the radiation thermometer placed at the same height above the ground as the shaded maximum thermometer with which it is compared; but while freely exposed at all times to direct sunlight, it ought to be protected as much as possible from disturbing influences.

4. Solar-radiation observations made on a plan similar to that adopted at Oxford show that the calorific intensity of the sun's light continued to diminish during the years 1865–66, when the frequency of solar spots was also diminishing, thus giving additional weight to the probability that changes in the heating power of the sun's rays are intimately connected with variations in solar-spot frequency.

X. *On the Structure of the Woody Zone of an undescribed form of Calamite.* By W. C. Williamson, F.R.S., Professor of Natural History in Owens College, Manchester.

Read November 3rd, 1868.

Whilst engaged, some years ago, on an inquiry into the nature of the fossil coal-plants known as *Sternbergiæ*, my attention was arrested by some structures allied to those found in *Dadoxylon*, but occurring in some stems of Calamites. At the same time, the curious specimen represented in fig 1, of which a woodcut was published in the 5th edition of 'Lyell's Manual of Geology' (fig. 478), fell into my hands, and threw new light upon the nature of the small round cicatrices seen at the upper extremity of the longitudinal ridges of each node in many Calamodendra. These circumstances led me, in 1852, to prepare numerous sections of these plants from the specimen in my cabinet, represented in fig. 2, in which the structure was preserved; but as the example only contained the innermost portion of the woody zone, I put the subject aside for a season, in the hope of meeting with further illustrative specimens.

Recently my attention has again been called to the subject by a correspondence with M. Cyrille Grand-Eury, of St. Etienne, who has obtained forms of Calamite altogether different from mine. Other, apparently different, types are in the possession of M. Adolphe Brongniart, of M. Schimper, and of my friend Mr. Binney. It thus becomes probable that several distinct forms of Calamites exist, and that a large amount of combined labour will be required to elucidate their varied aspects. Hence, though my present researches have been chiefly directed to one portion of the structure of one type, it appears desirable that what I have ascertained respecting that type should be recorded for the benefit of others labouring in the same field.

The publication by Sir Charles Lyell of the figure referred to has elicited various opinions respecting the fossil represented. The conclusion at which I arrived was, that the central portion (*a*) was a cast of part of the pith from the base of the plant; that the verticils of radii (*b*), which I would term verticillate medullary *radii,* in contradistinction to medullary *rays,* were prolongations of the pith passing through the woody zone to connect the pith with the bark; that *c* represented the woody zone of the lowermost portion of the stem, whilst *d* represented the exterior of a single articulation of the outer, or cortical layer of the plant.

But several difficulties opposed themselves to this explanation. 1st. The supposition that any *Calamodendron* consisted of two Calamites, one within the other, the one representing the exterior of the pith, and the other the exterior of the bark, was novel, and unsupported by other testimony. 2nd. That the inner structure (*a*) and the outer articulation (*d*) could not belong to each other, since the former consisted of at least seven or eight internodes, or joints, whilst the outer structure (*d*) was a single joint. It was therefore supposed by some that the central portions (*a, b,* and *c*) represented the pith and ligneous zone of one Calamite, which had been accidentally introduced into the interior of the cast of another, when foreign arenaceous material replaced the original vegetable tissues.

In reply to these objections I would urge the following arguments :—That the central pith (*a*) is a true Calamite of the type of *C. Suckowii, Steinhauerii,* and others, is unmistakable; that the medullary radii and investing ligneous zone belong to this pith is equally obvious, both the latter facts being demonstrated by specimens to be described in the following pages. The only doubtful point is the relation which these inner structures bear to the supposed bark (*d, e*). Now, though the latter consists of one articulation of about two inches in length, it does not follow that it did not belong, like the central pith, to a portion near the *base* of the stem, because we well know how rapidly these nodes increase in size as we ascend from the basal one. The aspect of the woody layer (*c*) demonstrates that it has been prolonged considerably below the base of the pith, or, in a word, that the pith has *not* extended so far downwards as to reach the lowest articulations of the stem; as if, reasoning from living exogenous types, we might regard the latter portion as a pithless root rather than a true stem.

But even were these explanations not sufficient, there yet remains another. The specimen shows that the carbonaceous matter of the ligneous zone (*c*) has been preserved after the cellular structures of the medulla (*a*) and of the verticils of medullary radii (*b*) had been replaced by inorganic sand. I deem it possible that the latter change may have taken place before the woody substance of the supposed bark (*e*) disappeared and was similarly replaced. In this case the small portion of ligneous zone thus preserved at the base of the plant might have become slightly detached from its original position, and floated upwards into an internode occupying a higher position in the outer stem than those of which it was originally the centre. The specimen indicates that only about two inches of the lowermost portion of the woody zone had been thus preserved, the external lineaments of the pith and medullary radii having been preserved along with it. I presume that after the base of the plant became imbedded in the stratified sandstone, according to the fashion common amongst the coal-measure plants, the greater portion of the woody contents decayed and floated out, this fragment at its extreme base alone escaping the general decomposition, and being permanently fossilized*.

Which of the above explanations may prove the true one can only be determined by future discoveries; but that the Calamite-like medulla, with its verticils of medullary radii, belongs to the black ligneous zone surrounding it, I shall now proceed to demonstrate from the structure of the specimen represented in fig. 2. This drawing exhibits the appearance of the specimen previous to my cutting it up into sections. It will at once be recognized as consisting of portions of three internodes from the lower part of a stem; owing to the preservation of the innermost portion of the ligneous cylinder, the medullary cast, representing the common type of Calamite, is not seen in its usual form, the transverse constrictions of the latter being here replaced by a projecting mass of organized carbonaceous substance (*b*), whilst the longitudinal grooves usually furrowing the several internodes are represented by sharply defined

* My friend Mr. Binney, whose extensive experience of Calamites gives weight to his opinion, authorizes me to state that he entirely concurs in the above conclusions.

projecting ridges (*c*); these, which lose themselves in the nodes, are separated from each other by more depressed excavated grooves (*d*) corresponding with the elevated longitudinal ridges of the common Calamites. A slight microscopic examination demonstrates that these two features (*c* and *d*) owe their existence to two very different elementary tissues, arranged in vertical laminæ, or wedges, which radiate in alternating series from the medulla to the periphery of the woody zone. It will be remembered that in 1841, Unger, in a work of Petzholdt's ('Ueber Kalamiten- und Steinkohlen-Bildung,' Dresd. u. Leipz. 1841, Tabs. 7 and 8), called attention to a similar arrangement of tissues in the *Calamitea striata* of Cotta, in which one of the alternating structures consisted of *transversely barred fibres,* such as are seen in *Stigmaria,* traversed by medullary rays, and of intermediate tissues composed of smaller and more numerous woody fibres, each radiating series of which had one large central medullary ray. The general type just described resembles, in its broad outlines, what I find in my specimen; but in their minute details the two plants are different.

As already mentioned, the raised ridges and the intermediate depressions in fig. 2 consist of two very distinct structures, each of the former (*c*) being composed of numerous longitudinally disposed vessels of a reticulated type, whilst the latter consist of oblong prosenchymatous cells. In the transverse section, both these structures are seen arranged in the same manner, radiating in *equally regular* parallel lines from centre to circumference. I shall henceforth speak of these alternating structures as composing the *vascular* and the *prosenchymatous* tracts.

Fig. 3 represents a portion of a transverse section made in the centre of an internode, as at 2 *a,* the figure being almost limited to two of the vascular tracts and an intervening prosenchymatous one. As the crenulated outline marking the junction of the woody zone with the pith (fig. 3 *a*) indicates, the portions *c*, *c* radiate from two of the longitudinal furrows characteristic of an ordinary Calamite, whilst *d* corresponds with one of the intervening prominent ridges. The portion *c* consists of the transversely divided mouth of vessels, having a diameter of from $\frac{1}{600}$ to $\frac{1}{700}$ of an inch; they are arranged in from 20 to 25 regular rows, radiating from the pith (*a*) to the periphery of the woody zone. At their medullary extremity these rows of vessels combine to form a sharp woody wedge (*c*), which fits into one of the longitudinal grooves of an ordinary Calamite.

The appearance presented by these vessels when more highly magnified is seen in fig. 4, where portions of two tracts are represented. The walls of each tube do not appear to have been very thick; but it is difficult to determine exactly how much of the substance represents the original woody tissue, and how much is due to subsequent mineral infiltration. There is now no hollow cavity within each vessel.

The prosenchymatous cells forming the intermediate tracts (fig. 3 *d*) have a larger diameter than the cells, averaging about $\frac{1}{400}$ of an inch. They are also more symmetrically arranged in linear series; but in other respects their distribution resembles that of the vessels just described. They radiate from within outwards in from 30 to 35 regular lines. When more highly magnified (fig. 5), each cell appears to have thick walls, like those of recent woody fibre, which I at first believed these tissues to be; but I think that the appearance in question is due to mineral infiltration, and that the true walls of these cells were thin. It will be observed that, in this section, their regular radiating arrangement is that of the pleurenchyma or true woody fibre of coniferous stems, rather than that of ordinary cellular tissue, or parenchyma.

Fig. 6 represents part of a tangential section, the letters *c* and *d* being used to indicate the same parts as in the last figure. We here see that the vessels (fig. 3 *c*) run from one articulation or internode to the other, in the shape of elongated tubes, arranged like the fibres of living Conifers, and separated at intervals by numerous medullary rays (fig. 7 *e*) consisting of vertical layers of cells, arranged in single series. The surfaces of the vessels in this section often display no trace of structure; but here and there we obtained distinct evidence that their walls were strengthened internally by woody reticulations. The intermediate prosenchymatous tracts (fig. 6 *d*) consist, as already stated, of oblong cells (fig. 8) of fusiform shape, but which do not exhibit, *in this aspect*, the regular serial arrangement that is so conspicuous in the transverse section; medullary rays appear almost, if not wholly, absent from this part of the structure. In only two instances have I detected anything that could be mistaken for such a ray; and these were possibly nothing more than a few linearly arranged cells, shorter than the rest.

On making a vertical section of a vascular tract (figs. 2 and 3 *c*) in the plane of a medullary ray (fig. 9), we discover that the vessels (9 *c*) are still regularly arranged in parallel series; and, on applying a high magnifying-power, we find their surfaces to be covered with small reticulations, arranged in an irregular order (fig. 12), but usually with from three to four contiguous areolæ between the two sides of each vessel. These reticulated vessels very closely resemble those seen in some varieties of *Dadoxylon*. The reticulations have no central dot, consequently they must not (as Mr. Carruthers has already pointed out) be confounded with the disks of true glandular fibre. This section reveals the form and arrangement of the cells constituting the medullary rays (9 *e*). They have thin walls, and are arranged in a muriform manner; only the long axis of each cell is often vertical instead of horizontal as is common in living plants. In other respects they appear to be distributed as is usual amongst Coniferæ, strongly reminding us of their arrangement in the carboniferous genus *Dadoxylon.*

Thus far I have confined myself to a description of the woody zone in its undisturbed form, as it appears in the middle of the internodes; but at and in the neighbourhood of the nodes or articulations (fig. 2 *b*) a remarkable modification occurs. As is well known, each of these nodes is represented in the common type of Calamite by a circular transverse constriction; but in the living plant it was merely an indentation of the pith, occasioned by a projecting lenticular ring of woody tissue, of which the medullary margin was somewhat wavy, or projecting at points corresponding with the longitudinal grooves into a series of small irregular teeth.

Fig. 10 represents a vertical section of this structure, as seen under a very low magnifier, *a* indicating the pith, and *b* the woody lenticular ring.

Fig. 11 represents a more highly magnified view of one of the tooth-like projections from this ring, as seen in its horizontal section. The cellular clusters at its internal angles (*i*, *i*) probably belonged to the pith.

I have already called attention to the remarkable series of horizontal verticils of cylindrical prolongations of the pith seen in fig. 1. It is well known that in many fossil Calamites, at the uppermost part of each longitudinal ridge of the several joints there is a small round mark or cicatrix, to which various functions have been assigned. The example figured indicates that wherever such marks occur, the specimen bearing them is a pith, and that the marks are merely the points from which what I have termed the verticillate medullary radii spring. In nearly every specimen hitherto found these radii have disappeared along with the woody zone which they penetrated, the example figured being the only one of its kind that I have either seen or heard of during thirty years of association with the plants of the coal-measures. 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. As this function was amply performed by means of the medullary rays in the fibrous tracts, we must assume that the *radii* had in addition some undiscovered special functions of their own. On turning to the tangential section (fig. 6), we find that a radius (6 *f*) penetrates the centre of the upper extremity of each cellular tract (*d*), in which portion it will be remembered there are no true medullary rays—a circumstance which indicates that the prosenchymatous tracts are not merely prolongations of the pith, since true prolongations of the latter passing through them have retained their separate forms. Each radius is cylindrical, somewhat compressed laterally, and occasionally, but not often, rather triangular. In figs. 10 *f* and 17 *f* we see its position in reference to the node of the woody zone, having a mass of vascular tissue (*c*) above, and the prosenchymatous tissue (*d*) below it. A very limited portion of the latter tissue, peculiarly deflected, interposes between the upper surface of the radius and the remarkable articular or nodal arrangement of the vascular elements next to be described.

It must be remembered that the longitudinal grooves of Calamites usually alternate in contiguous joints or internodes, the elevated ridges of one joint being continuous

* My friend Mr. Carruthers has suggested that the scars left when these radii are broken off represent the openings of meshes in the woody tissue through which *vascular* bundles passed to whorls of leaves or branches produced at the nodes (Geol. Journal, July 1868, p. 332); but my specimens do not sustain this opinion for the reasons given in the text.

with the furrows of the adjoining ones, though occasionally no such alternation takes place. In the former case, one of the radiating vascular tracts would, if prolonged straight upwards through the node, run into a prosenchymatous tract of the joint above. In the exceptional instances, the vessels are prolonged through the node with little disturbance, and continued into the corresponding vascular tract of the next joint. In both cases the vessels of the various articulations are shown to be continuous. This alternation in the arrangement of the tracts causes peculiar modifications in the disposition of the vessels on crossing the node.

Three disturbing elements exist at the articulation,—1st, the verticillate medullary radii; 2nd, the verticils of vascular bundles; and, 3rd, the alternation of the tracts.

Fig. 13 represents a transverse section almost in the plane of the verticillate radii; exactly so on the left of the figure, but traversing their upper surface to its right: *a* represents the pith, *f* the several medullary radii, and *c* the woody wedges which separate the latter. In fig. 14 one of these wedges is shown more highly magnified. It consists of from 30 to 40 radiating series of vessels, arranged like the fibres of most recent Coniferæ; but at its two outer margins are a very few rows of larger structures (*d*), which we find to be sections of the outermost rows of prosenchymatous cells seen in fig. 3 *d*, some of which, as already shown in fig. 6, separate each medullary radius from the nearest vascular tracts. At its inner extremity each wedge is pointed, having its two sides slightly excavated; hence across the centre of fig. 13 we have a crenulated outline of the pith, readily recognized as representing a section of the exterior of an ordinary Calamite. At this point of the stem the regular arrangement of the vessels has undergone little disturbance, space for the passage of the medullary radii being obtained at the expense of the prosenchymatous cells. This is shown in figs. 6 and 15, in both of which a thin layer of cells is seen, both above and at each side of each radius (*f*). But the case is altogether altered in the plane above the radii corresponding with the centre of the node.

At this point the radiating vascular laminæ forming the wedges *c* in fig. 13 become detached from each other by the intrusion of cellular masses, as seen in fig. 16. Sometimes these cells are in a single row (16 *g*), when they are undistinguishable from the ordinary medullary rays; at others, as at 16 *h*, *h'*, we have unmistakable proof that they are identical with the fusiform cells of the prosenchymatous cellular tracts (fig. 6 *d*). It appears that at each node the fusiform cells and the muriform ones of the medullary rays become blended and undistinguishable from each other, a connexion being thus established between these tissues at each articulation, such as does not exist in the internodes.

It is almost impossible to describe or delineate the wonderful meanderings of the vessels as they ascend across the node. One object of their windings is their redistribution to the two nearest vascular tracts immediately above the node. Fig. 15 attempts a representation of this singular rearrangement, the same thing being partially shown in the upper part of the similar tangential section (fig. 6). The vessels of the vascular tract (15 *c*) diverge as they pass between the two medullary radii (*f*, *f*), to be redistributed to the vascular tracts (*c'*, *c'*), part going to the one and part to the other, whilst many are deflected hither and thither, as if unable to decide which course to take. Throughout all these serpent-like contortions we have abundantly displayed the arrangement represented in fig. 16. But the most remarkable feature connected with this redistribution is seen above the vascular tract (15 *c*), at the portion of the node immediately below the prosenchymatous tract (*d*) of the internode above. At this point we have appearances that vary in different examples. Sometimes, as in fig. 6 *d'*, we have a number of long sinuous vessels, converging at a central point, where we find a small cluster of similar but transversely divided ducts, with a few cells in its centre; at others, as in fig. 15, these *transversely divided* tubes occupy a much larger portion of the area, whilst their open orifices radiate in somewhat regular lines from the central point, which consists, as before, of a small cluster of transversely divided cells. Around the margin of this circular area, which closely resembles a transverse section of some coniferous branch, we again find the long vessels, bending away in the plane of the section, to contribute their respective shares to the two vascular tracts 15 *c'*, *c'*. A vertical section, made in the plane of a medullary ray, enables us to interpret these appearances. As the vessels of the vascular tracts approach a node, instead of following the outline of the pith, as in the rest of their course, they are suddenly deflected from it, bending outwards in parallel arched curves, but return to their original direction after passing the node. Mr. Binney found a similar arrangement in his *Calamodendron*. Fig. 17 is a diagram designed to explain these appearances. It represents a section somewhat like that shown in fig. 10; but in order to illustrate the relations of the several parts to the medullary radius, the diagram is made to represent an oblique section, passing from fig. 15 *f* on the left to *c'* on the right of the same figure. But the arched vessels (17 *c*) must be understood to pass downwards, *on each side* of the medullary radius (17 *f*), and not to terminate abruptly at the latter, as the diagram indicates.

But, in addition to these arching vessels, we have at the nodes numerous groups of divergent vessels (17 *e*), varying in diameter in different parts of the plant, which proceed directly outwards towards the bark. It is one of these groups, transversely divided, which produces the appearance of a transversely divided branch, seen in fig. 15. In the centre of the latter group the cells and vessels are divided at right angles to their longer axes, whilst the peripheral ones run in the plane of the section. I think there can be no doubt that this arrangement was destined to supply some external appendages of the main stem with vascular tissue. Whether these appendages were branches or leaves is doubtful; but I incline to the former opinion.

Mr. Binney has recorded somewhat analogous arrangements in his Tab. 3. fig. 4.

Before attempting to interpret the facts which I have described, a further glance at the discoveries of some other recent observers is necessary.

Nothing could be more unsatisfactory than the state of our knowledge of the internal structure of the stems of Calamites prior to the investigations of M. Unger; and valuable as those were, they only threw light upon one branch of the question. Guided by that light, M. Adolphe Brongniart suggested, in his 'Tableau des genres de Végétaux Fossiles'*, that two distinct groups of plants had hitherto been confounded under the name of Calamites. He proposed that these should henceforth be separated, retaining the old name for one section, which he regarded as allied to the *Equisetæ*, and employing the generic term *Calamodendron* for the other, which he thought ought to be ranged amongst the Gymnospermous Dicotyledons. The structure of the genus *Calamitea* of Cotta, as demonstrated by Unger, is regarded by M. Brongniart as typical of his *Calamodendron*. He describes this genus as exhibiting, amongst other features, a woody cylinder composed of large radiating vertical tracts of transversely barred vessels intermingled with true medullary rays, alternating with

* Dictionnaire Universelle d'Histoire Naturelle.

corresponding tracts, composed of masses of a peculiar form of woody fibre, with one large medullary ray in the centre of each tract.

My friend Mr. Binney has thrown further light upon this subject in his volume 'On the Structure of *Calamites* and *Calamodendron**', which only came into my hands after the previous pages had been written. Mr. Binney does not attempt to separate *Calamites* from *Calamodendron,* but contents himself with describing his specimens, which are of great interest. The woody cylinder of every one of them essentially resembles that examined by Unger, in consisting of radiating alternate tracts of barred or scalariform vessels, and of coarse cellular tissue. This copious development of scalariform vessels demonstrates that Mr. Binney's examples present the same type of organization as the *Calamitea* described by Unger.

Dr. Dawson, of Canada, detected in *Calamodendron* some traces of what he terms "wood-cells, with one row of large pores on each side"†. And in another part of his paper he again refers to them as tissues in which "the disks or pores are large and irregularly arranged, either in one row or several rows." Of course neither of these descriptions exactly agrees with the reticulated fibres of my plant; but as Dr. Dawson expressly associates his examples with the fibres seen in *Dadoxylon,* I conclude that he may have met with a *Calamodendron* of a type approaching nearer to my plant than to those of M. Unger and Mr. Binney.

Dr. Dawson has further illustrated this subject in the 2nd edition of his 'Acadian Geology,' where he figured

* Observations on the Structure of Fossil Plants found in the Carboniferous Strata, by E. W. Binney, F.R.S., F.G.S.—Part 1. Calamites and Calamodendron. London, printed for the Palæontographical Society, 1868.

† "On the conditions of the deposition of Coal, more especially as illustrated by the Coal-measures of Nova Scotia and New Brunswick," Quarterly Journal of the Geological Society, vol. xxii. 1866.

the tissues* referred to; but none of his figures correspond exactly with the vessels of my plant, fig. 163 E alone exhibiting an approach to a resemblance.

Be this as it may, we now have suggested to us the possible existence of three types of *Calamodendron,* in each of which the stem consists of woody wedges, disposed vertically around the pith from which their component laminæ radiate, and which are separated from one another by alternating vertical cellular masses either of parenchyma or prosenchyma, which latter connect the pith with the bark. But if the descriptions of Mr. Binney and Mr. Carruthers are correct and generally applicable, it is also obvious that, though constructed on a common plan, important differential characters separate two of the types from the third. In Mr. Binney's plants the woody wedges are exclusively composed of scalariform tissues, and appear to contain no true medullary rays. On this point Mr. Carruthers speaks strongly, and relies upon the fact as one evidence of the Cryptogamous character of these fossils†; and Mr. Binney does not appear to differ materially from Mr. Carruthers. He figures in his plate 3. fig. 6 what he terms "medullary (?) bundles;" but these are the representatives of my prosenchymatous tracts, and not of the muriform medullary rays.

The thick radiating cellular laminæ separating the woody wedges in Mr. Binney's specimens consist of ordinary parenchyma. In Unger's *Calamitea* the woody wedges consist, as in Mr. Binney's examples, of scalariform tissue (vaisseaux rayés); but these vessels are separated by " des rayons médullaires très-étroits, d'un seul rang de cellules, et peu étendus en hauteur" (Tableau des genres de Vé-

* *Loc. cit.* figs. 162 *c*, *d*, and 163 E.

† "On the Structure and Affinities of *Lepidodendron* and *Calamites*, by W. Carruthers, Esq., F.L.S." Seemann's Botanical Magazine, Dec. 1866; see also Journal of Botany, Dec. 1867, "On the Structure of the Fruit of *Calamites*."

gétaux Fossiles, &c., extrait du Dictionnaire Universelle d'Histoire Naturelle, 1849, p. 50), which obviously correspond to my true medullary rays. The intermediate cellular laminæ consist of what Brongniart terms "woody fibres" (fibres ligneuses), but which appear to be identical with my prosenchymatous tissue, each layer having in its centre what he terms one large medullary ray composed of two or three vertical rows of cells. In my plant the woody wedges are constructed, like Unger's *Calamitea,* of elongated vessels, separated by numerous medullary rays; only the vessels are reticulated instead of scalariform. The intermediate cellular tracts also appear to resemble Unger's, consisting, as I have shown, of a peculiar prosenchymatous tissue. I find here nothing like the central medullary ray of Unger; but instead of it we have the large verticillate medullary radius in the upper extremity of each prosenchymatous tract. Thus we learn that Unger's plant has the scalariform vessels of Mr. Binney's type, with the medullary rays of mine, and constitutes, in these respects, an intermediate link between the two.

The prosenchymatous tissue is of considerable interest on several grounds. When divided vertically, whether on the plane of the medullary rays or tangentially, the cells appear to be arranged in no special order beyond what we see in many compressed forms of parenchyma. But when we turn to the transverse section, we discover the regularly linear radiating arrangement which I have described, and which is so characteristic of vascular tissues, as well as of the pleurenchymatous elements of Gymnospermous Exogens. From their occupying the same position as the cellular laminæ of other *Calamodendra,* which are unquestionably prolongations of the pith, we might almost regard them as huge medullary rays. These, however, as we have seen, exist in addition to them. They so closely resemble, in their linear arrangement, the pleurenchyma of coniferous wood, that it is difficult to regard them otherwise than as an elementary form of simple pleurenchyma, or woody fibre. But it is their elongated shape, the obliquity of their overlapping extremities, and their radiating disposition in the transverse section which give them that character, and not the existence of ligneous deposits in their interior.

The conspicuous occurrence of these prosenchymatous cells in a Calamite acquires additional interest from the circumstance that they are identical with those already described by Mr. Binney, under the name of "elongated utricles," as occurring in *Sigillaria vascularis**. In that plant the outer of the two woody zones which the stem contains is entirely composed of this peculiar tissue; but physiologically the fact deserves notice that, as Mr. Binney points out, it gradually passes into the ordinary parenchyma of the inner part of the stem. I may further observe that small masses of the same tissue, also disposed towards an arrangement in radiating lines, constitutes the external ridges of the living *Equisetum limosum* and its allies. Longitudinal strips, torn from the epiderm of that plant and viewed from within, exhibit an alternate arrangement of longitudinal bands that strikingly resembles what we find in tangential sections of *Calamites*; only the long vascular tracts of the latter are wanting in the recent plant, their place being occupied by cellular tissue. May we regard this prosenchyma as a rudimentary form of pleurenchyma? Dr. Dawson refers to the same tissue under the name of "bast-tissue;" but this term is only appropriate to true pleurenchyma, and not to the more rudimentary type under consideration.

We may now inquire what are the true affinities of these various forms of *Calamites*? Schimper, Carruthers, and

* "A Description of some Fossil Plants, showing Structure, found in the Lower Coal-seams of Lancashire and Yorkshire, by E. W. Binney, Esq., F.R.S." Phil. Trans. 1865, p. 591.

Hooker are disposed to regard the type described by Binney and Unger as Equisetaceous. On the other hand, though M. Brongniart believes in an Equisetaceous form of Calamite, he does not regard the above examples as belonging to it. He considers that they are *Calamodendra,* which he places amongst the Gymnospermous Exogens. Are we yet in a position, in the face of these discrepant opinions, to arrive at a conclusion on the moot point? The importance now attached to the doctrine of evolution gives significance to the question, and renders an answer desirable.

The inferiority of the cellular to the vascular plants is obvious and admitted. When we ascend to the vascular Cryptogams, we find that they retain indications of their natural alliance with the cellular forms, in having the vascular elements largely intermingled with cellular ones; whilst in the Gymnospermous Exogens the purely cellular element is almost eliminated from their woody layers, being only represented there by the medullary rays. Viewed in this aspect, Mr. Binney's *Calamodendron* appears to approximate to the recent Acrogens, in whose stems cellular and prosenchymatous tissues are abundant, combined with vessels of a scalariform type, but which, so far as I know, exhibit neither reticulated vessels nor medullary rays. But when we ascend to the Gymnospermous Exogens, we find the cellular element disappearing, whilst vascular tissues present themselves, chiefly in a reticulated*, spiral, scalariform, or glandular form. In my plant, whilst we have abundance of muriform medullary rays, we have few if any transversely barred vessels; every duct of which the structure can be traced is distinctly reticulated, whilst the prosenchymatous cells, as we have seen, assume

* I may observe that a small form of reticulated pleurenchyma, apparently almost identical with the reticulated vessels of my plants, enters largely into the woody zone of the living *Araucaria imbricata.*

a pleurenchymatous arrangement and aspect; so that in all these respects my specimen approaches nearer to the Gymnospermous Exogens than to the Acrogens. In the *Sigillaria vascularis* described by Mr. Binney (Phil. Transactions, 1865), we find abundance of the identical form of prosenchyma seen in my Calamite, associated with cellular tissue, scalariform vessels, and muriform medullary rays; whilst in *Sigillaria Brownii,* according to Dr. Dawson, we have an inner cylinder of scalariform vessels surrounded by an outer one of true glandular fibre.

It is clear that all these plants exhibit, so far as their stems are concerned, indications of mutual affinity with Acrogenous Cryptogams on the one hand, and with Gymnospermous Exogens on the other. The prevalence of cellular and scalariform tissues points in the former direction, whilst the arrangement and apparently exogenous mode of growth, both of their vascular and prosenchymatous elements, are suggestive of the latter. This is especially the case with the Calamites, which seem to me to constitute a well-defined link, connecting the Exogens with the Acrogens.

But whilst it appears reasonable to locate the Calamites, as a whole, in the position just indicated, the minor differences which the several types seem to present suggest the necessity for some change in their generic grouping. I would therefore propose that, until the correctness or otherwise of Brongniart's opinion that there exists an Equisetiform class of Calamites is determined, we retain his two genera of *Calamites* and *Calamodendron.* The genus *Calamites* to embrace all the Equisetaceous forms, if any such really exist, whilst *Calamodendron* may comprehend the *Calamitea* of Unger, and possibly Mr. Binney's specimens, the genus being characterized by the prevalence of *scalariform* vessels and medullary rays, and by the absence of verticillate medullary radii.

In addition, I would suggest the establishment of the new genus *Calamopitus* (κάλαμος-πίτυς) for those forms in which the woody elements consist of *reticulated* vessels associated with medullary rays, and having verticils of medullary radii near the nodes*.

The exact value of these medullary radii, as indicative of a generic distinction, remains to be ascertained, as well as the extent to which they are associated with reticulated vessels. If it should be found that they occur in Calamites with scalariform vessels, or if Calamites having none but reticulated vessels exist without traces of verticillate medullary radii, then it may be necessary to abandon the the term *Calamopitus*, and associate the whole series as variable examples of Brongniart's genus *Calamodendron*. At present, however, we know that neither Binney's nor Unger's plants possess the verticillate radiating prolongations of the pith. They are also absent from silicified Calamites from Autun, of which M. Brongniart showed me fine specimens many years ago, and which, he now informs me, are identical with Mr. Binney's plants. Dr. Dawson says that true Calamites "can always be distinguished" [*i. e.* from piths of *Calamodendra*] "by the scars of the leaves or branchlets which are attached to the nodes." But my plants indicate precisely the opposite conclusion to this, viz. 1st, that such scars appear to

* I do not altogether like this arrangement, because I have the strongest doubts respecting the existence of an equisetiform type of Calamitea part from what Mr. Binney has described. I should have preferred applying the old generic name *Calamites* to Mr. Binney's plants, and assigning Brongniart's term *Calamodendron* to my own. But when an author founds a genus, he is entitled to define it, and M. Brongniart has distinctly identified *Calamodendron* with a vascular zone consisting of scalariform vessels and true medullary rays. The plan proposed presents the further difficulty that, if Mr. Binney's specimens are really deprived of medullary rays, that important characteristic feature will exclude them from *Calamodendron*, and involve the necessity for establishing an additional genus for their reception. But as I regard this as a doubtful point, I am not, at present, prepared to separate them from *Calamodendron*.

belong exclusively to medullary casts; and, 2nd, that they are *not* the scars of leaves or branchlets. I am confirmed in this conclusion by the fact that, though these scars are very distinct on those joints of the pith of the specimen represented in fig. 1, from which the verticillate medullary radii have been broken away, *they are wholly absent from the longitudinal ridges of the exterior of the specimen.* If, as I believe, mine is a correct interpretation of these scars, we must abandon the notion that they were due to internal vascular bundles, or that they were scars occasioned by the separation of external branches; and, as a consequence, the verticillate arrangement of the branches suggested in the restorations of Dr. Dawson will fail to be sustained, *so far as it rests upon the position of these scars,* though supported by other facts. Of the external appendages of my plant as yet I know nothing. Since the axes of the cones described by Mr. Binney are characterized by the presence of scalariform tissue, they must belong to his plant rather than to mine; and there seems no reason to doubt that some species of *Asterophyllites* also represent the foliage of the same. All that we know respecting the structure of my plant externally to the woody zone is suggested by fig. 1, where we have a very thick layer of sandstone surrounding the woody cylinder, and which must be regarded as representing an equally thick bark. Whether the longitudinal flutings of its exterior really indicate the outermost part of the bark, or whether this, in turn, has been invested by an epidermal layer, represented by the thin covering of coal with which such Calamites are frequently covered, has yet to be determined. Of its growth we know nothing beyond the fact that the plant has developed offshoots from the base of its central stem, as appears obvious from the common occurrence of stems the lower extremities of which exhibit a strongly marked lateral curvature.

I believe that the two specimens described are both from the upper coal-measures. Fig. 1 was found in a sandstone quarry near Oldham; and though I am doubtful respecting the precise locality whence fig. 2 was obtained, I believe that it came from near Peel. I have a similar specimen from the Peel Delf-rock, near Worsley, a sandstone belonging to the Upper Coal-measures.

Since reading the preceding memoir, I have had the advantage of studying a very beautiful and important series of sections of carboniferous plants, prepared and chiefly collected by Mr. J. Butterworth, of High Crompton, near Oldham. Amongst these are several instructive sections of Calamites. This valuable contribution to microscopic science requires me to modify one or two conclusions at which I had previously arrived, since the specimens render plain several points which were formerly obscure. Most of them correspond very closely with Mr. Binney's examples in having the vascular tracts composed of scalariform vessels. *But in one I can trace a decided transition from the scalariform to the reticulated type,* thus suggesting the possibility of a link between Mr. Binney's specimens and my own. Nor is this all; in other specimens I find the cellular tracts most variable in their structure. Sometimes the cells are elongated *transversely,* so that one long cell extends horizontally across the cellular tract, reaching from one vascular tract to another. In another example the reverse is the case; the cells are much elongated vertically, but have rectangular extremities. In *the same* tract these rectangular cells pass into the prosenchymatous type, in which the ends of the cells diagonally overlap each other; and yet in the same specimen are parts of corresponding tracts in which the cells are of the ordinary parenchymatous type seen in Mr. Binney's plants. But whilst on these points Mr. Butterworth's specimens exhibit so many features in common with Mr. Binney's, as in mine, the woody tracts are *all* provided with some medullary rays. This structure identifies these specimens with the Calamitea of Unger, and makes it more probable than before that a further study of Mr. Binney's fine examples will reveal medullary rays in them also. The only absolute and permanent distinction that still appears to separate my type of stem from the rest is the existence of the verticillate medullary radii, which are equally absent from all other described forms, but which alone I should scarcely regard as constituting a sufficient basis for a generic distinction.

But, as I shall presently show, there are other circumstances which justify the provisional retention of my genus *Calamopitus*. Mr. Butterworth's specimens accord in a remarkable degree with my description of the curious arched deflection of the barred vessels from the surface of the pith when passing the nodes, and also reveal traces of vascular bundles passing from the interior to the exterior of the woody zone at the same point, as indicated in my fig. 17; but this arrangement is much less complicated than in my examples. The vessels of each vascular tract ascend in a compact form until they reach the node; they then divide right and left to be distributed to the two contiguous vascular tracts above. Each bundle undergoes no change in doing so, beyond bulging out somewhat to admit of a large admixture of cells like those of the cellular tracts, returning immediately to the former compact arrangement as the diverging bundles enter their respective vascular tracts in the joint above. The specimens indicate that the exterior of the woody zone had a furrowed Calamite-like outline, the external ridges corresponding with the *vascular* tracts, whilst the depressions marked the external line of the *cellular* ones—an arrangement reversing that which these structures bear to the surface of the pith.

But Mr. Butterworth's collection has, in addition, furnished me with the cone of my plant. It has been of much larger dimensions than those described by Mr. Binney, as well as much more complex in its internal structure, and otherwise distinct; but that it belonged to my plant is shown by the reticulated vessels of its central axis, as well as by their curious arched arrangement when crossing the nodes—an arrangement to which I have already referred as constituting so remarkable a feature of the plant which I have described. From this axis there are given off at each node ten well-defined radiating peduncles, each of which divides into bract-like appendages, which bend first downwards, and then curve upwards and outwards, first sending upwards into the cone two sporangium-bearers. The sporangia have walls consisting of a single layer of oblong tabular cells; and their interior is filled with defined cellular tissue. Each spore seems to be a spherical body, consisting of two layers, exhibiting no trace of elaters or external appendages. I have but briefly indicated a few of the features of this beautiful cone, because its more minute and elaborate features demand that I should devote to it a separate memoir, which I hope to be able to lay before the Society at an early date. The peculiarities of this cone seem to justify the establishment of the genus *Calamopitus*.

All the additional facts which Mr. Butterworth's invaluable specimens have revealed confirm my previous conviction of the close affinity existing between the structure and growth of the woody wedges of my Calamite and corresponding wedges taken from the stems of some Dadoxylons. Of course this resemblance implies that in their growth these wedges have been exogenous, which is unquestionably true. So far I agree with the opinion always held by M. Adolphe Brongniart respecting the stems of his genus *Calamodendron*. But that distinguished botanist has further held that these plants were *Gymnospermous* Exogens, which of course involved reproduction by means of stamens and pistils; but this, as I have just shown, is not the case. The cone to which I have referred is unmistakably Cryptogamic in its type. The same remark applies to the cones described by Mr. Binney. The conclusion, therefore, at which I arrive is, that the Calamites constitute essentially *one* large group of plants, with some considerable range of variation in the details of their internal organization, but not more than exists in many well-defined family groups of living plants (as, for example, the Equisetaceæ), and that their stems were exogenous, so far as the woody cylinder was concerned, and closely related to those of the Dadoxylons. But, on the other hand, their fructification was Cryptogamic, but not necessarily Equisetiform, though not without some features of resemblance to that type of recent Cryptogams. Thus we have in the Calamite a combination that appears to have no living representative. Mr. Darwin may fairly point to these plants as indicating a generalized structure which at some later period became differentiated, through the Dadoxylons of the carboniferous rocks and the true *Equiseta* of the Oolites, into the modern types of Coniferous and Equisetiform plants. It must be remembered, however, that these Dadoxylons are not *all* true Conifers like the living types. We have not yet found in them (with one exception) the peculiar glandular disk, with its central spot, which occurs in all the modern Coniferæ, even in the Cycadeæ. Consequently these supposed Conifers themselves may ultimately be shown to constitute an additional connecting link between the ancient and modern types of gymnospermous vegetation. Every additional study of the older fossil plants, including those of the Oolitic age, makes plain the difficulty, if not the impossibility, of identifying them exactly with living types. Special organs may and do exhibit close resemblances; but the general combinations are frequently different. In this respect the recent Cycads retain something of the features of the more ancient vegetation. In their stems we find the scalariform and annular vessels of the Acrogens side by side with the gymnospermatous inflorescence and the Araucarian forms of glandular tissue linking them with Conifers, whilst in one aberrant genus (*Stangeria*) we have the stems and cones of Cycads combined with the foliage and nervures of a true Fern. The differentiation which has been so complete in other plants appears to have remained unaccomplished in the Cycadeæ.

Various attempts have been made to *restore* the Calamite, as well as the other plants of the Coal-measures; and though such attempts have been hitherto, and still are, premature, they are not altogether useless, since they mark the successive stages of progress towards truth. In the instance of the Calamites, we have especially the restorations of M. Deslongchamps (given in the 'World before the Deluge' of Louis Figuier) and those of Dr. Dawson (Acadian Geology, 2nd ed. p. 442). The former represents the plant as giving off from its central stem large bushy branches, like those of some modern Araucarias. To this idea the structure of the woody zone affords no support. If any *large* branches had sprung from the main stem, the structure of this zone would have shown unmistakable evidences of the fact in the lateral deflection of large masses of vascular tissue. But I see no evidence of such large deflections. We have deflections on a small scale; but the diameter of the largest and thickest of these divergent vascular bundles never exceeds the breadth of one of the longitudinal ribs of a Calamite; hence the vascular portions of these appendages must have been slender. At the same time I infer that they were something more than leaves, from the arrangement of the vessels of these bundles when seen in a transverse section; they exhibit, as is seen in fig. 17, the radiating arrangement of a woody twig, rather than what we should expect in vessels merely destined to supply a leaf. The only wonder is, that lateral appendages so freely supplied with vascular tissues should ever be deciduous, which those of the Calamites seem to have been, or we should frequently find them *in situ*, which has not yet been done. The difficulty is partially surmounted by the supposition that such small branches were jointed, and exceedingly slender, especially at their points of attachment to the stem; and we find such slender-jointed twigs in the Asterophyllites, to which so many observers have referred as probably constituting the branches and foliage of Calamites. With this decision I am strongly disposed to agree. For the above reasons I regard the restorations of Dr. Dawson as approaching nearer to the truth than those of M. Deslongchamps. But of course I differ from Dr. Dawson when he regards his restorations as representing an Equisetaceous type of plant distinct from *Calamodendron*.

During this investigation I have been forcibly impressed with the almost universal occurrence, within the interiors of other plants, of the cylindrical rootlets of *Stigmaria*; they appear to have penetrated every thing that was penetrable. They have forced their way most abundantly into the interior of the lax piths of Calamodendra, Lepidodendra, and Dadoxylons, often making the interpretation of sections of these plants difficult to the eye unfamiliar with the aspect of these ubiquitous rootlets. Their penetrating tendency has culminated in one of Mr. Butterworth's specimens, in which one rootlet has forced its way into the interior of another rootlet which only happened to be a size larger than itself.

EXPLANATION OF PLATES I.–V.

1. Specimen of Calamite from a Coal-measure Sandstone-Quarry near Oldham: *a*, lower end of the pith, consisting of seven or eight joints; *b*, two verticils of medullary prolongations, or "*verticillate medullary radii*," penetrating the ligneous zone *c*; *d*, single joint of a Calamite, enclosing the above; *e*, supposed bark, replaced by sandstone.
2. Exterior of specimen of Calamite in ironstone, as it existed before being cut up into microscopic sections: *a*, internodes; *b*, nodes; *c*, projecting wedges of reticulated vessels; *d*, intermediate tracts of fusiform cells, or prosenchyma; *f*, extremities of "*verticillate medullary radii*."
3. Transverse section through the centre of an internode: *a*, pith; *c*, *c*, two vascular laminæ; *c′*, *c′*, inner margins of the same laminæ, corresponding to longitudinal grooves of Calamite; *d*, a prosenchymatous lamina.
4. Transverse section of vessels of fig. 3 *c*, more highly magnified.
5. Transverse section of prosenchymatous cells of 3 *d*, more highly magnified: *a*, proper cell-wall; *b*, infiltrated mineral matter.
6. Tangential section of part of a node, and of the internode below, made transversely to the verticillate medullary radii: *c*, *c*, two vascular tracts; *d*, *d*, *d*, portions of three prosenchymatous tracts; *d′*, converging vessels near the base of a prosenchymatous lamina, supplying a lateral branch above the node; *d″*, corresponding part to *d′*, but not giving off a lateral branch; *f*, *f*, *f*, three transversely divided medullary radii.
7. Portion of fig. 6 *c*, more highly magnified: *e*, *e*, medullary rays, divided at a right angle to their course; *g*, *g*, elongated vessels.
8. Portion of prosenchymatous tract, fig. 6 *d*, with the fusiform cells more highly magnified.
9. Vertical section of a vascular tract, made in the plane of a medullary ray: *c*, reticulated vessels; *e*, cells of a medullary ray in their lateral aspect.
10. Vertical oblique section of a node, nearly in the plane of one of the medullary radii: *a*, pith; *b*, central internal projection of the node into the pith; *c*, vascular tract above the node; *d*, prosenchymatous tract below the node; *f*, medullary radius.
11. Transverse section of part of fig. 10 *c*, nearly in the plane of *b*, consisting of transversely divided vessels disposed in radiating lines: *i*, *i*, small groups of irregular prosenchymatous cells at each inner angle of the projection.
12. Two vessels of fig. 9 *c*, more highly magnified.

13. Transverse section in the plane of the verticillate medullary radii: *a*, pith; *c*, *c*, woody wedges; *f*, *f*, *f*, medullary radii.
14. Portion of fig. 13, more highly magnified: *a* pith; *c*, extremities of reticulated vessels; *d*, *d*, a few rows of prosenchymatous cells; *f*, *f*, two medullary radii.
15. Tangential section of part of a node, close to the pith: *c*, vascular tract below the node; *c′*, *c′*, two similar tracts above the node; *d*, lower extremity of a prosenchymatous tract above the node, with section of the vessels supplying a lateral branch; *d*, *d*, uppermost portions of two prosenchymatous tracts below the node; *f*, *f*, two transversely divided medullary radii.
16. Diverging vessels of fig. 15 *c*, more highly magnified: *g*, *g*, reticulated vessels; *h*, *h′*, transverse sections of intercalated prosenchymatous cells.
17. Diagram illustrating the apparent direction of the vessels in fig. 10: *a*, pith; *b*, node; *c*, vessels of vascular tract deflected into outward curves on crossing the node; *d*, prosenchymatous cells; *e*, vessels passing to the surface to supply a branch.

XI. *Some Remarks on Crystals containing Fluid.* By J. B. Dancer, F.R.A.S.

Read before the Microscopical and Natural-History Section, Dec. 2nd, 1867.

Mineralogists and most microscopists are aware that many years ago it was noticed that certain natural crystals contained fluid pent up in cavities in their interior; and in the year 1818 Sir David Brewster had his attention accidentally directed to this subject by the explosion of a crystal of topaz, which he had exposed to a red heat for the purpose of expelling its colouring-matter. The sudden expansion of the fluid imprisoned in the cavities of this specimen caused it to split into numerous fragments; and Sir David was then induced to investigate the nature of the fluid, the form of the cavities which contained it, and the arrangement of these cavities in reference to the crystalline form of the mineral.

It appears that Sir Humphry Davy was the first to