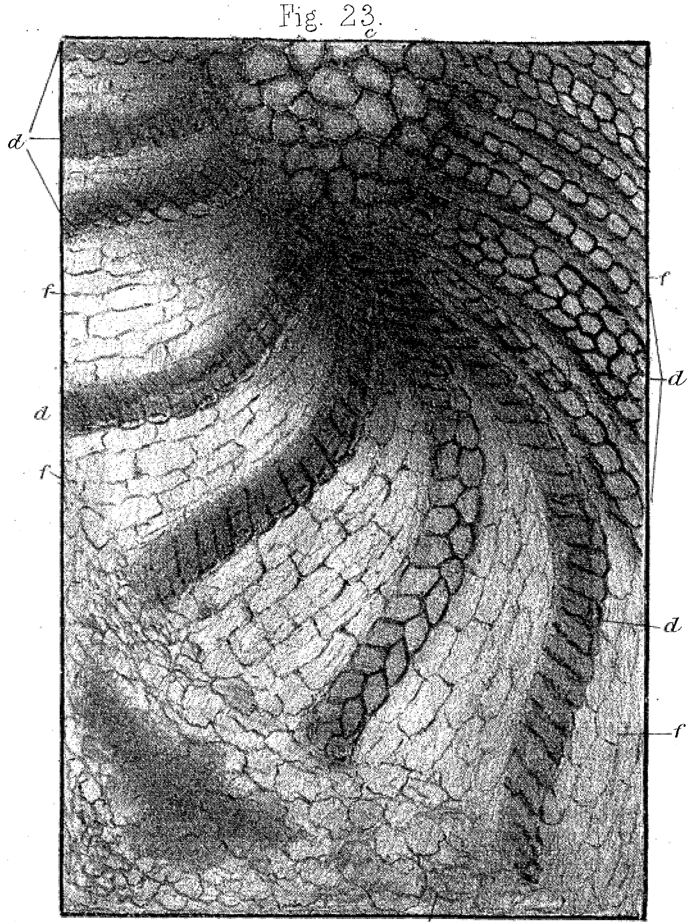

Fig. 25.

Fig. 26.

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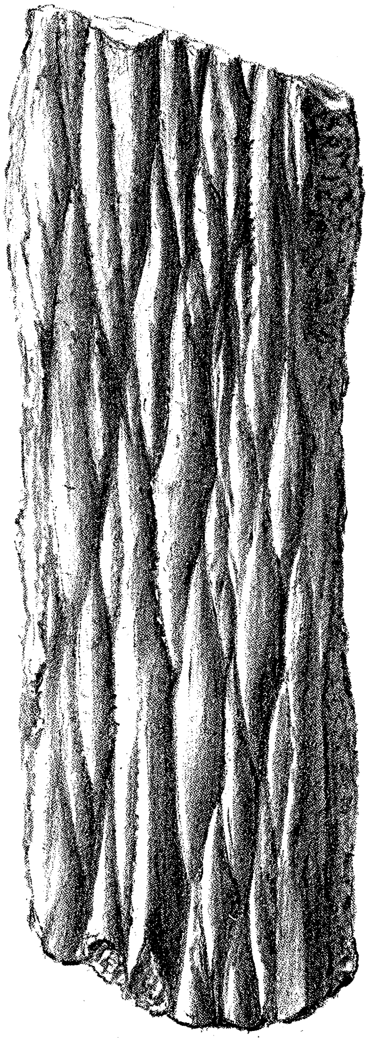

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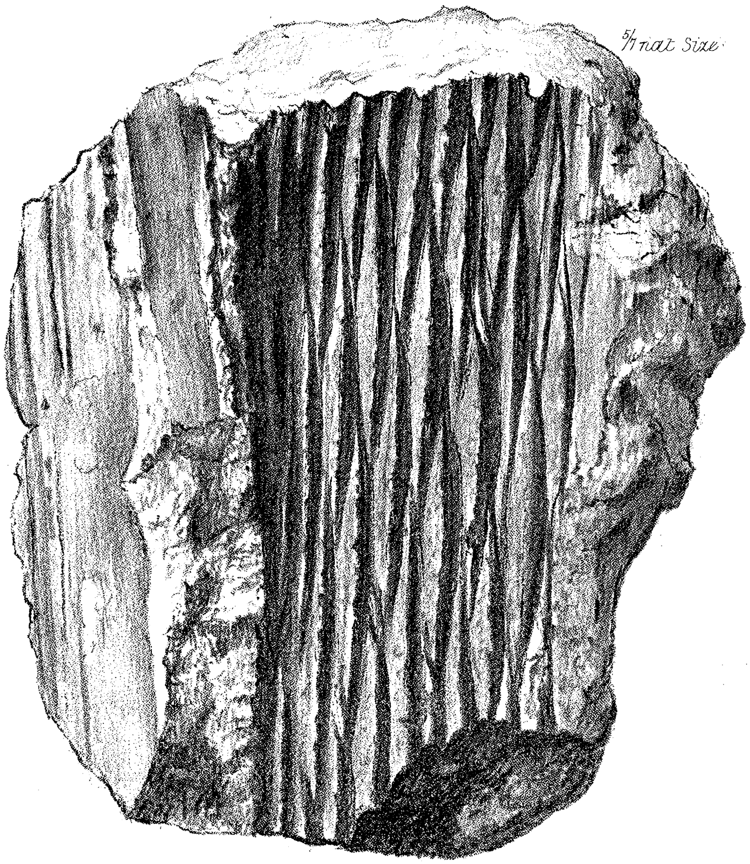

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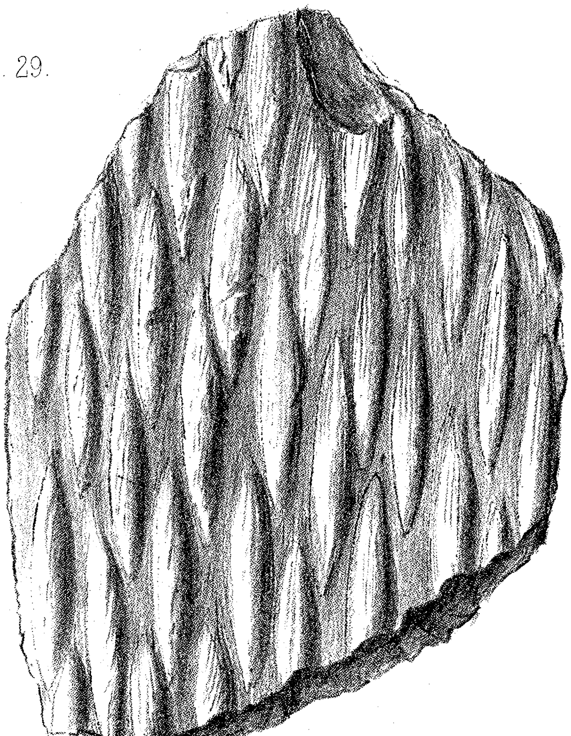

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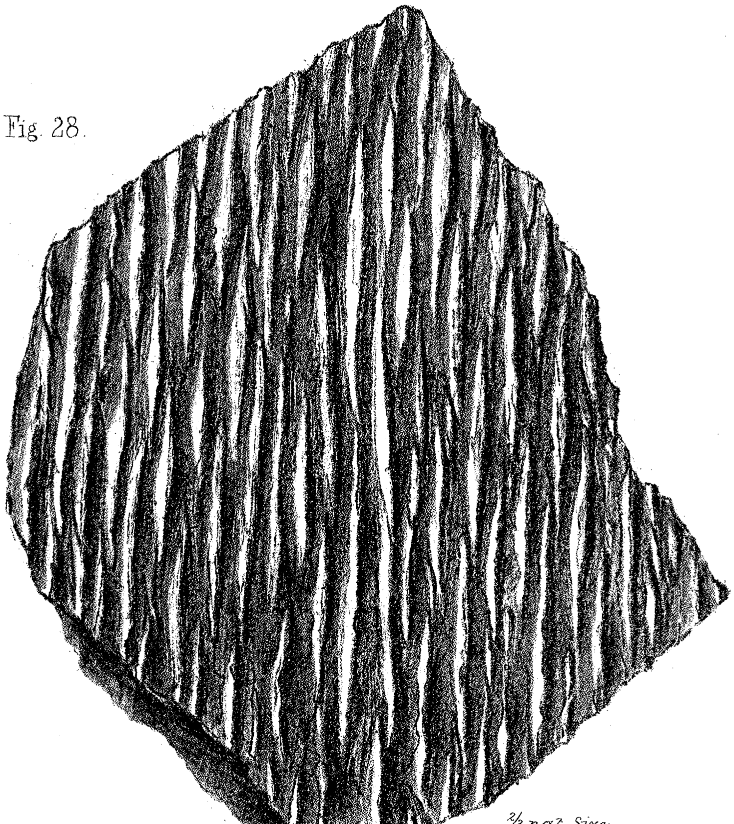

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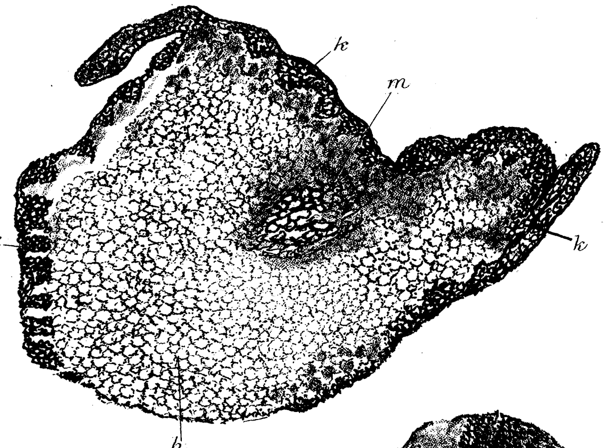

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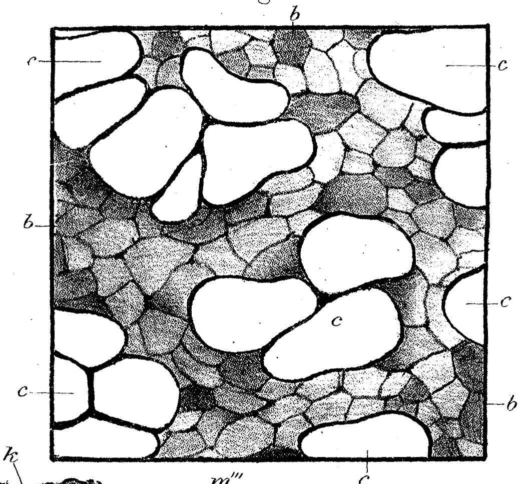

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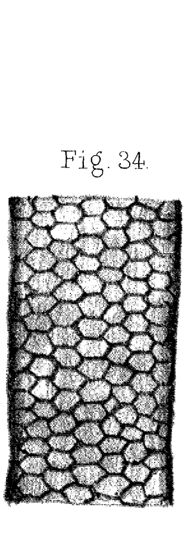

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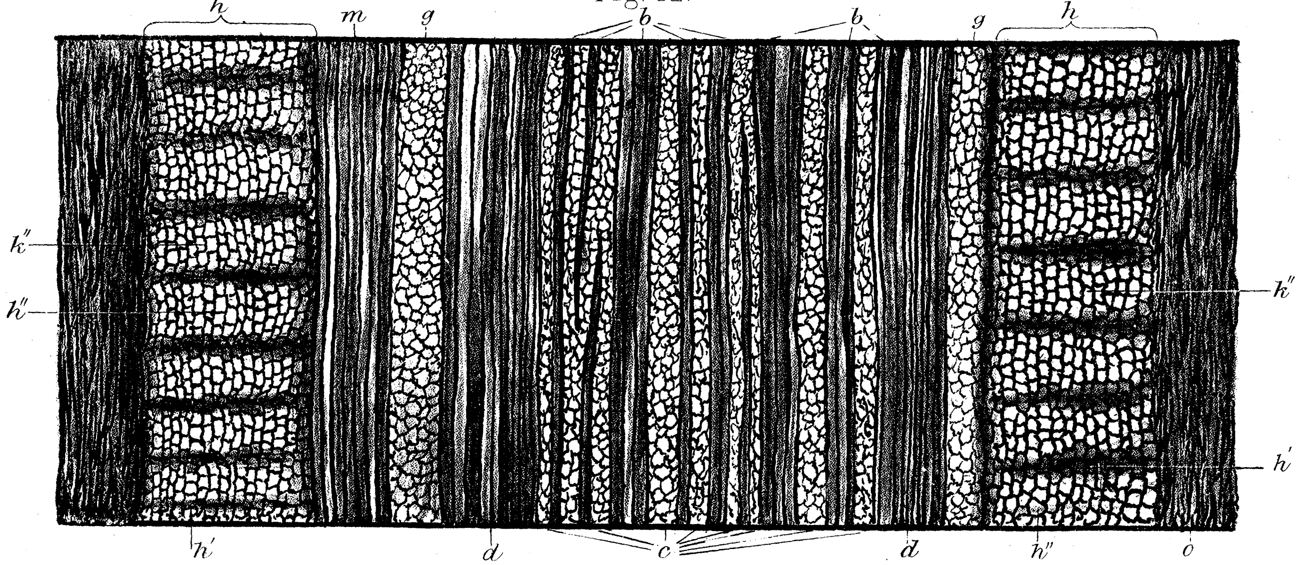

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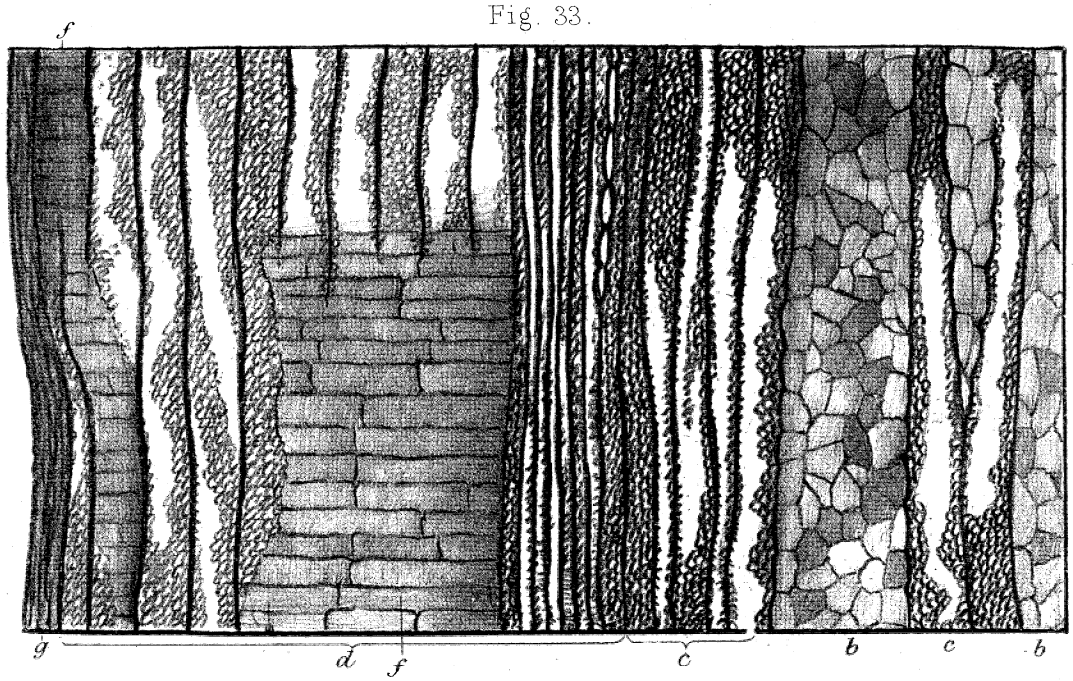

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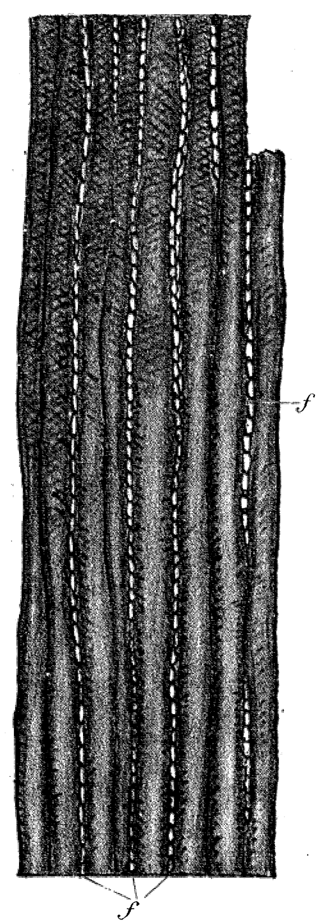

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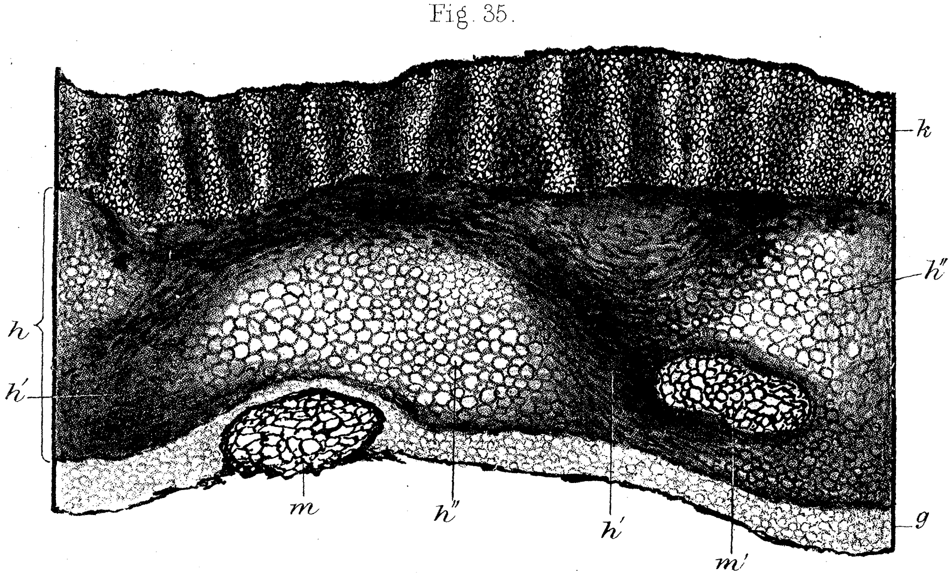

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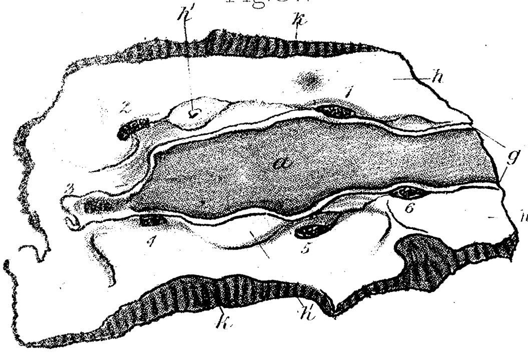

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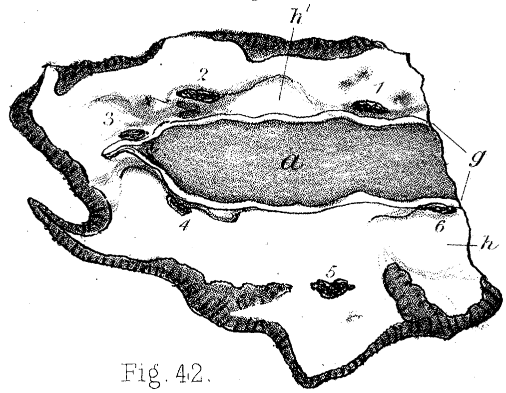

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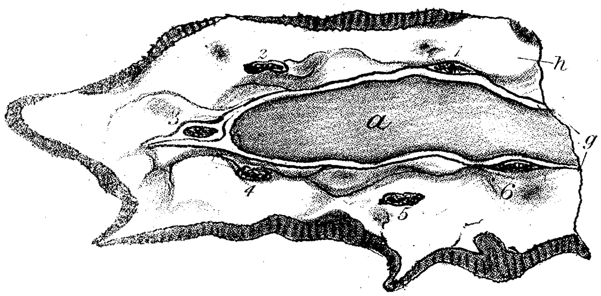

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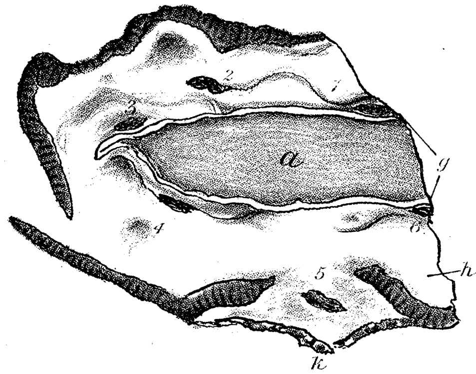

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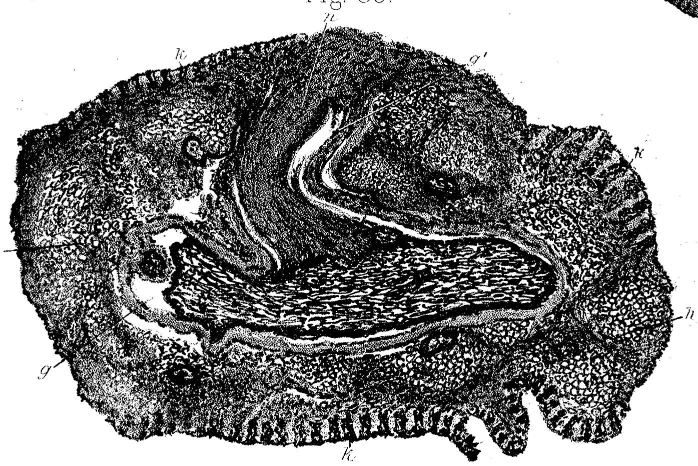

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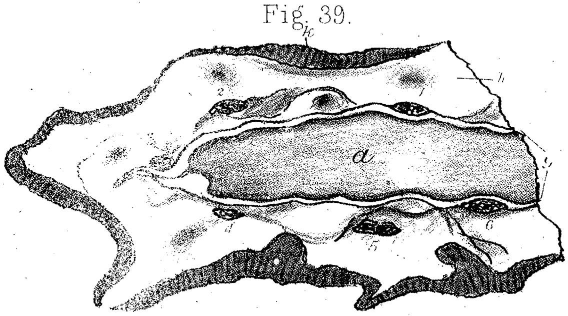

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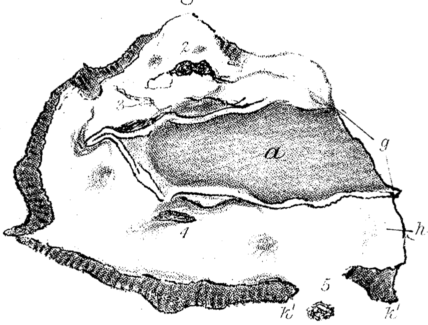

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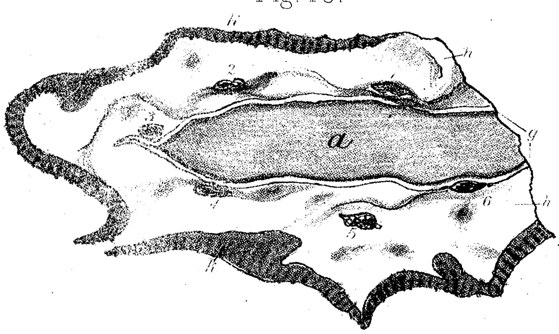

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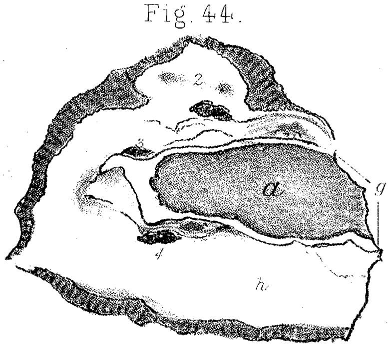

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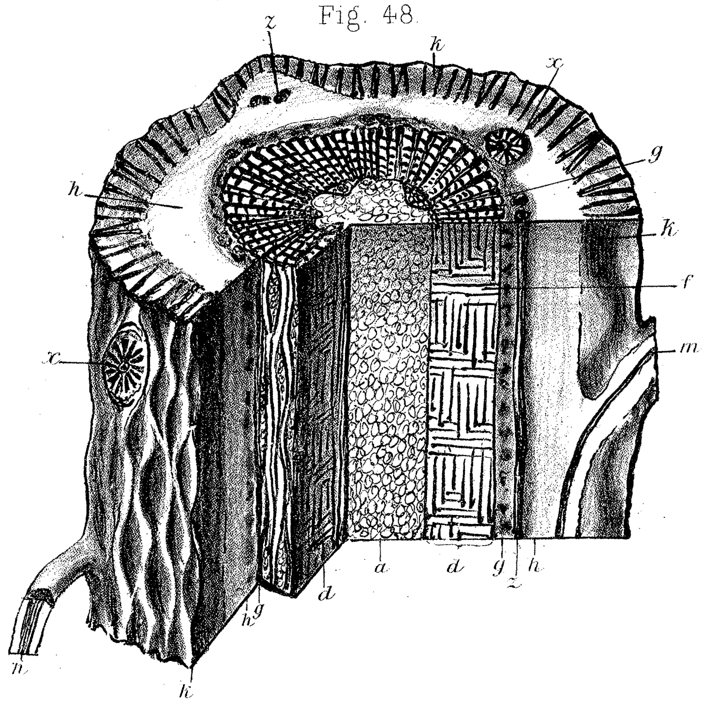

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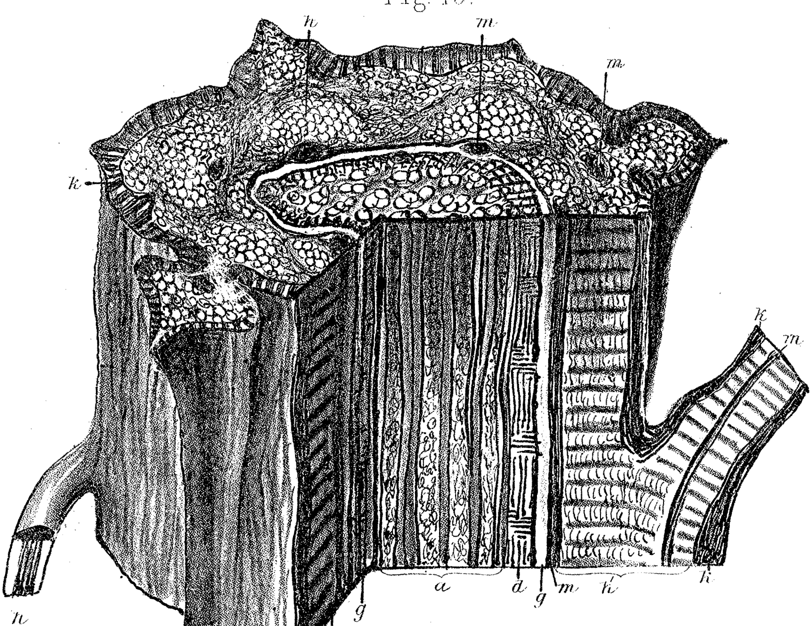

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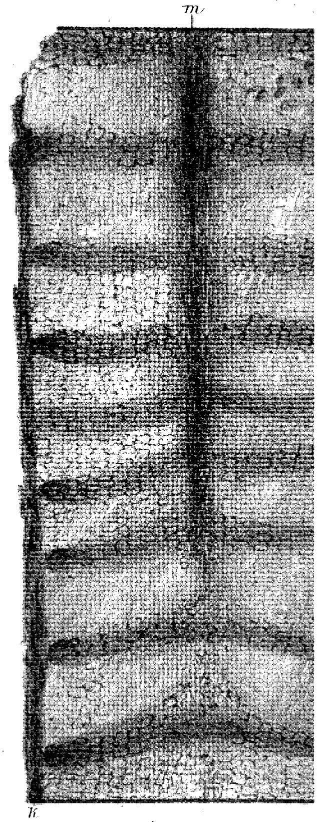

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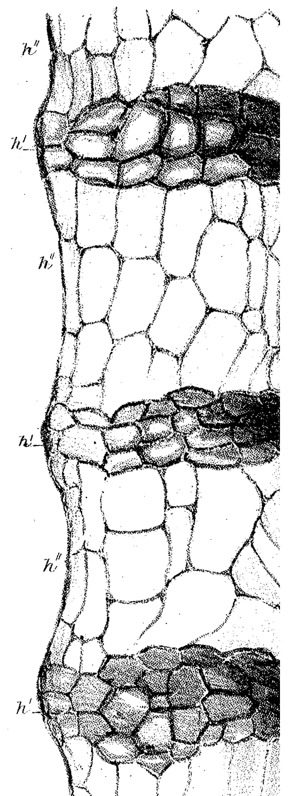

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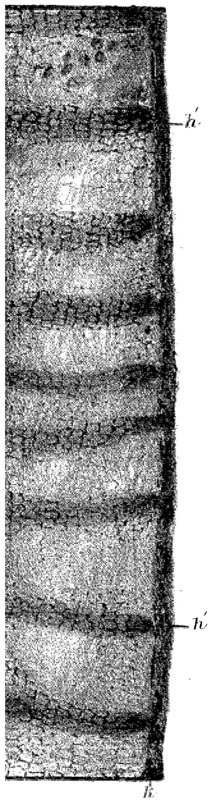

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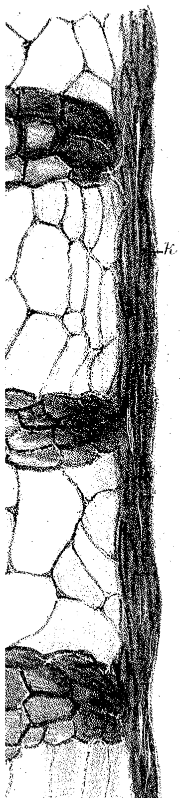

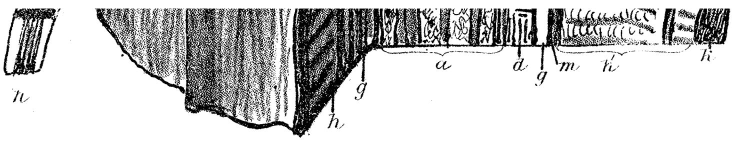

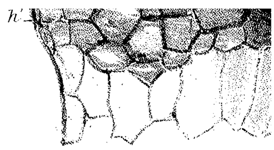

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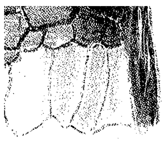

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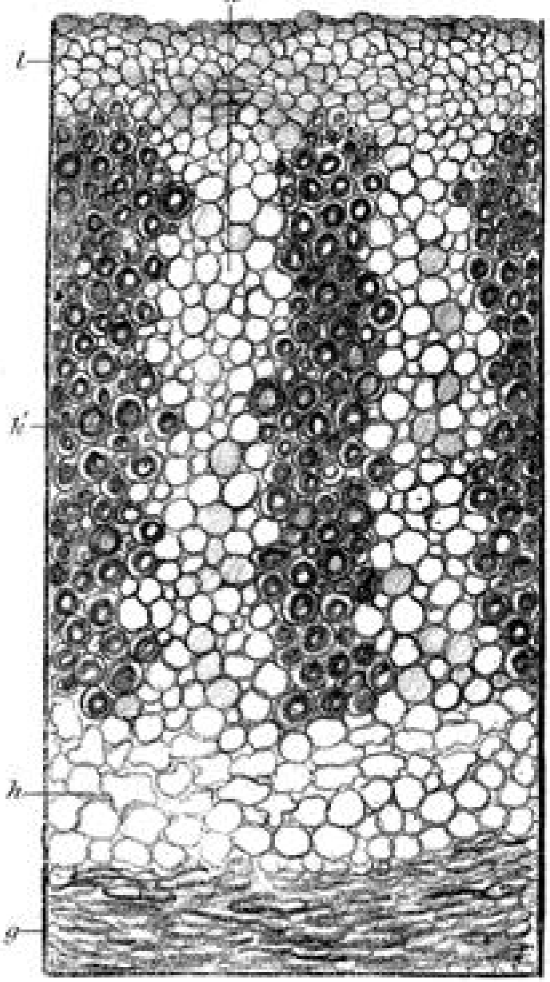
Fig. 10.



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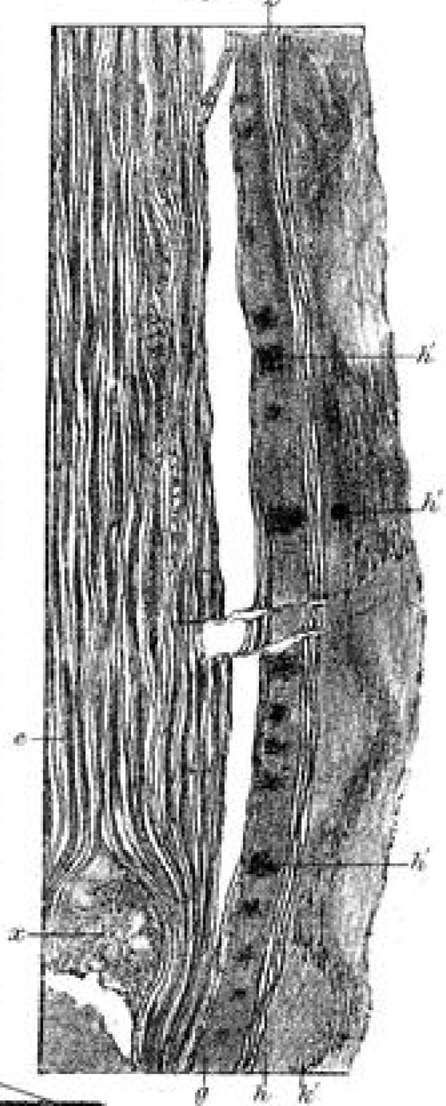

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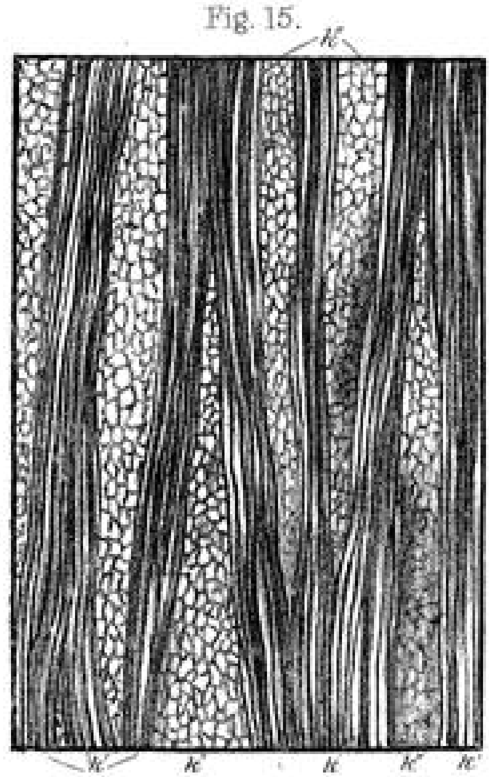

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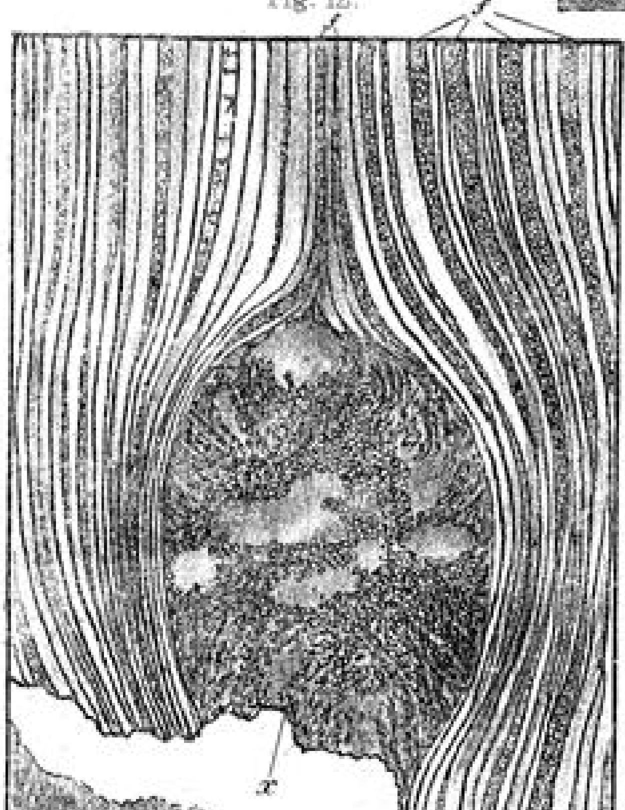

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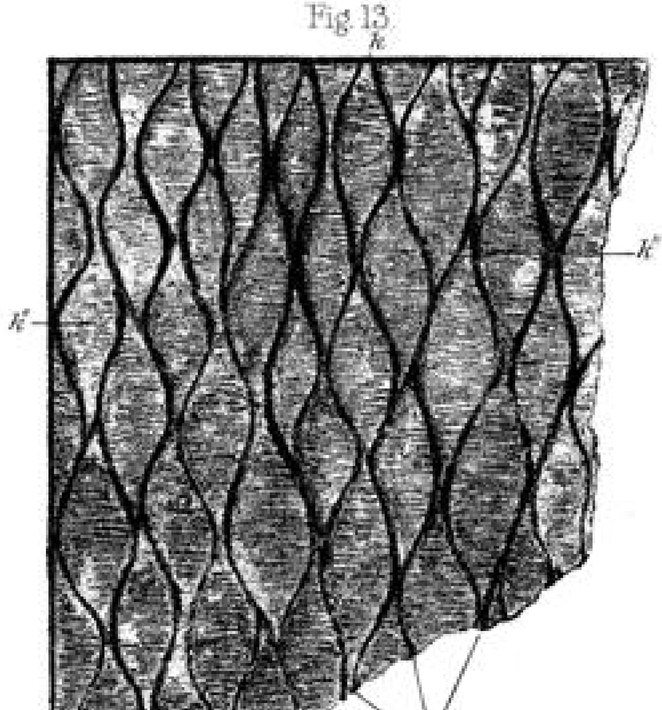

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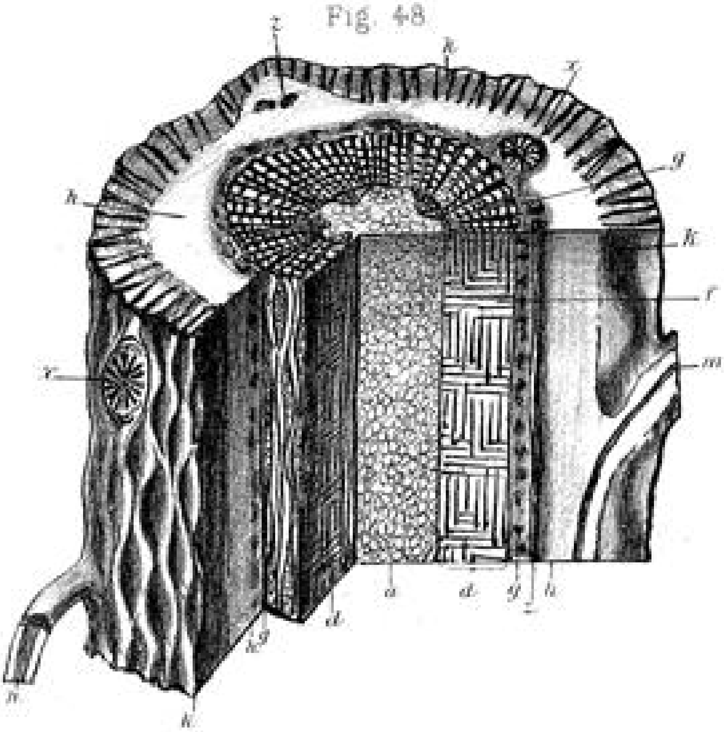

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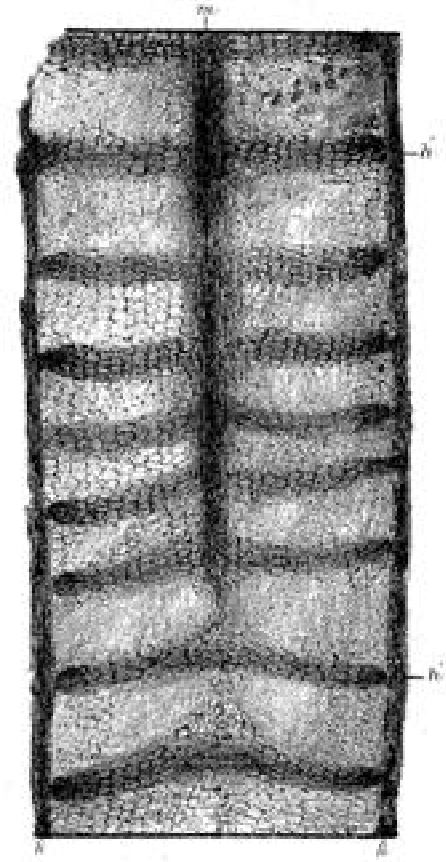

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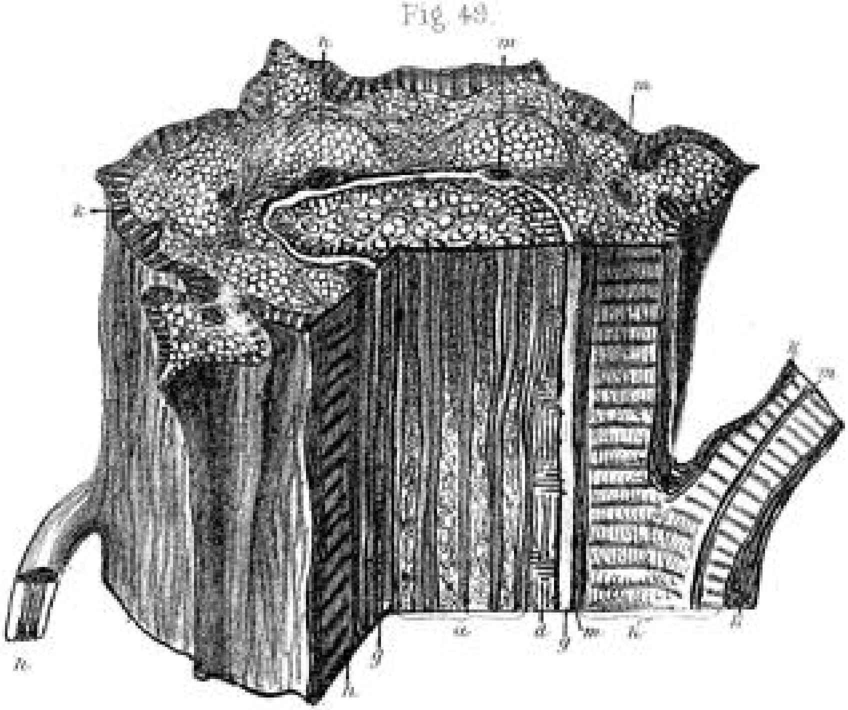

Fig. 45.