XVIII. *On the Organization of the Fossil Plants of the Coal-measures.*—Part I. *Calamites.* *By* W. C. Williamson, *F.R.S., Professor of Natural History in Owens College, Manchester.*

Received November 11, 1870,—Read January 26, 1871.

A few preliminary words may be necessary to prevent misunderstanding respecting the claims and objects of the following memoir. When I entered upon the investigation of which it records the results, I found, in the writings of various British and foreign authors, a copious Calamitean literature; but the widest discrepancies prevailed amongst them both as to facts and to inductions. I therefore determined to pursue the study of this group of fossils as if de novo, *to record the facts which I observed, and to draw from those facts alone such inferences as seemed legitimate, both facts and inferences being in a certain sense, and so far as was possible under the circumstances, new and original. But it necessarily follows that some of these facts and inferences are not absolutely new, though many of them, I think, will be found to be additions to our knowledge of the subject; whilst others, though not new, have presented themselves to me in a light different to that in which they have been regarded by my able predecessors in the study. Such being the object of the memoir, I have not deemed it desirable to include in it a record of all the observations made by preceding writers. As a rule I have only referred to them when the discussion of some moot point rendered such a reference necessary. The fundamental aim of the memoir is to demonstrate the unity of type existing amongst the British Calamites. Brongniart, Dawson, and other writers believe that there exist amongst these plants two types of structure, the one Cryptogamic and Equisetacean, the other Exogenous and Gymnospermous; on the other hand, Schimper and Carruthers regard the whole as Equisetaceous, affording an example of the diversity of opinion on fundamental points to which I have already referred. Of course, before arriving at their conclusions, Brongniart, and those who adopt his views, had fully apprehended the exogenous structure of the woody zone of the Calamite, which is further illustrated in this memoir. The separation of each internode into vertical radiating plates of vascular and cellular tissues, arranged alternately, was familiar to Brongniart, Unger, and other early observers. Cotta regarded the cellular tracts (my primary medullary rays) as medullary rays; but this interpretation was rejected by Unger, and the same divergence of view on this point has recurred amongst subsequent writers. Unger also noticed what I have designated secondary medullary rays, but at a much more recent date Mr. Carruthers disputed their existence. In their 'Fossil Flora of Great Britain,' Lindley and Hutton gave very correct illustrations of the position of the roots of Calamites relatively to the stem; and yet for years afterwards some of their figures reappeared in geological text-books in an inverted position, the roots doing duty as leaves; so far was even this elementary point from being settled. The true nature of the common sandstone form of Calamites, viz. that they are inorganic casts of the interior of the woody cylinder from which the pith has been removed, has been alike recognized by Germar, Corda, and Dawes; but they referred the disappearance of the cellular tissues of the pith to inorganic decay which took place subsequently to the death of the plant. It appears to me that the condition in which we find these cellular tissues affords no countenance to this conclusion. They are as perfectly preserved, when present, as any of the other tissues of the plant. Their inner surface, nearest the fistular cavity, presents no appearance of death and decay, but of rupture and absorption, which I conclude has occurred during life,—a different hypothesis from that adopted by my predecessors, and for which my reasons will be assigned in the memoir. The labours of Mr. Binney are referred to in the text. He figured the longitudinal internodal canals, but was disposed to believe that they had merely formed passages for vessels. He gave, however, excellent figures of the woody wedges, the primary medullary rays, and the cellular medulla, with its nodal septa or diaphragms.*

The above may be received as examples of the many discordant views entertained by the various authors who have written upon the subject of Calamites, and may probably be regarded as a justification of the method which I have deemed it best to adopt in this memoir.—Note added July 12, 1871.

Notwithstanding the large amount of attention which has recently been paid to the study of the Calamites of the Coal-measures, wide differences of opinion still exist respecting them amongst the highest authorities on the subject. Consequently I have availed myself of the valuable opportunities which the labours of Mr. J. BUTTERWORTH, of Shaw, near Oldham, have brought within my reach to make a very extensive series of observations upon the plant. For this undertaking the materials have been so ample that I feel justified in speaking strongly upon some points that have hitherto been doubtful, and on which some of my fellow-labourers in the field of palæo-phytology entertain views different from my own.

The questions at issue group themselves under several distinct heads:—

1. Do all the well-known plants hitherto designated Calamites belong to one natural family, or are there two groups of these objects—the one Cryptogamic, represented by the true *Calamites*, and the other Phanerogamic, and represented by the *Calamodendra* of BRONGNIART?

2. Are there several genera divisible into numerous species, with well-marked internal characteristics, or are there but few specific types, each of which, though they are all constructed upon one common plan, exhibits a wide range of variability in the details of its internal organization?

3. What are the casts commonly known as Calamites? and what parts of the plants do their varied superficial markings represent?

4. To what living plants are these fossil forms most closely related?

To all the above questions I think my materials suffice to give answers, though I would guard against the error of making the plants of the Lancashire Coal-measures, amongst which I have chiefly laboured, the representatives of all that may be found elsewhere, though the probabilities that we may so regard them are very strong. This lesson has been recently taught to such phytologists as needed it, myself being one of the number, by the history of the Palæozoic Conifera. The only true coniferous wood which I have seen in the Coal-measures of this country is the Sternbergian Dadoxylon, which I described some years ago in the Transactions of the Philosophical Society of Manchester; and even in that example, as I have recently shown*, some of the characteristics of the highest Conifers are wanting. But in New Brunswick Dr. DAWSON has found true coniferous woods in the greatest abundance, not only in the Carboniferous but in the Devonian beds—a fact which shows that even in studying the flora of that early age, when individual types were much more cosmopolitan than now, we require great caution in accepting those of one continent as evidences of what exist in another.

In the volume recently published by the Palæontographical Society† Mr. BINNEY has pointed out many of the more conspicuous features characterizing the Calamites of Lancashire. With some of his descriptions I cordially agree, but from others I have been obliged to differ, as will appear in the following pages. The plant has possessed three

* Monthly Microscopical Journal, August 1869.

† Observations on the Structure of the Fossil Plants found in the Carboniferous strata.

distinct concentric layers of tissues, a central pith, surrounded by a ligneous zone, which in its turn was invested by a thick cortical or epidermal cellular structure. The pith (Plate XXIII. fig. 1, *b* *), cellular and solid in the very young growths, very soon became fistular in the older internodes (1 *a*). The woody zone surrounding the pith closely resembled, in its organization, the first year's shoot of a recent Conifer. It consisted of numerous woody wedges (1 *f*), each one starting at its inner extremity from a narrow canal (1 *e*). These wedges were separated from each other by peculiar prolongations of the pith (1 *c*), to which I would assign the name of primary medullary rays; whilst secondary medullary rays separated the constituent vascular laminæ of each wedge, as in recent Exogens. These wedges, with their intervening primary medullary rays, extended vertically in straight lines from node (1 *i*) to node. At each of the latter points they underwent an entire rearrangement to be described in detail. Investing the woody cylinder was a thick, cellular, cortical layer, in which I have failed to discover any traces of vessels. At each node the cellular pith extended across the entire medullary area, so that the fistular interior of the stem consisted of a linear series of oblong chambers, each one of which corresponded with an entire internode, and was separated from its neighbours by the several transverse medullary diaphragms referred to.

Having thus indicated the *general* features of the most common type of Calamite, we may now proceed to a more detailed examination of the different varieties that I have obtained. The sections represented by the figures from 2 to 10 inclusive belong, I believe, to one variety, though they were not all prepared from the same specimen. This also appears to be the most common form, since a large proportion of the examples which I have examined belong to it. Its various tissues may be described in the order of their superposition, beginning at the centre.

The Pith.—This invariably consists of the common type of cellular parenchyma, though the forms which the cells assume vary according to the direction followed in making the section. When cut transversely (Plate XXIV. fig. 9, *b*) they exhibit the ordinary hexagonal form, though their sides are usually somewhat unequal; and in this section there is no approach to any linear arrangement, such as we find in the vertical sections (Plate XXIII. fig. 8 & Plate XXIV. fig. 10, *b*). In the latter we almost invariably find the cells elongated vertically. This is especially the case with the innermost ones, and with those (Plate XXIV. fig. 11, *b*) forming the inner wall of the longitudinal canals hereafter to be noticed. We also observe that they are arranged in linear vertical rows, their parallel faces being constantly at the upper and lower ends of each cell. The narrow transverse diameters often seen in the innermost of these medullary cells (as in fig. 8, *b'*) do not constitute a primary condition, but are the result of physiological changes to be described. Fig. 10 represents a vertical section through the centre of a node (*i*), and two internodes (*k*). It exhibits the two large fistular cavities of the latter (*a*, *a*) filled

* This figure is an attempted restoration of part of a stem including one node and part of two internodes, portions of the cortical layer and of the woody zone being removed so as to reveal the external Calamitean surface of the pith *b*.

with inorganic matrix, and the transverse diaphragm or septum of cellular tissue marking the node (Plate XXIV. fig. 10, *i*)*. It has been supposed by more than one writer that the fistular cavities did not exist in the living plant, but that they were the result of disorganization and decay. Such, however, is certainly not the case. The sharply defined outlines and exquisite preservation of their innermost cells demonstrate that no such decay has affected these specimens. In its very young state the pith was solid and unbroken—a fact demonstrated by the specimen represented in Table 3, fig. 7 of Mr. BINNEY'S Monograph already referred to. But the small size and exceeding rarity of all such specimens demonstrates that the rapid growth of the woody axis caused the pith to become ruptured and fistular at a very early period. The process thus commenced ended finally in a complete absorption of the pith, explaining some points in the history of these plants of which no explanation has hitherto been found. On looking vertically at the cellular diaphragm (fig. 10, *n*), we discover that whilst its more peripheral portions consist of elongated cells like those common to the rest of the pith, in its thinner central part we have a very regular and delicate form of parenchyma (fig. 7). Some writers consider that they have found vascular tissues in the pith. I have not done so.

The Woody Zone.—This, as we have seen, is a zone of variable thickness, consisting of a series of wedges composed of vascular and cellular tissue combined (fig. 1, *f*), separated from each other by cellular prolongations of the pith (fig. 1, *c*), in which the cells have a special permanent arrangement. Every woody wedge commences, at its apex, which is directed inwards towards the centre of the stem, at a narrow canal (fig. 1, *e*) of uniform diameter, and which runs in a direct vertical line from node to node. These several parts requires a separate examination. Each wedge extends vertically in a straight line (fig. 2, *f*), the length of the internode. It consists of a series of laminæ which increase in number as we proceed from within outwards from the intercalation of additional ones; hence the widening of the broad external base of the elongated wedge. Each separate lamina is composed of a linear series of vessels, disposed in a radiating line (Plate XXIII. fig. 9, *f*). In the transverse section, these vessels appear to be nearly square (fig. 6, *g*), whilst in the longitudinal one they exist as elongated, unbranched tubes (fig. 5, *g*), which are sometimes reticulated (fig. 4), and at others transversely barred. Very varied names have been assigned to these tubes by different authors. Mr. BINNEY speaks of them as "*pseudo-vascular*," and Dr. DAWSON and Mr. CARRUTHERS as "*scalariform*" tissue, neither of which terms appears to be exactly appropriate. They are unquestionably modified forms of spiral tissue, though we have every reason to believe that they were incapable of being unrolled; but they are not scalariform, in the sense in which the term is applied to the vessels of ferns and some other living Cryptogams, since they do not exhibit angles thickened by continuous ligneous deposits as is seen in those examples. Still less should they be designated pseudo-vascular, since they are true vessels. The term "barred"

* We have in this specimen a curious illustration of the fact that this pith was fistular whilst the plant stood erect, inasmuch as a number of vegetable spores (fig. 10, *x*) have found their way into the cavity, and now rest upon the diaphragm which has arrested their further descent.

seems an appropriate one to apply to them. In some parts of his Monograph Mr. BINNEY describes them as having "their walls perforated with oval openings." This is certainly not the case, the supposed openings being merely thin places in the tubes where the original cellulose wall has remained unthickened by secondary internal deposits of lignine. These vessels approach very closely to the true annular vessel; but I have never yet seen an example in which individual rings could be traced apart from their neighbours, as is so constantly observable amongst recent annular tissues. As these peculiar vessels are very common amongst the plants of the Coal-measures, occurring in the Sigillariæ and other genera as well as in Calamites, it seems desirable that they should be distinguished by some appropriate name, and the term "barred" appears to answer the purpose. The "reticulate" vessels so common amongst Calamites are but modifications of the same structure, occurring in the same stems with the barred varieties, and not unfrequently the two appear to be convertible. In several instances I have noticed that the vessels at the inner extremity of the wedge were barred, whilst those constituting its peripheral portion were reticulated. In many specimens, though the boundaries of the vessels are well defined, all trace of their internal organization has disappeared. Such examples appear as represented in the vessels (*g*) of fig. 3; but I believe that this is an abnormal condition due to imperfect fossilization, since we can constantly trace the transition from the smooth to the barred and reticulated forms. The vessels at the medullary or inner extremity of each radiating lamina are, as Mr. BINNEY has correctly pointed out, frequently smaller than the peripheral ones, though the difference is not always very marked. The largest vessels in each specimen range from ·003 to ·006 of an inch; the smaller ones are often less than half these diameters. Their number in a linear series varies with the age of the plant and with the part from which the transverse section is taken. In very young plants they are but few, whilst in one specimen I counted 354 in one row; as will be seen shortly, they are more numerous at the nodes than at the internodes. The number of the woody wedges, as well as the distances between the canals whence they spring, varies with age and other circumstances. I have discovered no evidence leading me to believe that the number of the wedges was increased after a young shoot, however minute, was once organized. In some instances I have counted as few as fifteen, and Mr. BINNEY has figured an example with but nine. On the other hand, I have counted as many as eighty in a transverse section of a stem little more than half an inch in diameter; in one old arenaceous cast I found that the outer surface indicated ninety of these wedges. Indications of wedges intercalated after the first growth had begun have only been met with in one example, in which a solitary wedge first appears at a point a little external to the concentric line formed by the inner angles of the rest of the series, and it was devoid of the usual accompanying longitudinal canal. This absence of regularly intercalated wedges has some physiological significance in relation to the age and growth of these stems. The distance intervening between contiguous longitudinal canals practically marks that existing between the centres of contiguous wedges. This often varies somewhat in the same section, though the variation is limited. In the specimen (figs. 9, 10) where the entire diameter of the branch, bark included, is only ·2 of an inch, the distance from one canal (*e*) to another is from ·03 to ·04. In specimens ranging from half an inch to an inch in diameter these distances increase from ·08 to ·1, whilst at the base of some very large arenaceous casts I have evidence that they increased to ·25. These steady enlargements of the wedges accompanying the general growth of the stem demonstrate a corresponding intercalation of new vascular *laminæ* into the exterior of each wedge as the exogenous development of the woody zone increased its diameter.

Secondary Medullary Rays.—Whether viewed in their transverse or vertical section, we discover that the laminæ composing each woody wedge are separated from each other by vertical cellular films, apparently undistinguishable by any important, definite feature from the medullary rays of the higher Exogenous Plants. Fig. 6 represents portions of four laminæ (*g*) from a transverse section of a wedge. Two of these are in contact, as is not unfrequently the case; the others are separated by lines of cellular tissue, which in most instances can be distinguished, in this section, by their darker hue, and by their cells possessing thinner and less sharply defined walls than is the case with the vascular tissues; but sometimes, in the transverse section of the stem, these cellular lines so closely resemble the vascular laminæ, that they are scarcely capable of being distinguished from each other. Such distinction is easy enough in the vertical sections, whether tangential (fig. 5) or radial (fig. 11). In the former we see that these cells (fig. 5, *d*) are arranged linearly in single vertical series, there being rarely more than two vessels in direct contact with each other. Sometimes we observe one isolated cell; in others several cells are superimposed. In all cases they are compressed laterally, so that their length greatly exceeds their transverse diameter. Their transverse septa vary their direction indefinitely, being sometimes rectangular, in others oblique and overlapping. Plate XXIV. fig. 11 represents one of several sections made with the utmost possible care. The section is a radial one, passing through the longitudinal canal (*e*) at its inner margin, and through the exact centre of the woody wedge at its opposite or cortical end. This exactness was rendered necessary by the circumstance that the two lateral surfaces of each woody wedge are impressed by similar cells belonging to the primary medullary rays; and it has been supposed by one of our authorities in Phytology that I had mistaken the one for the other. There is not now the slightest room for such a supposition. In this section we see the cells of the pith at *b*. At *e* we have the longitudinal canal; the entire range of the section to the left of the canal, in the drawing, consists of a lamina of barred vessels, whilst delicately projected upon the walls of the vessels throughout a great part of the section we have the vertically arranged cells of these secondary medullary rays. They exhibit the strongest tendency to arrange themselves murally and in continuous lines, stretching from the pith to the bark, only instead of representing modern bricks disposed horizontally, as is usual in the muriform medullary rays of Phanerogamous Exogens, they more resemble the long bricks of ancient Rome set upon their narrow ends. Still the extreme regularity of their arrangement justifies me in describing it as *muriform*.

On turning from the internodes to the well-defined nodes of these Calamites, we discover a series of very important modifications in the disposition of their tissues, altering many of their features. If a vertical section be made through the centre of the stem, we have the appearances presented at fig. 10, *i*, whilst fig. 2 represents the arrangement of the tissues in a tangential section made midway between the pith and the bark.

The first feature which arrests attention in the vertical section is the material transverse enlargement of the woody zone (fig. 10, *f*) which takes place at the node (10, *i*). This enlargement is both internal and external. In the former case the woody layer encroaches upon the pith, and in the latter upon the bark. The increment is due to the development of a considerable number of barred or reticulated vessels, but especially the former, which take their rise in contact with the outermost medullary cells above the node, and following an arching course across it, their concavities being directed towards the medulla, again terminate, as they arose from the medullary cells above the node, in those below it. It follows from this arrangement that only the outermost of these nodal vessels are prolonged across the internodes to the adjacent nodes above and below.

In the transverse section we find, as the vertical one would lead us to expect, that the woody wedges at the nodes are much longer from their medullary to their cortical surfaces than at the internodes. The canals from which they respectively take their rise are either wholly wanting here, or so reduced in dimensions as to become quite inconspicuous. The large primary medullary rays (fig. 1, *c*) have also become so restricted as in many cases to be scarcely traceable, bringing the wedges into very near contact, and rendering the resemblance between the section and the similar one of an ordinary Coniferous Exogen still more close than in the case of the internodes. But the most striking peculiarity in the nodal arrangement of the tissues is seen in the tangential section (fig. 2, *i*). In the example represented in the Plate we have part of one node (*i*) and of two internodes (*k k*). We now discover that each woody wedge, as it ascends to the node, divides into two portions, each of which bulges out somewhat, and which proceed obliquely upwards in a divergent manner to contribute their respective quotas to a corresponding but alternating series of wedges in the internode above. On magnifying one of these divergent portions (fig. 2, *o*) more highly, as is done in Plate XXIII. fig. 3, we discover that two changes have taken place compared with what was observed in the internodes:—1st, the vessels (*g*) pursue a more undulatory and divergent course, leaving wider spaces between them; and 2nd, those spaces (*d*) representing the secondary medullary rays, are occupied by irregular groups of cells which are very frequently arranged in double, and not unfrequently in threefold series. These sections also explain the almost complete disappearance of the primary medullary rays already noticed in describing the transverse section of this portion of the Calamite.

But another very important feature occurs in these nodal parts of the organism. In fig. 2, two lenticular spaces (*m*) appear in the diverging portions of the woody wedges, and an examination of large series of specimens demonstrates that these spaces represent branches. When the tangential section is made close to the pith, we find that the spaces are wholly occupied by cellular tissue, but when made in the centre of the woody zone, we have the structure represented in Plate XXIV. figs. 13 & Plate XXVIII. fig. 38. In fig. 13 the central mass (*m*) is a combination of vascular and cellular tissue. The distinction between the two elements is not seen in this tangential section, which is practically a transverse section of the structure. But in longitudinal sections, like fig. 10, we obtain evidence that a considerable number of vessels, derived from the woody wedges, are suddenly deflected and proceed outwards towards the bark in a compact parallel series. The point specially to be noted in these vascular communications with external branches is their small size. The aggregate of the cells and vessels composing each one is always less than that of the woody wedge which it penetrates. These arrangements will be referred to again when describing fig. 38, which represents another type.

The next structures demanding attention are the primary medullary rays, or radiating cellular masses (fig. 1, *c*), which separate the woody ridges, and which like the latter extend as continuous planes from node to node (fig. 2, *c*), where, as already indicated, they become merged with the woody tissue in the shape of enlarged secondary medullary rays. As the irregular parenchymatous cells of the pith pass outwards between each two contiguous woody wedges, they gradually assume a more regular disposition. Their parallel faces become also parallel with the surface of the pith, throwing them into linear series, which, in the transverse section, radiate from the medulla to the bark. At first these cells are of large size, but they rapidly become less as they pass outwards. This circumstance, combined with the simultaneously increased regularity in the arrangement of the cells and with their more uniform size, causes their appearance, as they approach the bark, to differ very little in the transverse section from the vessels of the woody wedges on each side of them. Indeed in many old stems the line of demarcation is only to be traced with exactness in the tangential sections. These cells seem to vary considerably in size. Sometimes they are comparatively narrow, as in fig. 9; but in others the central row stretches across the ray as a series of long narrow parallelograms, the long axis of each cell extending nearly from one woody wedge to the next. So far as I can ascertain, these variations are merely the result of differences in the rate and conditions of growth, since I often find them exhibiting considerable difference on opposite sides of the same stem. In the tangential section (fig. 2, *c*) these cells do not appear to be arranged in any regular order, merely presenting the aspect of an irregular parenchyma. But the case is different with the radial sections, one of which is represented in fig. 8. At *b* we have the medullary cells assuming the vertically elongated aspect frequently seen in all longitudinal sections of the pith, whether radial or tangential; but all the remainder of the section is composed of more or less regular lines of muriform cells, identical in every point of form, size, and general aspect with those of the secondary medullary rays (fig. 11).

In determining the physiological character of these cellular masses we labour under some difficulties, because of the general aspects of the plants to which they belong. The plants are, as abundant evidence proves, cryptogamic in their fructification and affinities;

and to speak of medullary rays in such examples, appears at the first glance to involve a misappropriation of terms. But, on the other hand, there is no doubt whatever that the woody zone which I have described is truly exogenous in its structure and mode of growth, though belonging to a Cryptogamic plant. Consequently we have in it the elements essential to the idea of one form of medullary ray. We have had, in the first instance, a cellular bud, within which vascular masses were developed; and the portions of the primitive cellular tissue, connecting the inner cellular pith with the outer cellular layer, whether we call the latter bark or epiderm, are essentially the same things, so far as their genesis is concerned, in the Calamite and in a young Dicotyledonous shoot of the first year. The strong disposition shown by the cells of these structures in the Calamite to assume a mural arrangement confirms, though it is not necessary to, the idea of these organs being medullary rays; and as these are the first of this class of organs that appeared in each young Calamite, I have applied to them the term usually employed by our best vegetable physiologists in such cases, viz. *primary medullary rays.* For similar and obvious reasons I assign to the rays separating the component laminæ of the woody wedges the title of *secondary medullary rays.* They are formed subsequently to the others, and, as in the case of Exogens, their number in the Calamite continues to increase as long as the wedges containing them continue to grow. All the facts I have detailed justify the conclusion published in some of my previous memoirs, that in this woody zone of the Calamite we have a true exogenous growth; whether we regard its intimate organization or its genesis, we are brought to this decision. There is a peculiarity in the exterior of this zone not to be overlooked. In his monograph already referred to, Mr. BINNEY figures a decorticated stem, the decorticated exterior of which is marked by strong longitudinal ribs and furrows, with a thickened node. This configuration of the decorticated Calamite has been common to the type now under consideration, as shown in my restored figure 1. Though subject to considerable variations as to the degree of prominence, the transverse section always presents a more or less undulating outline, of which the exteriors of the woody wedges constitute the projecting portions. When we come to consider the nature of the arenaceous casts usually seen in geological collections, we shall find that the contour referred to forms an unfailing indication whether any specimen under examination represents the exterior or the interior of the woody zone.

The Longitudinal Canals.—M. BRONGNIART many years ago obtained some silicified stems of Calamites from the Coal-measures of Autun, which showed that the woody wedges took their rise from narrow pores or canals. Mr. BINNEY has further demonstrated the same fact in his memoir, but was doubtful respecting their nature. He says that Dr. HOOKER, "after carefully examining these openings, I believe, came to the conclusion that they were passes for a peculiar kind of tissue which has unfortunately been destroyed, rather than the mere cavities which we now see in the specimens" (*loc. cit.* p. 20). This supposition, however, is certainly not correct. We have the clearest evidence that these are true intercellular canals (Plate XXIV. fig. 11, *e*) running from node to node, at which points, in the type under consideration, their extremities appear to terminate as cul-de-sacs. Their inner or medullary wall is almost invariably composed of very narrow elongated cells (fig. 11, *b*) with square extremities, being in fact elongated modifications of the ordinary medullary cells. I have not succeeded in discovering any cells in their peripheral wall; this appears to be composed of the innermost and first formed barred vessels of the woody wedge (11, *g*), to which each canal belongs. Their diameter varies from ·03 to ·1 of an inch, their width being uniform throughout their entire length, except at their extremities, where they rapidly contract until they disappear.

The Bark or Epidermis.—In a lecture delivered before the Royal Institution of Great Britain (April 16, 1869), Mr. CARRUTHERS incidentally mentions that the Calamitean stem possessed "a *thin* cortical layer." I am not aware, however, that the true bark has hitherto been either figured or described. The discovery by Mr. BUTTERWORTH, of the small stem represented in figures 9 & 10 removes much of the existing obscurity on this subject. Of all the scores of microscopic sections of stems of which I have either made or examined, it is remarkable that two examples alone exhibited evidences of the existence of a bark, all the rest having been decorticated. The same observation is applicable to those figured by Mr. BINNEY, in none of which is this tissue seen. These facts show that the cohesion between the bark and the woody zone must have been exceedingly slight, at least in the small fragments inclosed in the ironstone nodules from which the majority of our specimens retaining their structure have been derived.

The entire diameter of the small stem referred to is ·2 of an inch. The thickness of the woody zone at the internode is about ·05. At its narrowest part the thickness of the bark is ·025, whilst it becomes very much thicker at the nodes. It has in fact been a rather thick parenchymatous layer, in which the cells were very irregular both in size and distribution. Some few cells of large size appear dispersed amongst others of smaller dimensions. There is no trace of linear or other special arrangement of these cells, either in the transverse (fig. 9) or vertical (fig. 10) sections. Where the bark crosses the node, in the latter section, its surface has become somewhat disintegrated; but though Mr. BUTTERWORTH and myself have prepared several sections of the specimen, I have not been able to discover the slightest trace of vascular bundles, or even of solitary vessels crossing the cellular parenchyma. The peripheral outline of the vascular woody zone at this point is sharp and well defined, and the course of the vessels undisturbed*. The only difference seen between the longitudinal, tangential, and transverse sections, is a slight vertical elongation of the cells in the two former. The cells of the outermost surface differ little if at all from those of the interior, and I detect no trace of a special cuticular layer. It exhibits no indication of being an exogenous bark, no trace of the tripartite division seen in that of the gymnospermous Conifera existing in it.

* Unfortunately the arching vessels of the node exhibit no trace of a branch crossing them at this point, as is frequently the case with parallel sections of other specimens. Consequently we miss a valuable opportunity of seeing the relations of these branches to the bark.

The type which I have thus described in detail appears to be the one occurring most abundantly in the Lancashire Coal-measures; but along with it some others occasionally occur, which may have a specific value, though its exact amount is difficult to determine, since they are most of them rare, and of some only single examples have yet been found. Plate XXIV. fig. 14 represents one of those, of which I have seen several specimens. The entire diameter of the decorticated stem is ·21. Each woody wedge contains from six to eight laminæ (*g*), separated by strongly marked secondary medullary rays (*d*). Each of the principal laminæ consists of a linear series of from nine to twelve vessels, which are remarkable for their large size. We have already seen that the largest vessels usually found in the type already described, range from ·003 to ·006, whilst near the longitudinal canal they are generally much smaller; but in this instance the vessels are as much as ·01 in diameter. The specimen also illustrates very clearly the intercalation of additional laminæ, as at g', g''. The cells of the pith are smaller than usual, and those of the primary medullary rays (*c*) especially so. Not having a longitudinal section of the specimen, I am unable to determine whether the small structures intervening between the inner extremities of the vascular laminæ (*g*) and the longitudinal canals (*e*) are minute vessels or elongated cells. The specimen thus possesses a marked individuality, though I am at present unable to determine whether it represents a state or a species. Plate XXIV. fig. 15 represents an example of which we have both the longitudinal and transverse sections, both of which are very distinct in their peculiarities. The specimen is decorticated, and has a diameter of ·25. The exterior of its woody cylinder has been almost smooth, exhibiting none of the usual flutings arising from the prominence of the woody wedges (*f*). Indeed in the transverse section it is impossible to say where the woody laminæ terminate, and the cellular tissues of the primary medullary layers begin. The medullary cells (*b*) are remarkably large, and the canals (*e*) also rather larger than usual; but the vessels and the cells of the primary medullary rays are not more than ·0025 of an inch in diameter. The suddenness with which the large medullary cells contract to form the small cells of the primary medullary rays constitutes a striking feature of the plant, the general aspect of which is almost exactly the opposite of the one last described in every respect.

Fig. 16 represents the medullary extremities of one of the woody wedges (*f*), and two of the primary medullary rays of another variety possessing great beauty. The woody laminæ are very regular, and the intervening secondary medullary rays very distinct, whilst the manner in which the irregular parenchyma of the medulla (*b*) passes into the linear arrangements of the primary medullary rays (*c*) is very clearly shown. But the most remarkable feature of the specimen is the entire absence, from the apex of every one of the woody wedges, of the longitudinal canal. I at first thought that the section might have traversed a node into which the canals did not extend; but I am convinced that such was not the case. The place of the canal is occupied by firm, strong-walled cells. I think it probable that the example of which a xylograph is given by Mr. Binney in his work (p. 20), and which led Dr. Hooker to surmise that the canals had been channels for the transmission of special vessels, may have been of this variety. We have only seen two stems of this type*. Plate XXV. fig. 17 represents a transverse section of the half of one of the primary medullary rays (*c*), and the adjacent part of a woody wedge (*f*) of a remarkable form. Fig. 18 is a carefully drawn copy of a tangential section of part of a similar primary medullary ray from the same example. The laminæ of vascular tissue (*g*), instead of terminating at the usual boundaries of the woody wedge (*f*), have continued to be developed externally to it, encroaching upon the primary medullary ray, as exogenous growths increased the diameter of the stem. Practically the result of these additions has been to convert each large primary medullary ray into a series of smaller secondary ones, with but one, two, or three linear rows of cells in each, reducing them to a condition differing little, in the transverse section, from what we find in the secondary medullary rays of the woody wedges. But when we turn to the tangential section (fig. 18), we discover that these vessels (*g*), not having been subjected during growth to the uniform pressure mutually affecting those in the woody wedges, have not only pursued a more tortuous course amongst the large cells, but their form and diameter has been modified by the unequal resistance of those cells, so that whilst in some instances their diameter is ·005, in others they are reduced to a mere thread. I have only met with one example of this remarkable variety.

I have next to call attention to a peculiar form identical in many respects with one that I described in the fourth volume of the third series of the Memoirs of the Literary and Philosophical Society of Manchester, and to which I gave the generic name of *Calamopitus*. Some examples of this type possess the highest interest, because they throw a most important light on the nature of the forms of Calamite so common in the shales and sandstones of the Upper Coal-measures. Fig. 19 is a representation, of the natural size, of a transverse section of a compressed stem. The dark centre has been a large fistular medullary cavity, whilst the walls of the surrounding cylinder have been remarkably thin in proportion to the size of the stem; the diameter of the latter has been about ·66, the entire thickness of the decorticate woody cylinder, including its contained layer of pith-cells, not having been more than ·08—a condition of things most favourable to that flattening of the stem so frequently seen in the fossils which are laid horizontally in their matrix. Though this cylinder is so thin, it contains about eighty distinct woody wedges. Plate XXV. fig. 20 represents two of these woody wedges more highly magnified. Two features alone require to be noted in this section. One is the well-marked crenulated outline (*x*, *x*) separating the pith from the persistent woody zone. This line is especially remarkable for its distinctness where it crosses the primary medullary rays (*c*). In this feature the specimen resembles my previously described *Calamopitus*, as well as fig. 15 of the present memoir; only its crenulations are much deeper, approaching less towards a straight line, than in the latter figure. The second point referred to is the remarkable prominence exhibited by the external base of each woody wedge (*f*), which is

* Since the above description was written I have met with a third specimen, and think it possible that a new genus may be required for its reception, since it lacks some Calamitean features.

more marked than in any other specimen that I have examined. It will also be observed that, as in fig. 15, the transverse section exhibits little or no difference between the sections of the vessels of the woody layer and the cells of the primary medullary rays.

Plate XXVI. fig. 21 represents a fragment taken from the upper part of fig. 19, opposite to the small star, and which is in the highest degree instructive: in addition to the transverse section, this specimen exhibits, at its inferior half, the free longitudinal surface of the fossil running at right angles to the section. *a* is part of the central fistular cavity filled with dark ironstone, *b* is the cellular pith corresponding with fig. 20, *b*; and in like manner the crenulated line *x*, *x* corresponds with the similar line in fig. 20. In the left-hand portion the woody zone is retained *in situ*; but to the right this has been detached from the pith (*b*), the separation taking place at a vertical surface corresponding with the crenulated line *x*, *x*, and leaving behind it a fluted surface identical in every respect with that of the ordinary Calamites with which we have so long been familiar. The sharply defined longitudinal grooves (*e'*, *e'*), separating the concave ridges, are clearly seen to be identical in position with the longitudinal canals (*e*); whilst the prominent ridges (*f*, *f*), or exteriors of the woody wedges, occupy a position more peripheral, but radially vertical to that of the parallel grooves (*e'*)—arrangements which throw a flood of light upon the ordinary structureless examples of Calamites.

Plate XXVI. fig. 22 is a tangential section of this specimen made in the plane of the longitudinal canals, or a little more internal than the crenulated line (figs. 20 & 21, *x*, *x*); but since the section fortunately crosses a node at the line *i*, *i*, we obtain evidence that the arrangement of the vertical canals (*e*, *e*) at this portion of the plant differs from what exists in the types previously described. Instead of terminating near the node as cul-de-sacs, in the present example they enlarge into triangular spaces, and then, dividing right and left, they pass downwards to form the canals of the internode next below*. The cells of the pith describe at this point a series of Roman arches (*b'*, *b'*), which form the inferior boundaries of the canals at their bifurcation; the rest of the section is principally occupied by the ordinary parenchymatous medullary cells, as they present themselves opposite to the primary medullary rays, though here and there a few bundles of barred vessels demonstrate that it has dipped into the woody zone. This is especially the case at the node and near the centre of the specimen, where an elliptical figure bounded by vessels marks the position of a young branch such as is represented in fig. 13. But the section under consideration reveals some other important features. Within and below each of the Roman arches (*b'*, *b'*) we observe that the cellular tissue is ruptured longitudinally for a short space. In some instances this rupture (*l*, *l*) is so slight as to be scarcely appreciable, and might indeed have been deemed accidental but from its constant relations to some other features yet to be considered.

In Plate XXV. figs. 23 & 24 we have two radial longitudinal sections, both of them being so made that the superior half of each above the node (*i i*) has passed vertically

* In fig. 37 we have another radial section which intersects one of the horizontal portions of a canal (*c*) passing from one triangular space to another.

through the longitudinal canal (*e*). As in the other figures, *a* is the fistular cavity, *b* the medullary cells, *g* the vessels of the woody wedges which, in fig. 24, are seen to pursue their usual arching course as they cross the node (*i*). At *e* we have the longitudinal canals of the superior of the two internodes intersected in each of the sections.

In fig. 24 this canal passes out of the line of the section, but in fig. 23 it dilates, at the node, into one of the large triangular spaces seen in fig. 22. These, and similar sections which I possess from the same specimen, seem to indicate that, in it, the cellular medullary nodal diaphragm was not complete, but that the various internodal fistular cavities communicated freely with each other.

The most important feature of these sections is seen in fig. 23, *l*, where we find that the longitudinal fissures seen in fig. 22, *l*, *l*, are the inlets to well-marked oblong passages filled with the same amorphous matrix as occupies the fistular cavities of the pith, and which are thus proved to have been open canals when the plant was entombed. In the memoir on *Calamopitus* already referred to, I entered at considerable length into the history of these canals, applying to them the name of verticillate medullary *radii*. But at the time when that memoir was written my imperfect specimens had not enabled me to discover either the fistular character of these calamitean stems or the peculiar process of medullary absorption which has taken place in them. Hence I stated that "these radii appear to have been composed of the same tissue as the medulla itself, judging from the circumstance that the inorganic material with which they are filled is identical with that replacing the pith. They have most probably united the pith with the bark" (*loc. cit.* p. 163). It is now evident that the account which I then gave of the position of these curious rays in relation to the rest of the tissues, and which I further illustrated by a diagrammatic figure (*loc. cit.* tab. 5. fig. 17), is in all respects correct, with the exception that they prove to have been *canals* formed, first by a rupture, and afterwards by an absorption of the cells of the primary medullary rays, and were not special prolongations of the medullary parenchyma through those rays, as I deemed probable. Various attempts have been made to show that these canals originally transmitted special vascular bundles either to roots or to branches, which vessels were supposed to have become decomposed, admitting the inorganic matrix into the cavities formed by their disappearance. But all my specimens negative this idea. In the first place, these canals are not planted upon the node from which such branches would spring, but a little below it; whilst immediately above them, and in their right place, directly over the node, we find the true lenticular bundles going to such branches, springing from the innermost vessels of the ligneous zone. This is demonstrated in fig. 25, which represents a tangential section like fig. 22, only passing through the external instead of the internal surface of the woody zone; *c*, *c* indicate cellular primary medullary rays, *f* the woody wedges, *i*, *i* the node, with a verticil of lenticular structures (*m*) marking the position of the branches, whilst at *l*, *passing through the cellular tissue, below and altogether disconnected from the vascular structures*, are the disputed organs. The sketch (fig. 25) represents the section viewed as an opaque object, in which the white crystallized carbonate of lime with which the fistular pith is filled, and which has also occupied these canals, causes them to stand out with remarkable clearness. In the example of *Calamopitus* described in my previous memoir, I figured some sections of the vascular bundles going off to the branches where the vascular tissues were so conspicuous and had so remarkable an arrangement as conclusively to demonstrate their true character; and though in the specimen under consideration the similar structures (fig. 25, *m*) are not so highly developed, there is no question that in both examples their nature is the same. These facts do away with the possibility of the canals in question having any direct relationship with the branches.

At the Meeting of the British Association at Liverpool, Mr. CARRUTHERS suggested that these organs were points from which roots had been given off. Such, however, cannot have been the case, since in the specimens in which they occur they exist throughout the entire length of the stem from its base to its summit. Moreover they are located in the centre of the *cellular* tissue of the *upper* part of each primary medullary ray, whilst, as I shall immediately demonstrate, there is abundant evidence proving that the roots were given off from the *lower* part of each internode. The position of these canals in relation to each internode of the stem—their isolation, internally amid the cellular tissue of the medulla, and externally in that of the primary medullary ray—the obvious mode of their formation, 1st, by the rupture, and, 2nd, by the absorption of those cellular tissues—the entire absence from every example yet examined of all trace of vascular tissue, either in the medulla from which they spring, or in that accompanying them in their outward course—and finally, the circumstance that they are always filled with the same inorganic material as that which occupies the fistular cavities of the pith, are facts pointing irresistibly to a common conclusion, viz. that these organs were narrow canals, arranged in a verticil immediately below the transverse medullary septum of each node, and that they formed channels of communication *through* the woody zone, between the uppermost part of each internodal fistular cavity and the inner surface of the bark*. Being fully convinced that such is their true nature, I propose to recognize them by the name of "infranodal canals" instead of "verticillate medullary radii," which I formerly applied to them.

In the tangential section now figured, these canals exhibit an *oblong* contour; in all those described in my preceding memoir on the subject they were *round*. It will be seen that these differences correspond with what we find in the more ordinary, structureless Calamites of this class occurring so frequently in beds of shale and sandstone.

Having described the more important varieties of structure seen in our specimens, I will now endeavour to correlate these with the common forms so frequently seen in cabinets.

* I have represented one of these canals at *l* in the restored fig. 1, but having no conception what effect they had upon the bark, I have represented the latter as extended across their open extremities. This arrangement of the bark is purely hypothetical; the canals may have penetrated it as well as the ligneous zone.

Hitherto nearly all phytologists, with the exception of Mr. BINNEY and Mr. CARRUTHERS, have endeavoured to infer the structure of Calamites from the appearances presented by specimens from which all structure has disappeared. A comparison of their inferences with what are now positively ascertained facts, demonstrates the danger of this mode of procedure, and confirms an opinion I have elsewhere expressed, that no determinations respecting fossil plants can have much absolute value save such as rest upon internal organization; that is the basis upon which all scientific recent botany rests, and no mere external appearances can outweigh the positive testimony of organization in fossil types. But whilst thus insisting upon the supreme value of structure as a guide, I am not blind to the importance of a mass of evidence that has been derived from the study of external forms, and especially that for which we are indebted to my two friends, Dr. DAWSON, of Montreal, and M. GRAND' EURY, of Saint Etienne, in France. Whilst many of the specimens which I have described have unquestionably been aërial *stems*, the minute size of others makes it exceedingly probable that they were small branches; nevertheless there is no variation in the structure of these two classes of organs, beyond what has arisen from the gradual absorption of the pith as the plant increased in age. But we have in this difference the first clue to the history of the common fossil forms. It has often been observed that very small Calamites were exceedingly rare, leading to innumerable surmises as to the cause of this fact.

The specimens of Calamites usually seen are casts of the interior of the wood-cylinder of the stem, either composed of sandstone or of shale, and are generally covered with a thin homogeneous layer of carbonaceous matter. The early writers almost invariably turned these specimens upside down, believing their obtuse or conical bases to be the uppermost extremities of the stems. These observers experienced further difficulties in the circumstance that whilst the internal casts were fluted longitudinally and marked at intervals by transverse constrictions, similar features were exhibited, more or less strongly, by the external surface of the carbonaceous covering of each specimen. Hence the apparent probability naturally suggested itself, that in the living plant one calamitean structure had existed in the interior of another. But it was invariably believed that the internal Calamite represented a solid pith that had disappeared from the inorganic decomposition of its tissues after death, the place of the lost tissue having been supplied by sand or mud, according to the nature of the sediment under which the plant became buried. At an early period of my recent observations I became satisfied that the living plant had possessed a fistular medulla, and M. GRAND' EURY, studying a very different class of specimens to mine, arrived at the same conclusion*.

* Observations sur les Calamites et les Asterophyllites, par M. GRAND' EURY, Comptes Rendus, tom. lxviii. p. 705. That author correctly says, "la présence fréquente aux jointures de cloisons plus ou moins entières est une évidence complète que ces tiges étaient fistuleuses." But in his definition of the genus *Calamites*, and in many of his general observations embodied in the same memoir, this careful observer has been seriously but almost inevitably misled, arriving at several conclusions diametrically opposed to the demonstrations which my better preserved specimens have afforded.

In young stems and branches these fistular cavities coexisted with a surrounding pith, consequently when they became filled with sand or mud, the latter materials would harden into a permanent cast of each hollow cavity. But though such casts might exhibit the nodal constrictions due to the transverse medullary diaphragms, they would show none of the longitudinal ridges and furrows characteristic of Calamites. The reason for this would obviously be the intervention of the pith between its central cavities and the inner surfaces of the woody wedges to which such furrows were due. Hence no one, finding such a cast, would recognize it as belonging to a Calamite. But as each stem increased in age and dimensions the pith gradually disappeared, not by mere decay, but by a vital process of rupture and absorption. As in the living Exogens, the existence of the pith seems to have been correlated with the first formation of the circle of woody wedges; and when the growth of these was fairly started, it seems to have been no longer needful to the plant except at each node, where it continued to exist either as a complete or, what is more probable, as a partial diaphragm. After this disappearance of the pith, successive additions continued to be made to the exterior of each woody wedge, as in true Exogens, and also to that of the primary and secondary medullary rays. No definite traces of concentric rings indicative of interrupted growth appear in the transverse sections*. The pith does not appear to have been necessary to the plant whilst these external additions were being made to its woody tissues. Fortunately one specimen has been found by Mr. BUTTERWORTH in which I have discovered remarkable evidence of what has taken place as the pith disappeared. Plate XXVII. fig. 26 represents three woody wedges (*f*) and two primary medullary rays (*c*, *c'*) from a stem which must at least have had a diameter of 1 inch. The wedges and medullary rays present the usual features, but the pith is everywhere breaking up into large spaces, which, opposite the primary medullary rays, assume the definite rounded form represented at fig. 26, *c'*, *c'*. The shrivelled, half absorbed cells at *b'* have nearly disappeared, and within this line they are wholly gone. At *c'*, *c'* the absorbent action has reached its limits; it has touched the boundary line indicated by fig. 21, producing that undulating outline of the medullary cavity which gives to its common arenaceous casts their calamitean form, and which here, as elsewhere, is only found in stems of notable dimensions. In the specimen of *Calamopitus*, which I have previously referred to as described in the Transactions of the Manchester Literary and Philosophical Society, the absorbent action has gone yet further. Almost every trace of the pith has disappeared through its operation. The inorganic cast of the medullary cavity exhibits its sharply defined Calamitean outline in immediate contact with the persistent vascular and cellular tissues of the woody zone; and it is an interesting fact that the specimen which thus exhibits the entire completion of the process of pith-absorption is the largest in which I have hitherto discovered structure, its

* In this respect the Calamites only exhibit the same phenomena as appear in *Dadoxylon*, *Dictyoxylon*, and other exogenous stems of the Coal-measures, in British specimens of which I have rarely seen concentric rings of growth that I could identify with periodic checks arising from secular variations of climate. Nevertheless such rings do occasionally occur.

medullary cavity alone having a diameter of 2 inches. I think this chain of facts justifies me in my conclusion that the common Calamitean medullary casts owe their form to a vital process carried on during the life of the plant, and not to an inorganic decay of the pith-cells occurring after its death*.

Of the common instances in which we find the well-defined Calamite composed of shale or sandstone, and covered by a carbonaceous layer, we have now no difficulty in discovering an explanation. The medullary cavities, and in the case of the *Calamopitus* the verticillate radial canals also, have been filled up with inorganic matter which formed an exact cast of each cavity and canal. This cast, having become indurated, retained permanently the grooves and ridges impressed upon it by the inner surface of the woody zone; in the case of the *Calamopitus* there also projected more or less prominently from the surface of the cast the inorganic contents of the verticillate infranodal canals, which in their uncompressed condition would stand out from the central cast like spokes from the nave of a wheel. So long as the woody zone retained its integrity these conditions remained unchanged; but pressure and chemical agencies gradually produced alterations. As the vegetable tissues of the plant became converted into coal, their structure disappeared along with much of the material composing them. And when the process was completed, what remained was deposited, as if by a process of electrotyping, in the form of a thin film of coal, moulded upon and taking the shape of the hardened central cast,

* That the common specimens of Calamites were inorganic casts of the interior of the woody cylinder, occupying the cavity left by the disappearance of the pith, was suggested by Mr. Dawes ten years ago ("Further Remarks upon the Calamites," Proceedings of the Geological Society of London, vol. vii. 1851); though I had overlooked the circumstance until after the present memoir was read before the Royal Society. I arrived at my conclusions from independent evidence. But Mr. Dawes differs from me in adopting the idea of decay to account for the disappearance of the pith, the reverse of my opinion that it was the result of a vital process of absorption. Transverse sections of sandstone Calamites exhibit a crenulated outline of geometric regularity; and this outline recurs throughout the entire length of specimens from 6 to 8 feet long. I can scarcely conceive of inorganic decay producing so sharply defined and uniform a result. Had the woody zone been a continuous cylinder, whose inner walls were unbroken, such conditions might have occurred; but this is not the case. As we have seen, it consists of a ring of detached wedges, separated from one another by radiating masses of cellular tissue, *which latter are continuous with, and prolongations of, the pith.* Now that the decay should not have extended along these prolongations (my primary medullary rays) but *invariably* have stopped at a crenulated line of which the tissues themselves afford no indication, is, to me, incredible. The uniformity of these results appears a sufficient proof of the correctness of my hypothesis. But there remains further evidence. In the case of *Calamopitus* we have to account for the infranodal canals. Whatever else these may have been, they were clearly outward prolongations of the central medullary cavity; and if decay was the agent producing the latter, it must equally have produced the former. In other words, this capricious agent, dependent upon a variety of outward conditions, though it respected the cellular primary medullary rays *as a whole*, yet attacked each one of them at certain circumscribed points, arranged in regular verticils which recurred with most unvarying uniformity, immediately below each node, from one end of the stem to the other. I must confess myself unable to accept such an explanation. These infranodal canals obviously existed in the living plant, in which they fulfilled some unknown function. At the same time they are but prolongations of a central cavity which must have coexisted with them. I therefore conclude that the entire structure resulted from the operation of that vital force which works out its designs with unbroken regularity, respecting boundary lines of which the eye, even though aided by the microscope, can frequently detect no trace.—October 3rd, 1871.

whilst the corresponding casts of the infranodal canals, unable to bear the pressure to which they were subjected, were forced down upon the medullary cast, on the surface of which they now appeared as very slightly elevated tubercles. The effect of these changes was the more or less complete reproduction, on the *exterior* of the carbonaceous layer, of forms which really belonged only to its *interior*, a reproduction which has occasioned much of the existing misapprehension respecting these fossils. Had the longitudinal ridges and furrows seen on the exterior surface of the carbonaceous film belonged to the corresponding portion of the living plant, they would have alternated with those of the medullary cast, as is shown by the restored diagram (fig. 1). But this is very rarely the case. Hence I cannot avoid the conclusion that external markings afford no absolute clue to the real nature of the external surface either of the bark or of the woody zone of the living Calamite. I have referred to the scars or tubercles so frequently seen on the medullary casts of Calamites; these are always arranged in verticils. The scar is sometimes circular, at others oblong, but always planted on the upper extremity of each vertical ridge, immediately below each node. The common aspect of the round variety is shown in Plate XXVII. fig. 27, and the oblong one in fig. 28. In both figures *l* represents the scars in question, *i* the node, *e* the inner angle of each woody wedge, and *c* the broad inner surface of each primary medullary ray. These scars are usually a little raised above the surface of the ridge upon which they are planted, but not invariably so. They, as I have already intimated, are the remains of the infranodal canals; and the degree of prominence which the scars exhibit has partly depended upon the extent to which inorganic matter has penetrated the interiors of the original canals, and partly on the chemical changes which the woody cylinder, through which these canals passed, has undergone. In the specimen of *Calamopitus* figured in the 4th edition of LYELL'S 'Manual of Elementary Geology' (fig. 478), as well as in my memoir on *Calamopitus* (fig. 1), we see that in the sandstone casts these scars are merely the bases or remnants of what that fine specimen exhibits so perfectly, viz. a verticil of radiating projections, each more than $\frac{1}{8}$ of an inch in length, and exactly resembling the spokes of a wheel, of which the central medullary cast is the nave. This specimen demonstrates that the common conditions seen in figs. 27 & 28 are very deceptive ones, which would inevitably mislead a student who had seen no other form; but read in the light afforded by the specimen above referred to, and of those represented in figs. 22, 23 & 25, their history becomes simple enough.

Before quitting the common forms of these internal casts I would call attention to a feature which I have noticed in several specimens, but of which I have as yet discovered no explanation. Plate XXVII. fig. 29 represents four internodes of a very long Calamite in the Cabinet of Mr. WILDE, of Glodwick Collieries, Oldham. The drawing is of the natural size. In the two lowermost internodes (*k*, *k*), and to a large extent in the uppermost one (k'), the longitudinal grooves are regularly parallel with each other and, like the internodes themselves, uniform in size; but in the shorter internode (k'') this is not the case. Plate XXVII. fig. 30 represents a few of the ridges and furrows of the latter enlarged about three diameters. Some of them are *much* thicker at one end than at the other, whilst there are few in which the two sides are quite parallel*. But besides this peculiarity, the internode itself is unlike its neighbours, being only about half their length. Were this all, the internode might be regarded as an accidental anomaly; but when phenomena appear in regularly recurring series such an explanation is inapplicable. In Mr. WILDE'S fine specimen, of which fig. 29 represents a very small portion, every *eighth* internode exhibits these peculiarities. Similar appearances are seen in another specimen in the same collection, but here they appear in every *fifth* internode. I have as yet failed to correlate these appearances of the medullary cast with any known external features of Calamites, but that they have some special significance cannot be doubted; they most probably indicate some specific features of the plant to which they belonged.

Amongst the abundant stems of Calamites exhibiting the peculiarities upon which I have already dwelt, are others of a very different aspect. Plate XXVII. fig. 31 represents a well-marked example of a not uncommon type belonging to Mr. NIELD, of Oldham. In the ordinary forms the casts are equilateral, being thickest towards the centre of each internode, and having their smallest diameter at the constricted node; but in the examples under consideration these proportions are reversed. The protuberance of the node is the most strongly marked on one side (fig. 31, *i*), whence a branch has been given off. The longitudinal surface-furrows are very strongly marked in the immediate vicinity of the node, but as they recede from it they become faint in outline and are at least doubled in number, indicating that, in the internodes (*k*), the number of the longitudinal woody wedges was multiplied, whilst the primary medullary rays became less conspicuous than at the node. On examining the prominent but concave phragma (Plate XXVII. fig. 32) or cicatrix left by the detached branch, we discover that there is a marked difference between the half of it above the nodal constriction and that below the line. In the former the surface-grooves and ridges bend uninterruptedly over the projecting margins of the cup-like cavity, and are prolonged to its centre; but in the latter, though they enter the cup, they are arrested very near its margin, the rest of the lower half of the cavity being occupied by fractured matrix. These differences indicate corresponding ones in the relations of the branch to each of the two internodes; it springs from, and is organically connected with, the one below the node, whilst it is merely in contact with the one above, which it indents by the pressure occasioned by the growth of its truncated base. Plate XXVII. fig. 33 represents a similar specimen to the last, only it retains the branch belonging to the middle node in its normal position, which is rarely the case. In these two and some other allied specimens the branches spring from the main stems at definite angles, indicating some regularity in the phyllotaxis of the plant. The amount of the angle of divergence depends upon whether the growth has taken place from left to right, or from right to left. If the former, the angle of divergence has been 140°, which, according to BRAUN'S method of indication, would give the fractional symbol $\frac{7}{18}$; but if the latter, that angle would be 220°, giving the symbol $\frac{11}{18}$. I have met with a few stems in which these branches were given off in verticils, three being planted on each node; and I have

* A similar condition is represented on one out of four internodes in Tab. 6, fig. 7 of PETZHOLDT'S "Ueber Calamiten und Steinkohlenbildung." The plant figured is *Calamites approximatus*.

observed that those of one node are intermediate, or alternating with, those of the contiguous one.

A question is at once suggested by these specimens. What are they? Are they a distinct species of Calamite, or are they merely some specialized portion of well-known forms? The plant which BRONGNIART figured and described under the name of *Calamites ramosus* exhibits some features in common with them (Histoire de Végétaux Fossiles, pls. 17. figs. 5 & 6), as also do some examples of his *Calamites arenaceus.* But after examining a large number of specimens, I have come to the conclusion that they have been *vertical* subterranean rhizomes. One specimen in the Cabinet of Mr. WILDE especially confirmed this conclusion. At its lower extremity it exhibits all the appearances of fig. 31, but at its upper end, after giving off a strong branch, it is prolonged in the form of an ordinary Calamite. A similar specimen in the Cabinet of Mr. NIELD does the same. That these rhizomes have been vertical is demonstrated by the direction of the branch in fig. 33, by the verticillate arrangement of the branches in the variety just referred to, and by the two significant specimens. When large branches are met with, detached from such parent rhizomes as fig. 31, the base, composed of several internodes, is seen to be truncated as shown in Plate XXVII. fig. 36; but very frequently the concentric shortened internodes are much more numerous than in that example. These internodes exhibit, even at the truncated base, the same longitudinal ridges and furrows as occur on the free stems, indicating that their woody wedges, to which these lines are due, radiate regularly from a central point representing the medulla. Of course such specimens as that figured are mere casts of the medullary cavity, and beyond indicating the size of the internodes and the arrangement of the innermost margins of the woody wedges, they throw no light upon the actual relations of the woody zone of the branch to that of the rhizome; but they do show that the medulla of the branch is only connected with that of the central rhizome by an exceedingly small cellular union, represented in fig. 36 by the dot forming its central point.

M. GRAND' EURY has published (Comptes Rendus, *loc. cit.*) some interesting statements respecting the Calamites of St. Etienne. He found long rhizomes running away from a central stem, giving off aërial shoots, and then continuing their subterranean course to repeat the process at successive and more distant intervals. But the condensed abstract of his memoir published in the Comptes Rendus does not enable me to identify his specimens of *horizontal* growths with those which I have just described, though the latter are the only ones I have met with in England which I can regard as rhizomes. Neither have I been able to satisfy myself as to the exact relationships between these rhizomes and such specimens as that represented in fig. 34, a common type of the subterranean base of an aërial stem, and a form which now demands a moment's consideration.

The conical bases of Calamites are not uncommon. Sometimes they are very obtuse, the internodes diminishing rapidly in size; at others they are drawn out in a more tapering manner. Occasionally they are quite straight, but much more frequently they are curved, as if they were lateral shoots from some other structure, which in the curved examples has doubtless been the case. The lowermost internodes of many such specimens exhibit verticils of irregularly disposed protuberances (Plate XXVII. fig. 34, *p*) planted upon the inferior extremity of each internode. These I have always regarded as indicating the exact position of the roots of the Calamites in relation to each node, viz. immediately *above* it. The specimen represented in Plate XXVIII. fig. 35 settles this point. Mr. BINNEY had already published, in his Monograph, a drawing of a fine specimen (page 5), showing a large number of the lowermost articulations giving off roots; but it afforded no clear evidence whether those roots were planted above, upon, or below each node. Mr. WILDE'S specimen leaves no room for doubt*. Several of its nodes exhibit similar indications to that shown in fig. 35, which is a sandstone cast detached from the exterior of the stem, preserved by Mr. WILDE; *p* is a smooth surface or cast from which the actual root has been separated, but the latter remains *in situ* at *p'*. At its extremity it appears to have divided into several slightly diverging branches, or, what is possible, its branched portion may have been broken off and the part left split by pressure. Two points are clearly indicated by this instructive example:—1st, the cast of the root is perfectly smooth, exhibiting none of the ridges and furrows which are so strongly marked on the internodes (*k*) of the parent stem; 2nd, these ridges and furrows pursue their course right across the base of the root, almost entirely undisturbed by its close contact with them. These two facts seem to indicate that the root is an adventitious structure, and that if it received any vessels from the woody zone they were few in number, and did not exist as a cylindrical prolongation of the exogenous woody axis of the stem into the root, as would be the case in a recent phanerogamous Exogen. That these roots branch at their extremities into the plants known as Pinnulariæ appears to be established on the testimony of so many observers that no grounds exist for doubting the correctness of the conclusion, though I have had no opportunity of verifying it.

A much more difficult question to be determined is the nature and position of the aërial branches. When we obtain specimens in which subterranean rhizomes are directly prolonged into aërial stems, we find that the large phragmata or cicatriculæ, seen in Plate XXVII. figs. 31, 32 & 33, give place to others similarly located, but becoming very much smaller in size as soon as the stem emerged from the ground. The upper portions of the curved lateral aërial stems, appear entirely devoid of all but these smaller cicatriculæ. Hence we may conclude that in all instances the aërial branches were of small diameter. These inferences are sustained by what we know of their minute organization. In my memoir on *Calamopitus* I gave figures of several *transverse* sections of these branches as seen in *tangential* sections of the main stem (*loc. cit.* tab. 3, fig. 6; tab. 4, fig. 15), whilst in a diagram representing a longitudinal section (tab. 5, fig. 17) I showed how these branches spring directly from the innermost part of the woody zone exactly at the node; at the same time I pointed out that, in the sections in question, the diameter of each branch never exceeded the width of one of the small longitudinal ridges, seen on the surface of each Calamite. I have now further evidence of the correctness

* This position of the roots was long ago shown by LINDLEY and HUTTON in the 'Fossil Flora of Great Britain,' Tab. 78 A; but I have again dwelt upon it because the fact was disputed at the Liverpool Meeting of the British Association.

of these conclusions. Plate XXVIII. fig. 37 represents part of a longitudinal section of the specimen of *Calamopitus*, of which figs. 19 to 25 inclusive exhibit other aspects. Like figs. 23 & 24 it is a vertical section which has traversed one of the horizontal portions (37 *e*) into which each longitudinal canal, in that variety, divides at the node: we have the usual arched nodal arrangement of the wood-vessels; and at *m* is indicated the position of a branch of which the tissues have perished, such a branch being identical with those indicated in Plate XXVI. fig. 25 *m*, at the lower extremity of the primary medullary ray b' in fig. 22, in Plate XXIV. fig. 13, and in Plate XXIII. fig. 2 *m*. In all these examples, except 25, we find evidence not only that the branches originate in the innermost part of the woody zone, receiving additional vessels from the latter as they proceed outwards, but in several of them we have proof that a minute amount of cellular tissue in their centre forms a pith, continuous with that of the parent stem, as I have already shown to be the case with the larger subterranean branches. In the *Calamopitus* already so often referred to this is very marked. In the section delineated in plate 4. fig. 15 of the memoir quoted, and reproduced at Plate XXVIII. fig. 38 of this memoir, we see that this cellular tissue already appears as a well-defined pith. But since the above description was written, Mr. BUTTERWORTH has placed in my hands a transverse section of a stem which has been about an inch in diameter without its bark. The section has taken a slightly oblique direction, one half of it passing *through* the node, and the other a little on one side of it. But fortunately the nodal portion passes through the finest example of an aërial branch I have yet seen, and which accords with the remarks already made. Plate XXVIII. fig. 39 represents the branched part of the section referred to. The plant has belonged to the same type as fig. 16, not being furnished with longitudinal canals*. The base of the branch (*m*), and which is inserted into the woody zone, is wedge-shaped. It takes its rise from the innermost or medullary angle of one of the woody wedges, the two halves of which (f', f') are pushed asunder by it as it proceeds outwards, receiving additional vessels from each half as it does so, increasing its diameter. At its medullary extremity its vessels are distinctly seen to be intermingled with some large cells, reminding us somewhat of the arrangement seen in fig. 3; but the chief portion of the branch consists of parallel vessels which pass directly outwards. I conclude that the section has cut through the branch a little on one side of its medullary portion, which consequently is not seen. The part imbedded in the woody zone, as well as the remaining portion of what has been external to it, consists of one undivided joint or internode, no transverse nodal constrictions being visible in it. At its emergence from the woody zone the branch has a diameter of ·101 of an inch, which is about one half more than that of the exteriors of the woody wedges in its neighbourhood. The wedge from which it springs is thus dilated by it at that point to about double its usual dimensions. These measurements sustain what I have already said respecting the small size of the aërial branches. We thus have the longitudinal transverse and tangential sections of Calamites combining to fix with approximate certainty the position of these branches in relation to the central axis. These conclusions

* See note on p. 488.

respecting the small size of the aërial branches lead to some practical suggestions. If they prove to be of universal application, they leave us in no doubt as to which are aërial and which subterranean branches. Wherever a branch has had a diameter equal to that of several of the woody wedges combined, it appears to have been a subterranean one. The aërial ones, on the other hand, have rarely, if ever, had a diameter, apart from their yet unknown cortical investments, exceeding that of two woody wedges. This conclusion agrees with what we see on the indisputably aërial stems of ordinary Calamites. I have already observed that, in such, the concave depressions, indicating the points from which branches have fallen, are very small. The form of these concavities, allowing for the effect of surface-pressure, corresponds exactly with that of the base of the specimen now described. The exceeding rarity of fossil stems to which branches remain attached, at least in British strata, indicates that the connexion between the two has been very slight. The conical base of the twig imbedded in the woody zone has been united with the vessels of the latter throughout its entire surface; but the suddenness with which the vessels have been deflected from a vertical to a horizontal course may have been a source of weakness, and led to the almost habitual disarticulation of the branches. These appear to have been detached as easily as the leafy shoot is screwed out of the top of a pine-apple, leaving, in like manner, conical cavities behind them impressed upon the casts of the pith.

I do not propose to enter at length in the present memoir into the questions of the foliage and fruit of the Calamites. Of the foliage I have not seen sufficient to enable me to balance the discrepant testimony of the writers who have preceded me. My indefatigable friend, Dr. DAWSON, of Montreal, thinks he is able to distinguish the leaves of Calamites from those of the fern-like *Asterophyllites*. M. GRAND' EURY regards the *Asterophyllites* as belonging to stems that have but a vague and distant resemblance to those of Calamites. Mr. CARRUTHERS is inclined to believe that *Asterophyllites*, *Annularia*, and *Sphenophyllum* are but modified forms of one common genus, and that they collectively represent the foliage of Calamites. The structure of the stems and branches which I have described exhibit so marked a tendency towards verticillate arrangements, that we should naturally turn to fossil leaves similarly disposed in searching for the foliage with which to clothe them. At present, however, our information does not appear to me to be sufficiently definite to enable us to settle the disputed question. The three genera named are the only ones found in the Coal-measures possessing the needful verticillate arrangements, and I have no doubt that we must seek the required foliage amongst them, but under what limitations is yet to be ascertained. The remarks just made apply with almost equal force to the fructification of the Calamites. Several varieties of cones or strobili have been found in the shales of the Lancashire measures belonging, or allied to STERNBERG'S genus *Volkmannia*; but these rarely retain their internal structure. Mr. BINNEY has figured, under the name of "Cone of *Calamodendron commune*," one from ironstone, in which the structure is preserved; whilst Mr. CARRUTHERS has described and figured the same cone* under the

* Journal of Botany, December 1867.

name of *Volkmannia Binneyi*, and referred it to *Calamites*. I have figured and described another very distinct cone, resembling a *Volkmannia**, of which the central axis affords the clearest proof of a Calamitean origin. Besides this, I have before me a third form of cone, discovered by Mr. BUTTERWORTH, in which the fruit-bearing organs are arranged in verticils, but of which the structure is very different from that of either of the other two†. Of the form described by Mr. BINNEY and Mr. CARRUTHERS I have made a number of preparations, and have examined a still larger number of specimens. Hence I have now in my cabinet three distinct types of verticillate spore-bearing Cryptogamic cones, in which the structure is exquisitely preserved; but of these three, that which I have described in the Manchester Transactions is the only one of which the central woody axis exhibits the same organization as the Calamitean stems now described. It does so in the most minute details; hence I have no doubt respecting its Calamitean character; but the other two differ so widely from it, from each other, and from the stems of all known Calamites, that I greatly doubt the propriety of uniting them. When stems, however varied in minor details, exhibit so remarkable a conformity to a definite type as I have shown to be the case with all the varieties of Calamites, I cannot conceive of the central axes of their fruit-bearing organs becoming so widely divergent from that type as must have been the case if the fruits described by Mr. BINNEY and Mr. CARRUTHERS belong to the same genus. In the Calamite the medullary axis is purely cellular, and its vascular zone is the more external one even in the youngest twigs; but in the fruit in question these conditions are reversed. The vascular tissues are all found in the central part of the axis, involving a metamorphosis to which I know no parallel amongst living plants. I would speak on this question with the reserve demanded by limited information, but I am at present disposed to believe that the only Calamitean fruit *of which the internal organization has hitherto been ascertained*, is that which I have described in the Manchester Transactions. The others, I suspect, belong to the *non*-Calamitean forms of Annularian plants, whichever they may be.

We have as yet failed altogether to correlate, with accuracy, the fruits of which we know the organization, and those just referred to as found in the Coal-shales, and of which we only know the external forms. Much work remains to be done ere we can succeed in this part of an inquiry of which we have but touched the threshold. Are we under these circumstances in a position to determine the position of Calamites in relation to living plants? Recognizing the necessity of proceeding with caution, I think we are. A further question also presents itself. Are we to recognize two genera of Calamitean plants, or are they all to be included in one genus? I fear my valued friend ADOLPHE BRONGNIART will scarcely agree with my reply to this second question, though I think that if he had the opportunity of carefully studying the sections in my cabinet

* "On a new form of Calamitean strobilus from the Lancashire Coal-measures," Memoirs of the Literary and Philosophical Society of Manchester, 3rd series, vol. iv. 1869–70.

† This cone is the subject of a memoir by the author, just published by the Manchester Society, "On the Organization of *Volkmannia Dawsoni*," in which the new fruit is referred to either *Asterophyllites* or *Sphenophyllum*.—October 3rd, 1871.

he would soon be induced to do so. It is clear to me that the separation of Calamites into two groups, the one Cryptogamic and the other Phanerogamic, the former represented by Calamites and the other by Calamodendron, must be wholly abandoned. Internal organization affords no solitary fact upon which such a division can rest. The specimen illustrated in the figures 19–25 is one of the *thin-walled* types which M. BRONGNIART, and those who hold his views, would regard as an unmistakable *Calamites.* Prior to his recent visit to England, Dr. DAWSON held the views of the French botanist as strongly as he himself does; and when he saw the specimen in question, he unhesitatingly identified it as one which was *not* a *Calamodendron.* It was this, and some allied examples, which led the Canadian geologist to declare to the Geological Society of London that "specimens in the collection of Professor WILLIAMSON show forms intermediate between *Calamites* and *Calamodendron*, so that possibly both may be included in one family"*,—language which, when we remember the strength of Dr. DAWSON'S previous convictions, bespeaks the true philosopher, to whom scientific truth is a sacred thing. The preceding descriptions and illustrations leave, I think, no reasonable room for disputing that the thin-walled and the thick-wooded plants, the latter being the *Calamodendra* of BRONGNIART, are but different species of one group, if they represent more, in some instances, than different ages of the same species.

The structure of the woody zone is unquestionably exogenous†. The arrangement of its vessels and medullary rays, its mode of growth, and that of its aërial branches all demonstrate the truth of my conclusions on this point. But the bark is the cellular covering of a Cryptogam. Whichever of the verticillate-leaved plants of the Coal-measures constituted its foliage, they are all equally cryptogamic. My strobilus, the Calamitean character of which it is impossible to doubt, is filled with round spores that are unmistakably Cryptogamic. The structure of the roots affords clear evidence that they were not the woody prolongations of the main axis seen in the roots of the Gymnospermous Conifers, but adventitious appendages of the Cryptogamic type. All these facts point to one conclusion, viz. that the Calamites were all Cryptogamic plants, but that they possessed a much higher organization than is seen in any of the Cryptogams living at the present day. Some writers affirm that the living Isoetaceæ exhibit an exogenous stem. Since I have had the opportunity of studying them for myself, I must confess I have failed to trace the evidence of the alleged exogenous growth; but the authority of HOFMEISTER and other botanists is sufficient to show that it exists; in the Calamites the proofs of such growth are incontrovertible.

There is no question that the only living plants with which Calamites can be compared are the Equisetaceæ, with which Mr. CARRUTHERS has unhesitatingly united them;

* Abstract of the Proceedings of the Geological Society of London, No. 217, May 1870.

† I have already pointed out the resemblance which a transverse section of a Calamite, made at an internode, bears to a similar section of a branch of the first year belonging to any exogenous plant. The Calamite may be regarded as exhibiting *permanently* a condition that is *temporary and transitional* in the living plants. This observation has especial reference to the non-multiplication of the woody wedges after their first appearance in the stem of Calamites.

but it seems to me undesirable to do so; though there are some points of resemblance between the two plants that sorely tempt a botanist to do so. But before attempting to determine the question, we must ascertain what are the several points of resemblance and of difference.

Different botanists have defined the Equisetaceæ in various ways; but most of these definitions of the family include two things: 1st, a sheath to each joint of the stem; and 2nd, hygrometric elaters attached to each spore. That the former of these has no existence in Calamites is universally admitted*. The plant figured in M. BRONGNIART'S great work under the name of *Calamites radiatus*†, exhibits what that distinguished botanist regarded as a true sheath. But I recently examined the specimen which is, or was, in the Strasburg Museum, and I satisfied myself that the supposed sheath is a mere verticil of leaves; a conclusion in which its eminent custodian, Professor SCHIMPER, fully agreed with me. Consequently the fact must be admitted, that one of the universally existent features of recent Equisetaceous plants does not appear in the fossil Calamites.

In his description of his *Volkmannia Binneyii* Mr. CARRUTHERS announces the discovery of spores with attached elaters, and on the strength of this supposed fact he further rests his conclusion that the Calamites are Equisetaceæ. But to this I entertain two objections. I have not seen Mr. CARRUTHERS'S specimen, but I have made sections of and examined a considerable number of strobili of the same species; and though I find spores in abundance, I have failed to detect a solitary example furnished with elaters. I think the evidence for a conclusion, so scientifically important as that to which the recognition of elaters would lead us, must be very clear and decisive before we accept it; and if we find one solitary example which may possibly be interpreted as bearing such organs and a large number of others, of the same species, in which no such organs can be found, we must be quite sure that the exceptional specimen is incapable of any interpretation that will bring it into harmony with all others of the same sort. Judging from his figures, I think it probable that, in Mr. CARRUTHERS'S specimen, the outer cell-walls of the spores have become accidentally ruptured, and the detached portions projecting from the spores have been mistaken for elaters. But even if, contrary to expectation, elaters should be shown to exist in these cones of Volkmanniæ, it still remains to be proven that the species in question belongs to Calamites; and until such connexion is established we must scarcely, on the strength of its possibility, alter our definition of a great and important natural family of plants.

I am not aware that the minute organization of the Equisetums has yet been illustrated in detail by any English writer; but it has been very effectively done by the late Dr. J. MILDE in his 'Monographia Equisetorum'‡. But even this admirable mono-

* If we regard the sheaths of Equisetums as verticils of coalesced leaves, the verticils of free leaflets supposed to exist in Calamites may be said to represent them. In the former case these verticils exist persistently on the deep subterranean rhizomes, as well as attached to the aërial stems. Nothing takes the place of these subterranean appendages in Calamites.

† Végétaux Fossiles, tab. 26, figs. 1, 2.

‡ Nov. Act. Academiæ Cæsariæ Leopoldino-Carolinæ Germanicæ Naturæ Curiosorum, Dresden, 1867.

graph leaves unnoticed some points of importance to my present inquiry. In Plate XXIX. fig. 41 I have represented a longitudinal section of a node in a cylinder of *Equisetum maximum*. Fig. 42 represents a segment of a transverse section of an internode of the same plant, whilst fig. 43 exhibits one of the canals (42, *e*) with its surrounding parts yet more highly magnified.

The internal organization of these plants presents some striking resemblances to that of the Calamites. Their stems are jointed and their internodes fistular, whilst the medulla stretches permanently across the stem at each node (41, *i*), forming a cellular diaphragm (41, *n*). There is a thick persistent medullary layer (41, *b*) separated from an outer or cortical layer (41, *h*) by a series of canals (42, *e*, 43, *e*), like those common in the Calamites, and which reach from node to node without penetrating either. At each of the outermost angles of these canals we find a few longitudinal spiral vessels (43, *g*), and in the mass of dense cellular tissue which lies externally to each canal, we have two other small clusters (43, *g'*) of similar vessels. Primarily cellular, these vessels become variously modified into annular, reticulated, barred, and scalariform types. The first glance at these sections tempts us to regard the canals (*e*) as the homologues of the longitudinal canals of the Calamite, and the vessels (*g*, *g'*) as the degraded representatives of the woody wedges, the copious vascular laminæ of which seem thus to have dwindled down to a few detached vessels. This resemblance is rendered yet more remarkable if we examine the corresponding vessels in some other species of *Equisetum*. Dr J. MILDE has shown that in *E. variegatum*, *robustum*, *brachyodon*, *hyemale*, and *ramosissimum*, these vessels are arranged in two laminæ, which radiate from the outer angles of the canal towards the cortex in two parallel lines. Let the intervening space between these lines be filled up with similar ones, and we should have the woody wedge of the Calamite; at the same time we have no evidence that this arrangement in the recent forms is the result of an exogenous growth*. When we turn to the longitudinal section (fig. 41), we again discover points of resemblance. The canals (42, *e*) are not very visible; but we can readily mark their course by tracing that of the vessels (*g*) which accompany them, whilst the outer series (*g'*) is also seen imbedded in cellular parenchyma. But the most striking features of this section appear immediately beneath the node. At this point we have a dense mass, convex externally, and consisting of very large reticulated vessels (41, *y*), in which the vessels (*g*, *g'*) coming up from below suddenly disappear. This cluster of enlarged reticulated vessels terminates very abruptly at the node, as if truncated, having previously given off a divergent cluster (41, *z*) to the base of an adjoining branch (41, *m*), and from which a few spiral vessels alone are prolonged into the branch, but between which and the cluster (*z*) whence they spring is placed an extension (*i'*) of the nodal septum which bounds the branch cluster (*z*) in the same way that the main node (*i*) does the cluster *y*. These dense additions to the vascular tissues in the neighbourhood of the node appear at first sight to represent the arched

* SACHS figures the superficial arrangement of these vessels at the nodes of *Equisetum maximum*; it exactly corresponds with that of the woody wedges in my fig. 2, a fact favouring the idea of close Equisetacean affinities. See SACHS's 'Lehrbuch der Botanik,' p. 349 D.

vessels of the thickened woody zone in the same region of the Calamite; but when we compare the two more minutely, we discover them to be very different things. We have seen that, in the fossil genus, the woody zone is materially thickened at each node by the addition of a number of arched vessels, which differ only in their increased numbers from those of the internodes. There is no change in the character of the individual vessels, nor interruption to the continuity of their course. The woody zone of the inter node gradually thickens into a lenticular form as it ascends to the node, and as gradually diminishes again as it enters the internode above. There is no abrupt termination or change in the vascular mass, neither is there any nodal diaphragm crossing it and intersecting the course of the vessels; but it is otherwise in all these points with the Equisetums. Plate XXVIII. fig. 40 represents one of the coarsely spiral vessels (*g*) of fig. 41, taken from the point where it ascends from below, and enters the vascular mass (41, *y*). The ordinary spiral texture has already become yet more coarse and irregular (*w*), and this irregularity degenerates as the vessel increases in diameter into a large open network of lignine (*x*) deposited in the interior of the tube. Still higher the vessel is yet further enlarged, and now, forming part of the vascular mass (41, *z*), it is rendered angular by the pressure of other vessels like itself. Its angles (*z*) are here thickened by a continuous deposit of lignine, as in true scalariform vessels, and on its flat faces similar deposits occur in the form of minute and regular reticulations. We have nothing approaching to this condition in Calamites. We further discover in the node of the Equisetum that, in addition to the cellular diaphragm, or extension of the pith that stretches across the fistular cavity, a still more dense layer exists, not only within the diaphragm, but which, as shown in fig. 41, is continued in a direct line across both the vascular and cortical zones; at the exterior of the latter it merges in a second one (41, *i*) at right angles to the first, and which separates the base of the branch (41, *m*) from the main stem. In both instances, as already shown, this dense layer truncates the vascular masses *y* and *z*. The presence of this dense layer has perhaps something to do with one of the differences between the branches of Equisetums and Calamites, which in the former are very much more persistent than the deciduous ones of the latter appear to have been. I have shown that in the more matured stems of the Calamites the pith becomes wholly absorbed, which is not the case with the Equisetums. It may be urged that the reason for this difference lies in the fact that the stems of the former have been much more persistent than the annual growths of the latter. Such may be the case; but the distinction holds equally good in the case of the permanent subterranean rhizomes of the Equisetums, where also the pith remains intact, not even becoming fistular. The existence of these rhizomes in both instances presents another feature of resemblance; but as they occur equally in many other Cryptogams, *e. g.* the Marsileaceæ, they have little definite value in relation to the present argument. But this is not the case with the medullary rays that abound in the Calamites. Of course we should not expect to see the *secondary* ones represented in the Equisetums, because they do not possess the vascular laminæ between which these structures are located; but if the canals (*e*, *e*) of Plate XXIX. fig. 42 represent the similar ones in the Calamite, then the outward prolongation of the cellular pith (*a*) between the two canals, in the direction of *h*, corresponds with a primary medullary ray in a Calamite; yet we nowhere see, in the recent plants, the remarkable muriform arrangement of the cells common to all varieties of the latter objects. After fairly weighing the evidence for and against the admission of the Calamites amongst the true Equisetaceæ, as proposed by Mr. CARRUTHERS, it appears to me that the reasons against doing so preponderate over those which favour such a course; to disturb generally accepted definitions of a living family of plants for the sake of doing this seems to me unwise. I should therefore propose the recognition of a distinct family of *Calamitaceæ* *, which from their complex organization must necessarily stand high up in the great Cryptogamic division of the vegetable kingdom, which division their exogenous stems would directly connect more closely than has yet been done with the true Gymnospermous Exogens—a connexion which I believe will be still further strengthened when some other plants of the Coal-measures, especially the Dictyoxylons, have received a more careful study than they have yet obtained †.

The only question that remains for consideration is that of generic and specific nomenclature. At present we have four generic names applied to Calamites,—*Calamites*, *Calamodendron*, *Calamopitus*, and *Astero-calamites*. The supposed distinction between the first and second of these I think I have proved to have no existence; and I doubt the sufficiency of the evidence, resting as it does upon a single specimen, for the recognition of Professor SCHIMPER'S genus *Astero-calamites* in this list ‡. Nevertheless we have existing two very distinct types of Calamites, viz. those which have, and those which have not possessed the infranodal canals—a distinction that appears in every part of the fossil, whether it be the medullary cast or the carbonaceous investment; hence it is a distinction most easily recognized in nearly every specimen that falls into our hands. It appears to me desirable that we should distinguish these two types by different generic names. In order to avoid a needless multiplication of terms, I would gladly have given up my new genus *Calamopitus* and employed *Calamites* to represent one of the types and *Calamodendron* the other. But M. BRONGNIART retains his original views respecting the gymnospermous nature of his genus *Calamodendron*, and, doing so,

* Whilst deeming this course desirable I do not attach much importance to it, provided the accepted definitions of the natural order of Equisetaceæ be sufficiently extended to embrace these fossil forms. As those definitions now stand they exclude the Calamites.

† The greater portion of the Cryptogamous plants of the Coal-measures, with the exception of the Ferns, exhibit this exogenous growth of their woody zones, thus linking them with the Exogens rather than with the Endogens. The arborescent form which these carboniferous Cryptogams assume affords us a better opportunity of learning their true position in the vegetable scale than their dwarfed living representatives, none of which, with the exception of the Ferns, exhibit the arborescent condition. So far as the stem is concerned, we have in the fossil forms both the exogenous growth and the medullary rays of true Exogens; indicating close affinities with that highly developed class, and between which and the cellular Cryptogams they may be regarded as constituting a connecting link. On the other hand, may not the Ferns, with their detached bundles of vascular tissue, hemmed round and isolated by dense layers of woody fibre, connect in like manner the lower Cryptogams with the Endogens?—Jan. 26th, 1871.

‡ It appears to me not improbable that this curious specimen belongs to *Asterophyllites* or to *Annularia* rather than to the true Calamites.

he naturally objects to my employing his name in a new sense. Under these circumstances I propose designating all the plants which have no infranodal canals, indicated by the absence of verticils of round or oblong scars, *Calamites*, whilst to those which have possessed such canals, I would assign the name of *Calamopitus*, already applied to them in my previous memoir on the subject.

I am disposed to regard all existing specific names and definitions as worthless. They separate things that I believe to be identical, and confound others that are obviously distinct. The medullary casts, with their altered carbonaceous coverings, appear to afford very imperfect data for the determination of species. Practical purposes may require the provisional employment of a few such names, but they have little if any scientific value. One remarkable plant has been included amongst Calamites which I believe has no affinity with them,—I refer to the *Calamites verticillatus*.

I have to acknowledge the kind assistance which I have received during this inquiry from several gentlemen. Mr. WILD, of the Glodwick Collieries at Oldham, has allowed me the free use of his fine collection of specimens, and Mr. NIELD, of the same town, has been indefatigable in giving me facilities for obtaining others. I have also received help from Mr. WHITTAKER, of Oldham, and from the Rev. W. HIGGINS, of Huyton. But I am mainly indebted to Mr. BUTTERWORTH, of Shaw, without whose invaluable cooperation this investigation could scarcely have been carried on.

DESCRIPTION OF THE PLATES.

To facilitate comparative references, each letter of the alphabet up to *p* is employed throughout the following figures to indicate homologous structures.

a. Fistular medullary cavities.
b. Pith-cells.
c. Primary medullary rays.
d. Secondary medullary rays.
e. Longitudinal internodal canals.
f. Woody wedges.
g. Vessels of woody wedges.
h. Cortical layers.
i. Nodes.
k. Internodes.
l. Infranodal canals.
m. Branches.
n. Nodal diaphragm.
o. Divergent woody wedges.
p. Roots.

PLATE XXIII.

Fig. 1. Diagrammatic restoration of part of the stem of a *Calamopitus*, from the left portion of which the bark has been removed exposing the exterior surface of the woody zone, and from the right both bark and wood are removed, revealing the outer surface of the pith. The branch at *m* exhibits its medulla (b'), surrounded by its woody zone, f'.

Fig. 2. Tangential section of a *Calamites* crossing the node.

Fig. 3. Portion from fig. 2, *a*, more highly magnified.

Fig. 4. Reticulated vessel of Calamites.

Fig. 5. Tangential section of part of a woody wedge with barred vessels and medullary rays

Fig. 6. Transverse section of part of fig. 5.

Fig. 7. Cells from the centre of the nodal medullary diaphragm of a *Calamites*.

Fig. 8. Longitudinal section of a primary medullary ray with medullary cells at *b*.

Fig. 9. Part of a transverse section of a Calamite with the cortex *in situ*.

PLATE XXIV.

Fig. 10. Longitudinal section of the same. *x*, spores accidentally introduced into the fistular cavity.

Fig. 11. Longitudinal section of a woody wedge, showing the pith, longitudinal canal, and secondary medullary rays.

PLATE XXIII.

Fig. 12. Barred vessels of Calamites.

PLATE XXIV.

Fig. 13. Tangential section of a Calamite near the pith, showing the transverse section of the commencement of a branch.

Fig. 14. Two woody wedges of a *Calamites* with large vessels.

Fig. 15. Part of the transverse section of a thin-walled *Calamites* with a smooth exterior to its woody zone.

PLATE XXV.

Fig. 16. Inner part of the transverse section of a woody wedge of a *Calamites* (?) unprovided with longitudinal canals.

Fig. 17. Transverse section of a portion of a woody wedge and part of a primary medullary ray of a *Calamites* in which vascular laminæ encroach upon the primary medullary rays.

Fig. 18. Tangential section of part of a primary medullary ray of the last specimen, further enlarged. *g*, vessels of the vascular laminæ; *c*, cells of the primary medullary ray.

Fig. 19. Transverse section (natural size) of a thin-walled *Calamopitus*, imbedded in its dark matrix.

Fig. 20. Small segment of fig. 19, more highly magnified.

PLATE XXVI.

Fig. 21. Small portion from opposite the star in fig. 19, viewed diagonally, and exhibiting part of the outer surface of the specimen.

Fig. 22. Tangential section of the same *Calamopitus* crossing the node in the plane of the internodal longitudinal canals, or close to the surface of the medulla.

Fig. 23. Vertical section of part of the same crossing one of the infranodal canals, *l*.

Fig. 24. Similar section across the node in the plane of the two woody wedges above and below it.

Fig. 25. Tangential section of the woody zone of the same near its external surface, and viewed as an opaque object.

PLATE XXVII.

Fig. 26. Segment of the transverse section of a *Calamites* in which the pith was being absorbed as far as line of arrested absorption, c'.

PLATE XXVI.

Fig. 27. Round scars left by the infranodal canals of a *Calamopitus*.

Fig. 28. Oblong scars of another variety of *Calamopitus*.

Fig. 29. Internodes of an arenaceous medullary cast of a *Calamites*.

Fig. 30. Portion of the internode (k'') of fig. 29, enlarged.

Fig. 31. Portion of a subterranean rhizome of a *Calamites* with the phragmata or scars left by the detached branches.

Fig. 32. One of the phragmata of fig. 31.

Fig. 33. Part of a rhizome with a branch in situ.

Fig. 34. Subterranean base of the aërial stem of a *Calamites*, exhibiting the points whence the roots were given off.

PLATE XXVIII.

Fig. 35. Base of the root of a *Calamites in situ.*

PLATE XXVII.

Fig. 36. Lower extremity of the medullary cast of a subterranean branch.

PLATE XXVIII.

Fig. 37. Vertical section of the *Calamopitus* fig. 19, indicating the position of a branch, *m*.

Fig. 38. Tangential section of part of a large *Calamopitus*, exhibiting a transverse section of an aërial branch.

Fig. 39. Transverse section of a *Calamites*, exhibiting a longitudinal section of the base of an aërial branch.

Fig. 40. Single vessel from near the node of an *Equisetum maximum.*

PLATE XXIX.

Fig. 41. Longitudinal section of the stem-wall of an *Equisetum maximum.* *m*, part of the sheath.

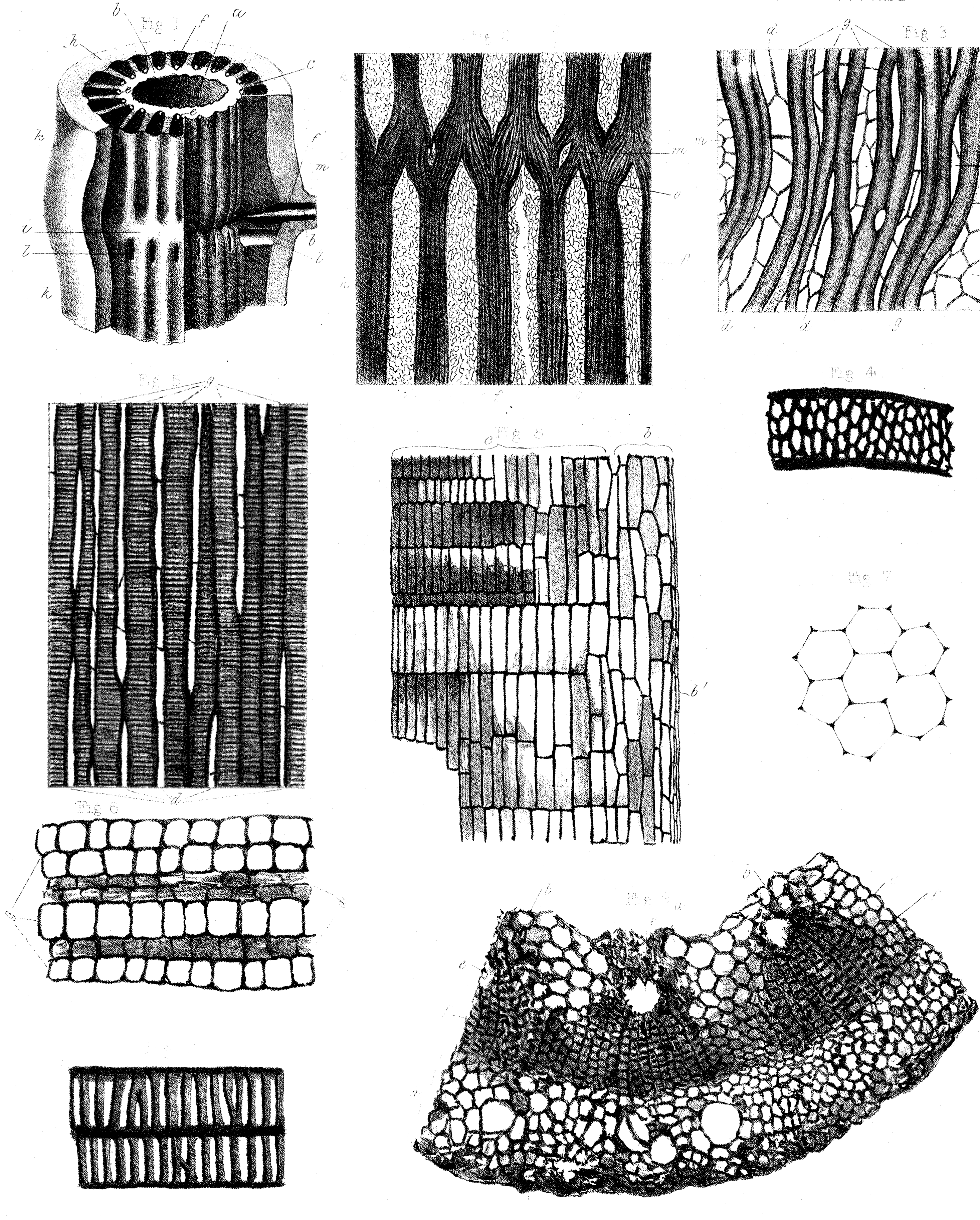
Fig. 42. Segment of a transverse section of *Equisetum maximum.*

Fig. 43. One of the vascular canals (*e*) of the last figure, with its surrounding tissues, more highly magnified.

RELATIVE DIMENSIONS OF THE VARIOUS PARTS OF INDIVIDUAL CALAMITES.

Number of specimen.	Diameter of the entire specimen.	Thickness of wall of entire cylinder.	Thickness of woody cylinder independent of the pith.	Approximate proportion of the thickness of ligneous zone to that of the entire cylinder.	Distance between contiguous canals.	Approximate proportions of the distance between the canals to the thickness of the woody zone.	Average diameter of the longitudinal canal.	Average diameter of the largest vessels.	Number of woody wedges in the cylinder.	General remarks.	References to figures in the memoir.
1.	1·16	·25 ·12	·25 ·12	$\frac{1}{4}$ to $\frac{1}{9}$	·10 ·12	1 to $\frac{1}{2}$	·02 ·005	·003 ·004	....	Pith nearly absorbed..................	Figs. 5, 8, 9 & 11.
2.	·66	·08	·06	$\frac{1}{11}$	·08 ·1	$1\frac{1}{3}$ to $1\frac{2}{3}$	·013	·0025 ·0016	about 80	Fistular cavity large	Figs. 19–25.
3.	·31	·1 ·12	·07 ·1	$\frac{1}{3}$ or $\frac{1}{4}$	·04 ·06	1/[illegible] to $\frac{1}{8}$	....	·0025	21		
4.	·2	·035	·05	$\frac{1}{4}$	·03 ·04	$\frac{1}{5}$ to $\frac{1}{7}$	·015	·0025	13	Bark present. Thickness at internode 025	Figs. 9, 10.
5.	·62	....	·2 ·25	$\frac{1}{3}$	·07 ·11	$\frac{1}{6}$ to $\frac{1}{7}$	....	·005	24	No long canals	Fig. 16.
6.	·21	·09	·07	$\frac{1}{3}$	·045 ·05	$\frac{1}{5}$	·005 ·0075	·01	22	Vessels very large	Fig. 14.
7.	....	....	·81	....	....	....	....	·005	......	Section apparently made at a node. 354 vessels in linear series.	
8.	·25	·075	·045	$\frac{1}{5}$	·075	$\frac{1}{3}$	·01	·0025	15	....	Fig. 15.
9.	....	....	·27	....	·123 ·143	$\frac{1}{2}$	·01 ·013	·005	....	Pith-cells being absorbed	Fig. 26.
10.	·18	·133	·07	$\frac{1}{2}$	·033	$\frac{1}{6}$	·0066 ·01	·0025	21	Pith thick.	
11.	·5	·29	·24	$\frac{1}{2}$	·05 ·073	$\frac{1}{10}$ to $\frac{1}{7}$	·01	·005	27	One intercalated wedge without any canal.	
12.	·31	·123	·083	$\frac{1}{4}$	·05 ·06	$\frac{1}{6}$	·01	·0033	25		
13.	....	....	·23	....	·24	....	....	·005	....	Vessels in primary medullary rays...	Figs. 17, 18.
14.	·37	·12 ·2	·11 ·13	$\frac{1}{3}$	....	....	·01	·005 ·0064	21		
15.	2	....	....	....	....	....	....	·0017	above 60	Innermost part of woody zone alone preserved. No canals present.	Fig. 38.

In the above Table the distance between the longitudinal canals indicates the distance between the centre of one woody wedge and another The actual thickness of the ligneous zone will be subject to great variation according to whether the transverse section is made at the node or at the internode. In most of the above examples it has been made at the latter point.



W. C. Williamson, Del.
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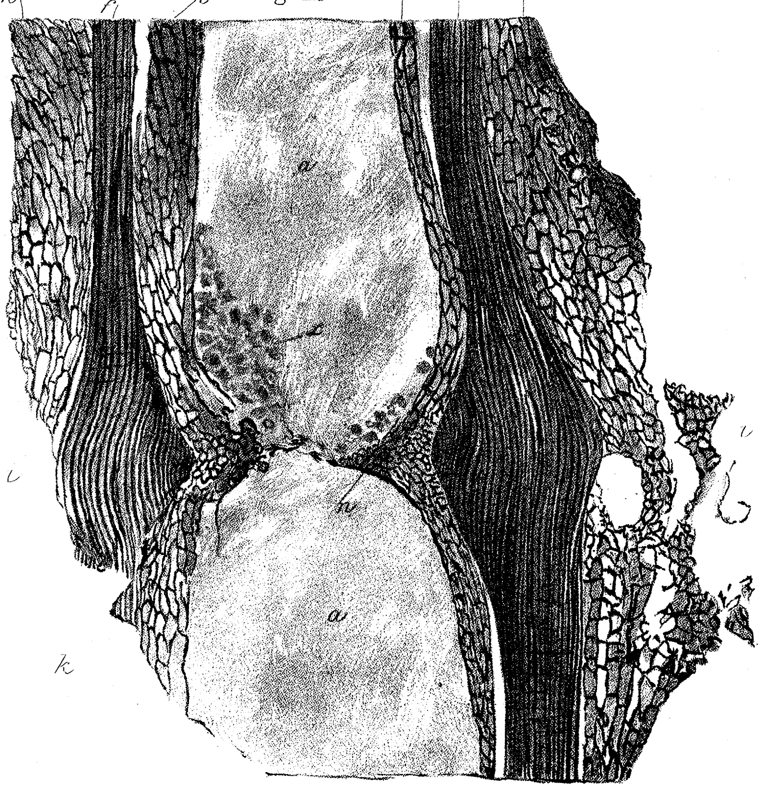
Mackie & Macdonald, Lith. London

Williamson.

Fig 10



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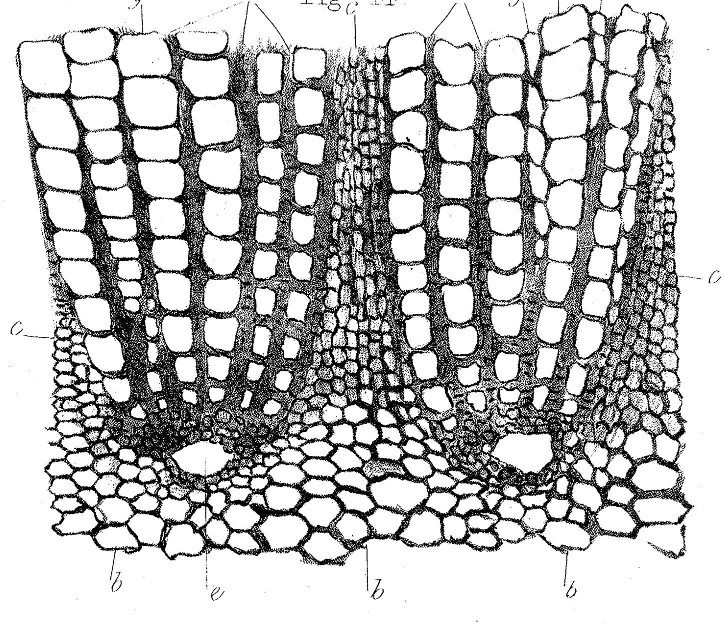

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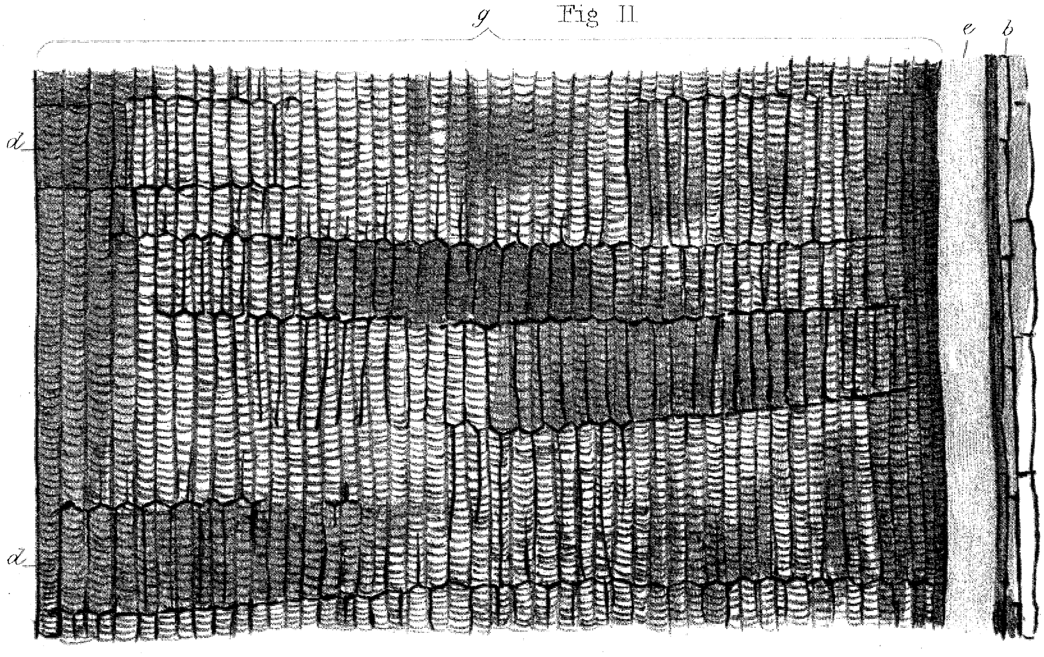

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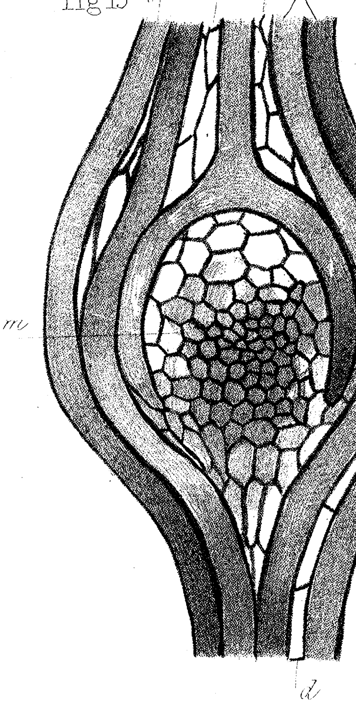

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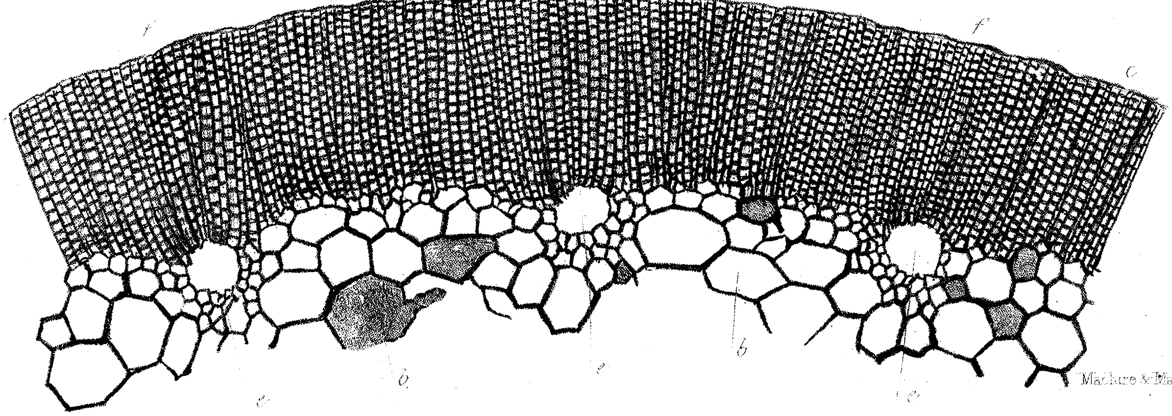
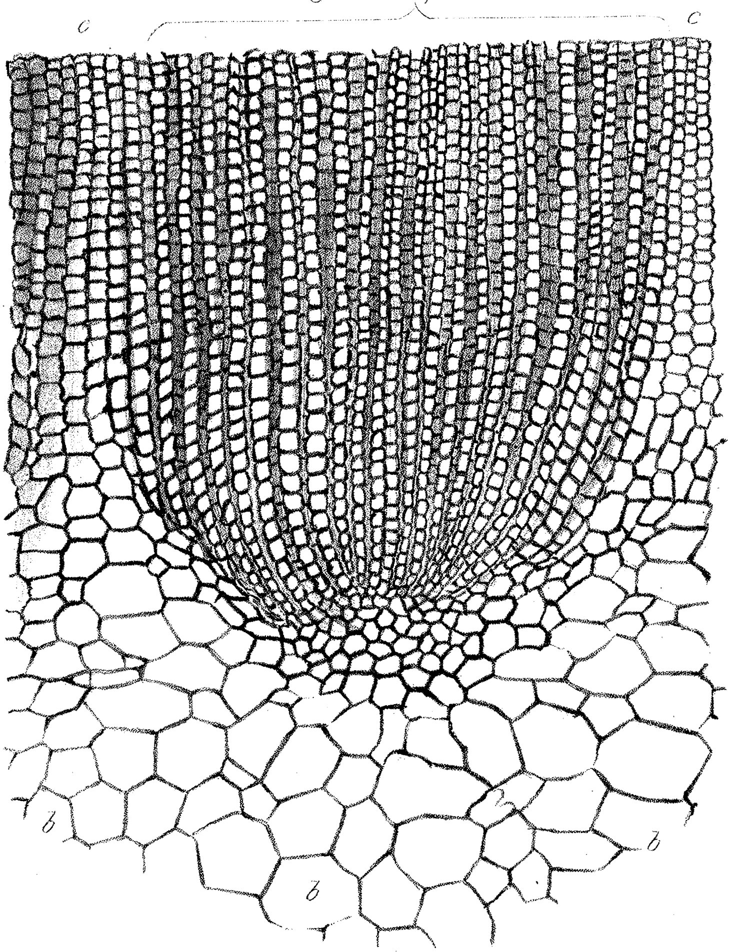


Maclure & Macdonald, Lith. London.

W. C. Williamson, Del.

W. H. Wesley, Auto. lith.

Fig 16



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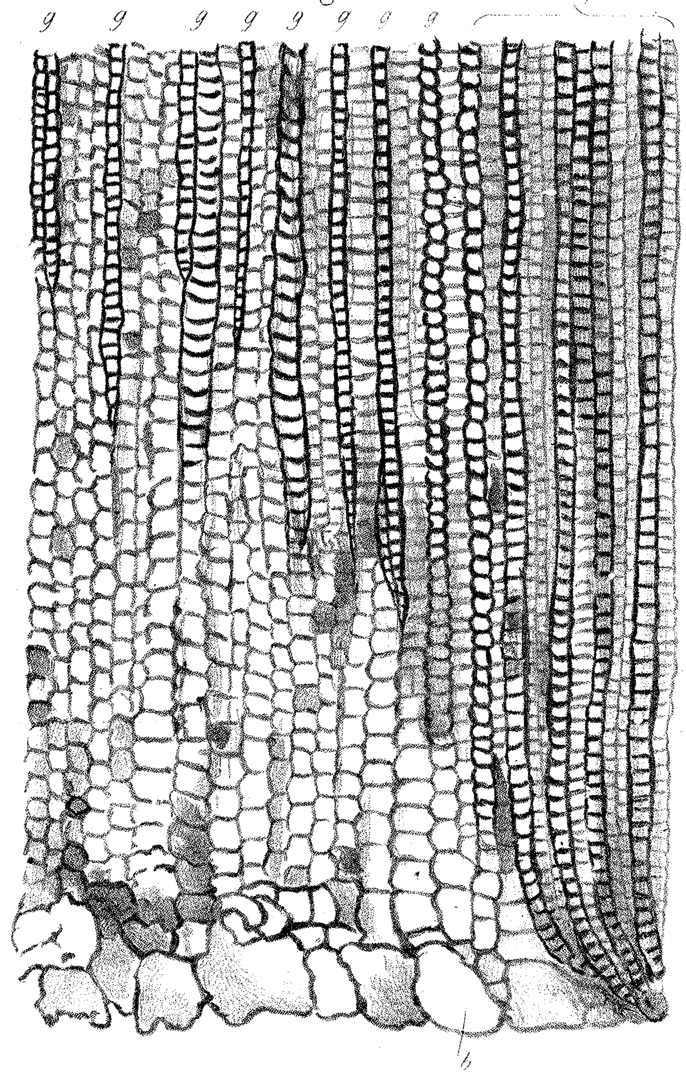

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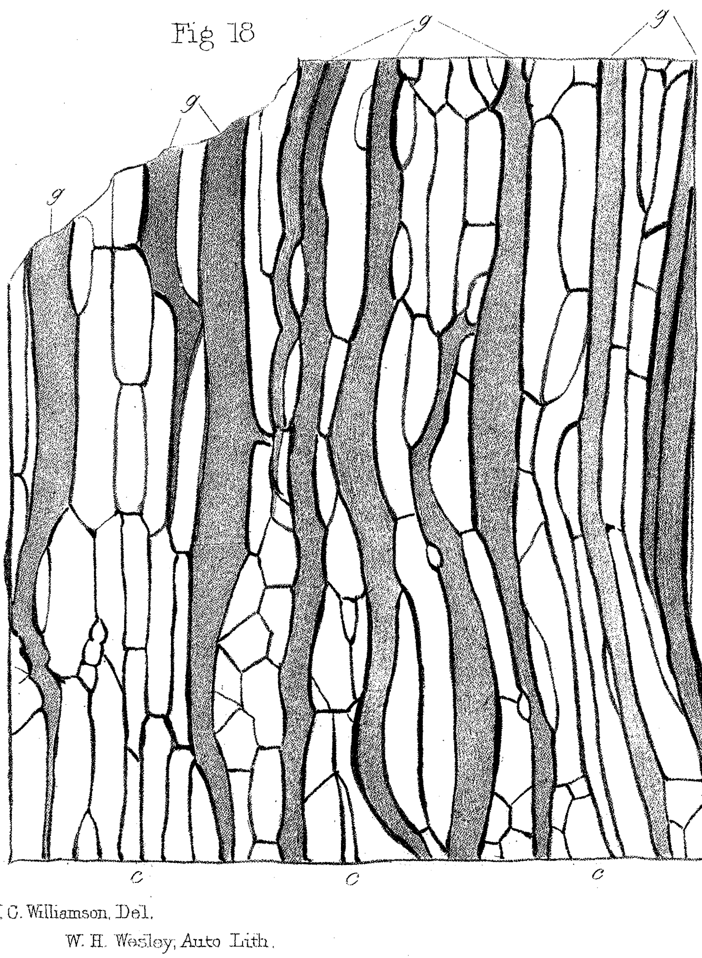

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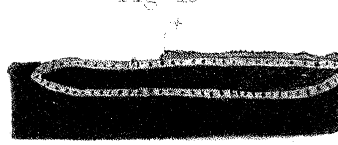

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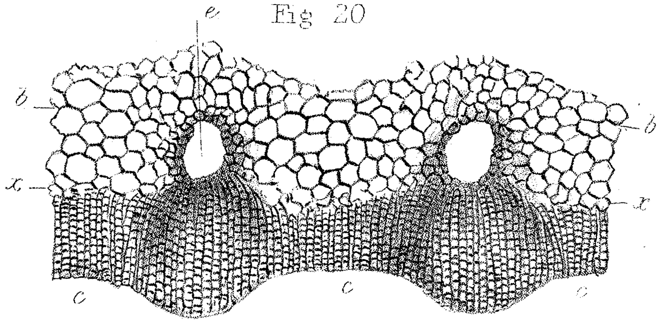

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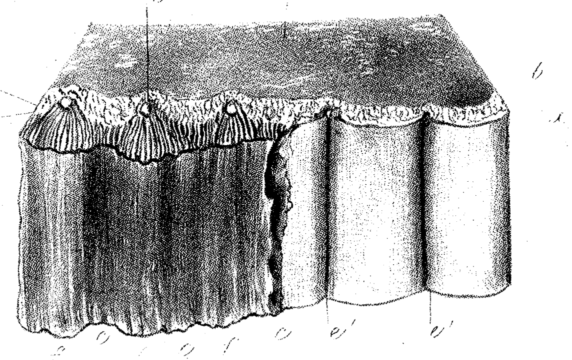
Fig. 21



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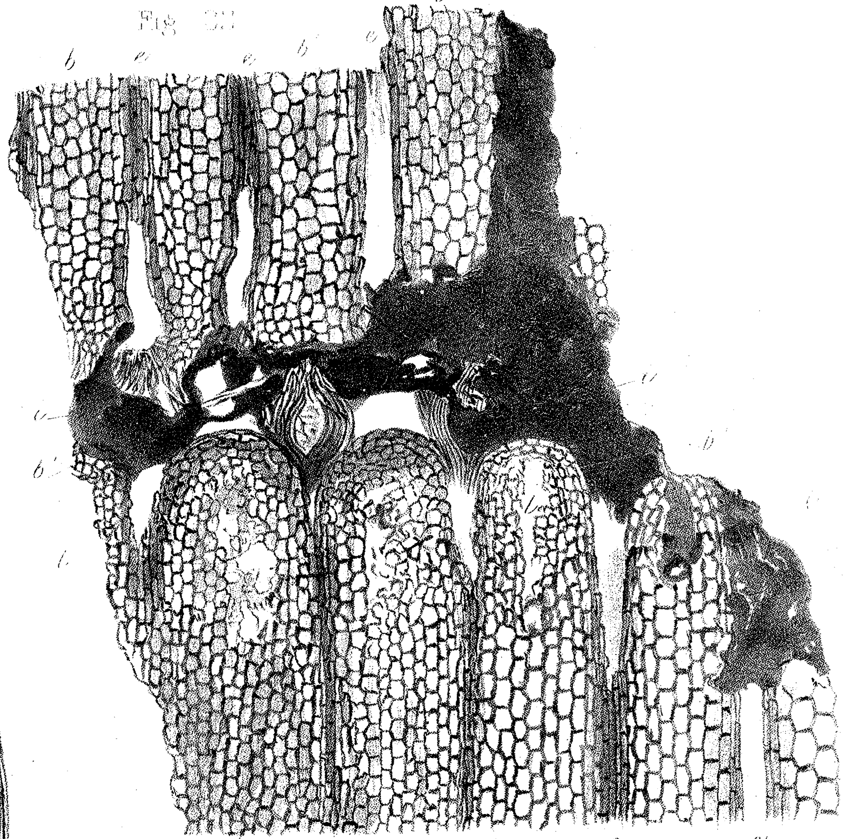
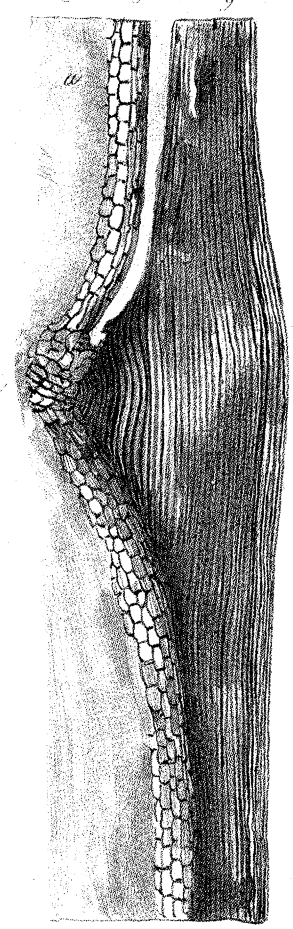


Fig. 23

Fig. 24



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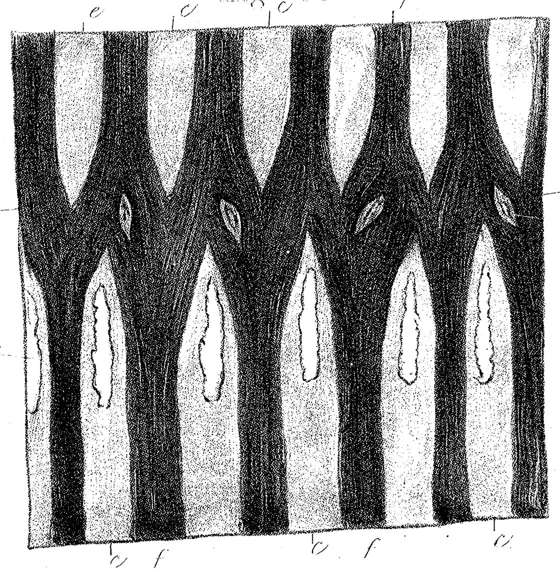

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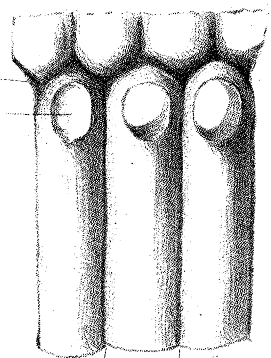

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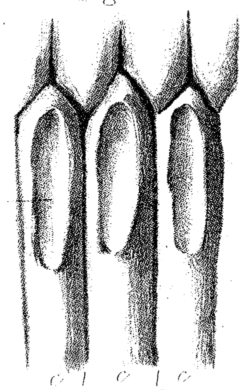

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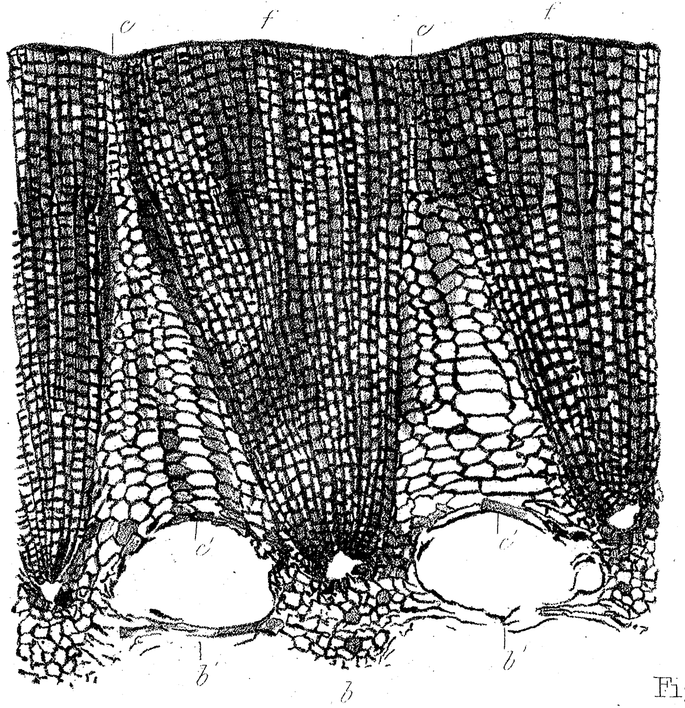
Fig 26



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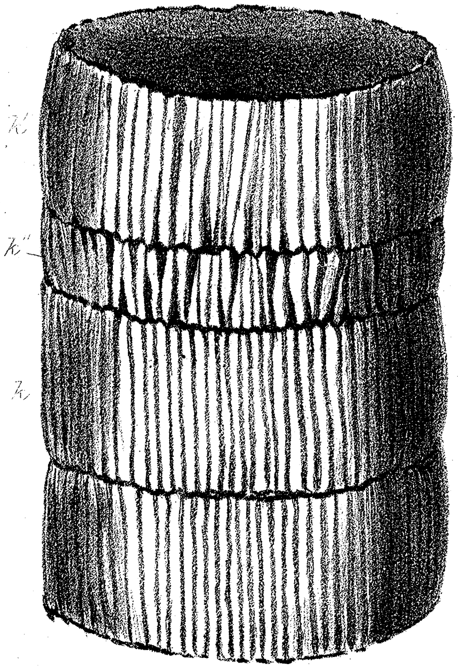

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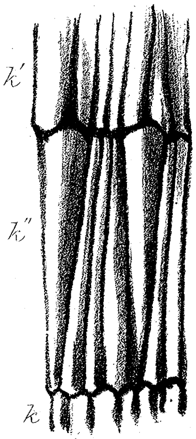

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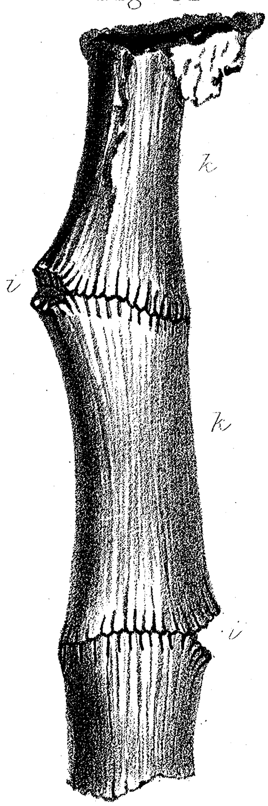

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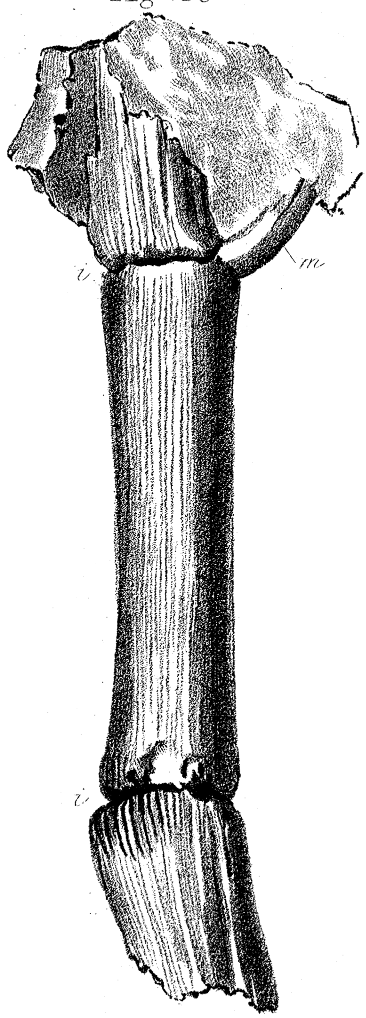

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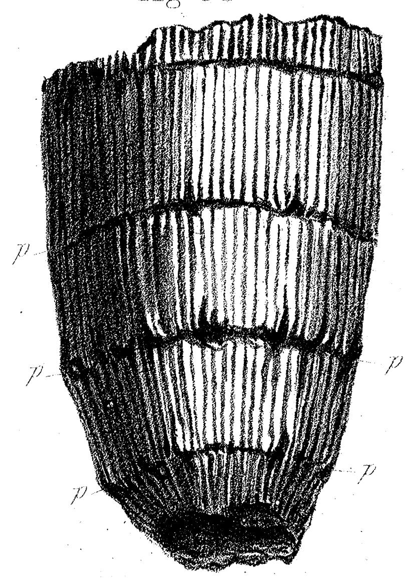

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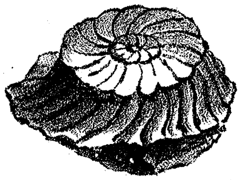

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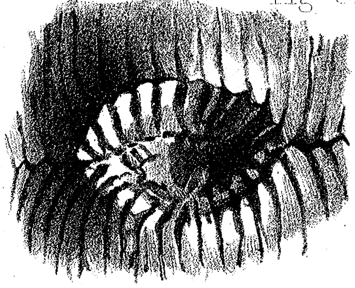

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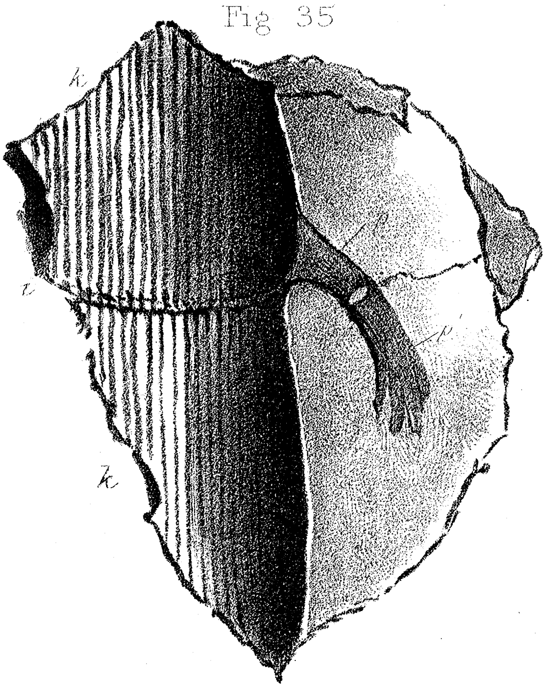
Fig 35



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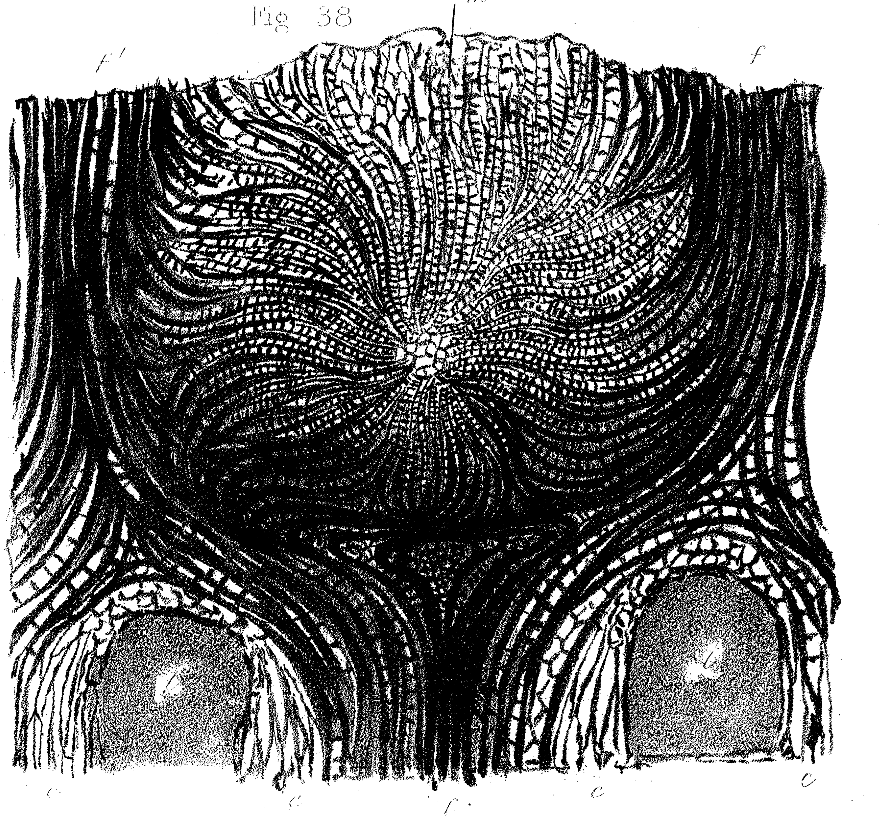

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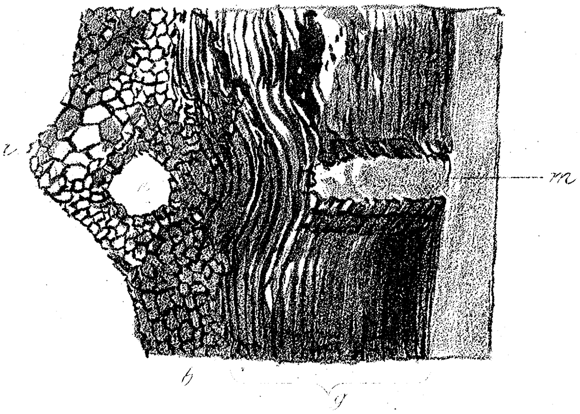

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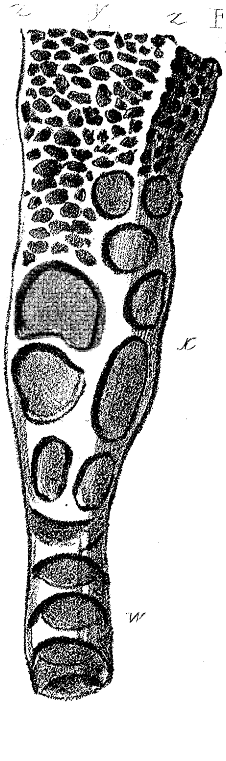

Fig 39

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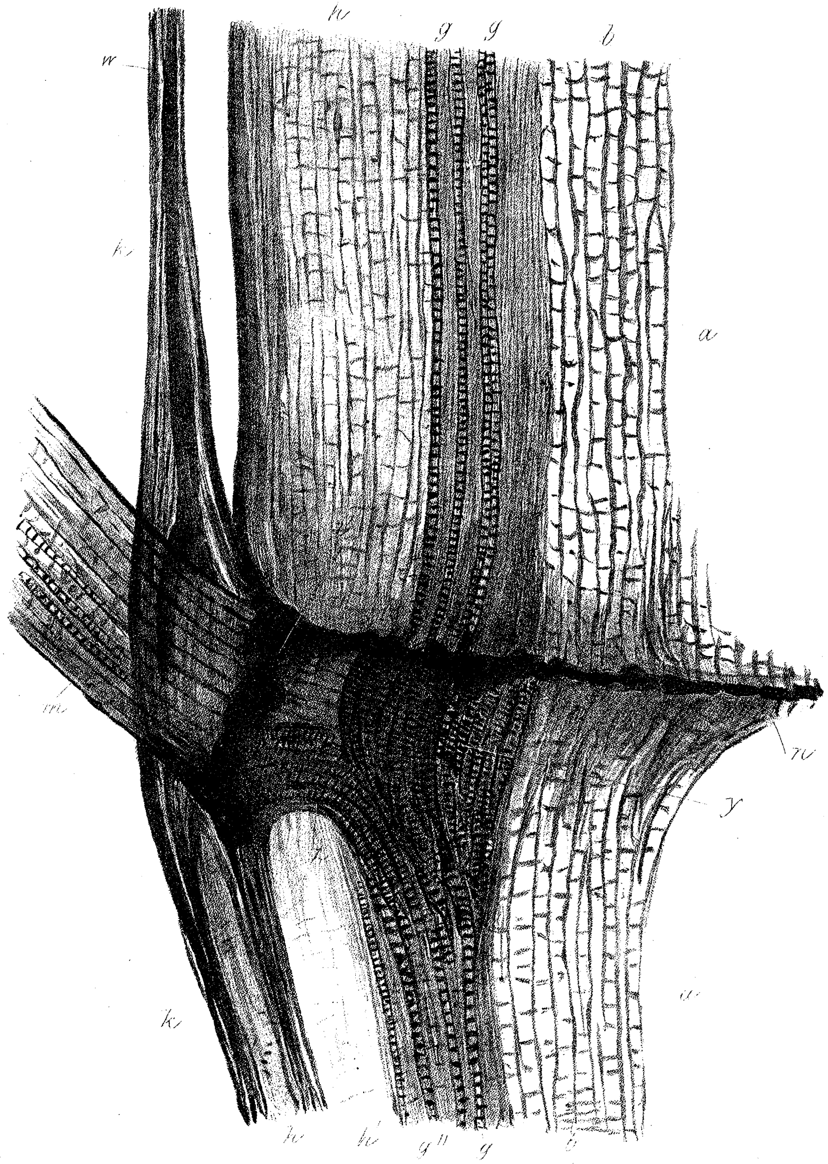
Fig 41.



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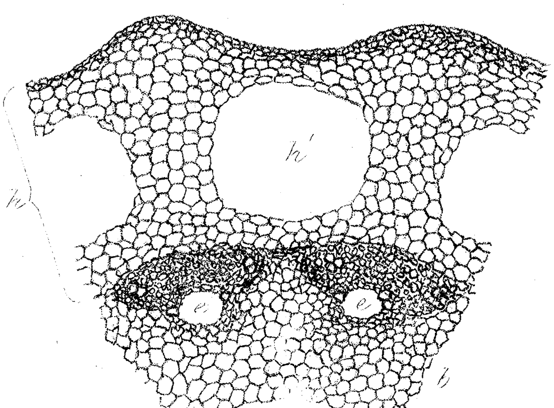

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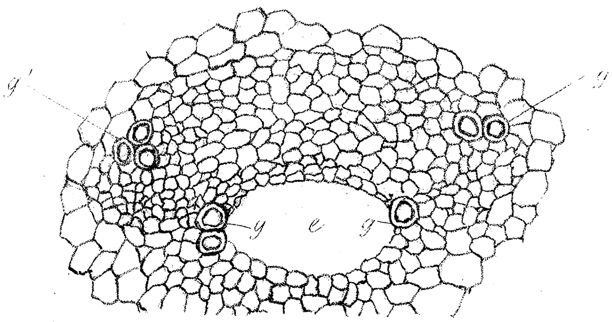

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