whole column of mercury is surrounded by the vapour. The high boiling-point is a further proof that this alcohol, as well as œnanthylic acid, is a normal compound.

We are now acquainted with the complete series of normal alcohols up to octyl alcohol. The following Table shows that the boiling-points in this series increase very regular for each increase of $CH_2$. The boiling-points which are here given have been determined, either by the whole column of the thermometer being immersed in the vapour, or, if this was not the case, the required corrections were applied :—

*Table of Normal Alcohols.*

| | Boiling-point. | Difference. | Observer. |
|---|---|---|---|
| Ethyl alcohol, $C_2H_6O$ . . | 78°·4 | ° — | Kopp. |
| Propyl alcohol, $C_3H_8O$ . . | 97–98 | 19 | Different observers. |
| Butyl alcohol, $C_4H_{10}O$ . . | 116·0 | 18·5 | Lieben and Rossi. |
| Pentyl alcohol, $C_5H_{12}O$ . . | 137·0 | 21 | Lieben and Rossi. |
| Hexyl alcohol, $C_6H_{14}O$ . . | 157·0 | 20 | Franchimont and Zincke. |
| Heptyl alcohol, $C_7H_{16}O$ . . | 175–177 | 19 | H. G. and C. S. |
| Octyl alcohol, $C_8H_{18}O$ . . | 196–197 | 20 | Renesse. |
| | Mean . . . . | 19·6 | |

## XI. "On the Organization of the Fossil Plants of the Coal-measures.—Part V. *Asterophyllites*." By W. C. Williamson, F.R.S., Professor of Natural History in Owens College, Manchester. Received May 17, 1873.

(Abstract.)

On two occasions the author directed attention, in the Proceedings of the Royal Society (vol. xx. pp. 95 & 435), to the structure of some stems which appeared to him to belong to the well-known genus *Asterophyllites*, briefly pointing out at the same time their apparent relations to a strobilus of which he had previously published figures and descriptions (Transactions of the Literary and Philosophical Society of Manchester, third series, vol. v. 1871) under the name of *Volkmannia Dawsoni*. In the present memoir he gives a detailed exposition of the various parts of the plant, including the roots, rootlets, stems, branches, leaves, and fruit, in different stages of their development. This is done chiefly in two modifications of the primary type—one from the Lower Coal-measures of Oldham in Lancashire, the other from those of Burntisland. In its youngest state, the Oldham form first appears as a mere twig, having a central fibro-vascular bundle enclosed in a double bark. The vascular bundle consists entirely of vessels which are chiefly, if not wholly, of the

reticulated type. When divided transversely, it presents a triangular section, the triangle having long narrow arms and very concave sides. The bark is already differentiated into two layers, and has its exterior deeply indented by three lateral grooves—one opposite to each concave side of the vascular triangle. The outer layer is prosenchymatous, with vertically elongated cells; the inner one consists of cylindrical parenchyma arranged in radial lines, the cells being also elongated vertically. As the plant grew, successive vascular layers were added exogenously to the exterior of the vascular axis. Each layer consisted of a single linear row of vessels, which were of large size opposite the concavities of the triangle, and small where they approached its several angles. The radial arrangement of those in the several growths was equally regular; they were disposed in single radiating series, new laminæ being intercalated peripherally as the stem grew. These radiating laminæ were separated by small medullary rays. Owing to the fact mentioned, that the laminæ radiating from the concave sides of the central triangle consisted of much larger vessels than those radiating from its angles, three or four such growths sufficed to convert its concave sides into slightly convex ones, whilst a few more such additions converted the vascular axis into a solid *cylindrical* rod. At this stage its transverse sections appeared definitely divided into six radiating areas—three of large open vessels radiating from the sides of the primary triangle, and three of small ones proceeding from the sides and extremities of the angles. When these growths have thus given a cylindrical form to the vascular axis, a change takes place in its further development. Concentric growths again begin to form, but in them all the vessels are of almost equally small diameters: hence the abrupt termination of the three areas of large vessels in the younger growths produces a distinct circular boundary line, marking a special stage in the genesis of the stem. From this point the additions go on uninterruptedly, the vessels of each radiating lamina or wedge increasing slowly in size from within outwards as the stem advances towards maturity. During these further developments the bark has continued to be separated into two well-defined forms. An inner layer consists of very delicate elongated cells with square ends (prismatic parenchyma); these are seen in the transverse section arranged in radiating lines proceeding from within outwards. The outer bark consists of narrow, elongated, prosenchymatous cells, having very thick walls; at intervals, corresponding with the spaces between the successive verticils of leaves in the ordinary examples of *Asterophyllites*, we find distinct nodes where the bark expands into lenticular disks. The vascular axis passes through these nodes without undergoing any visible change, either in the position of its vascular layers or in giving off vessels to the nodes or their appendages. The thin peripheral margin of each node sustains a verticil of the slender leaves of *Asterophyllites*, of which there are about twenty-six in each verticil. The aspect, dimensions, and arrangements of these

leaves correspond exactly with what is seen in the ordinary specimens found in the coal-shales. Transverse sections of them exhibit a single thick central midrib, but no traces of vascular tissues have hitherto been found in them.

The laminæ of the vascular axis are separated by numerous medullary rays of small size; these rarely exhibit more than four or five cells in any vertical series, and usually but one or two. The exterior of the bark is deeply indented in each internode by three very deep superficial grooves, each one of which occupies the side of the stem corresponding with a concavity of the central triangle of the vascular axis. These grooves, which are sometimes double instead of single, extend from node to node, but do not indent the nodal disks. Owing to the great depth to which these penetrate the bark, they give a very characteristic tripartite aspect to each transverse section of these stems.

The Burntisland type agrees with the Lancashire one in all its leading features of structure and growth; but its vessels are all barred instead of being reticulated, and the author has not met with such beautiful examples of its nodal disks as he has done in the case of the other form, neither has he seen its leaves attached. On the other hand, he has found specimens of much larger diameter than any that have hitherto been detected in Lancashire, exhibiting the characteristic peculiarities already referred to in an exquisitely beautiful manner. The author has also obtained one section from this locality in which a branch is given off. The vessels of this divergent organ are derived from the central portion of one of the segments of small vessels, seen in the transverse sections, which proceed from one of the angles of the central triangle.

Having elucidated the details of the aërial stems, the author proceeds to examine such organs of fructification as appear to belong to these plants, commencing with the *Volkmannia Dawsoni*, which he described at length in the Transactions of the Philosophical Society of Manchester in 1871. This is a verticillate strobilus with a central vascular axis, of which latter transverse sections exhibit a close correspondence with the triangular bundle of *Asterophyllites*, being also triangular, with concave sides and truncate angles. But in order to adapt this primary fibro-vascular bundle to the requirements of the fruit, each of the truncate angles is enlarged, so as to make the entire section an almost hexagonal one. This axis is surrounded, as in *Asterophyllites*, by a double bark—an outer prosenchymatous one, and an inner one of more delicate cellular structure. At each node this bark expands into a lenticular disk fringed with stiff narrow bracts, which extend upwards and outwards beyond the sporangia. The latter rest upon the bractiferous disks and the basal portions of the bracts, each verticil being fertile. The sporangia are closely packed in about three concentric circles, and attached by sporangiophores originating from each side of the base of each bract. The sporangia have cellular walls; they are full of large spores, each of

which has its surface prolonged into a number of very long radiating spines. This fruit the author unhesitatingly identifies with the aërial stems previously described.

He then examines various so-called *Volkmanniæ* found in the Lancashire Carboniferous shales, of which the internal structure is not preserved, but which, being found with leaves attached to them, admit of no doubt as to their belonging to *Asterophyllites*. These are regarded as being identical with *Volkmannia Dawsoni*; hence the author accepts the latter fruit as giving the internal organization of the ordinary Asterophyllitean strobilus. The fruit, which has been previously described by Binney, Carruthers, and Schimper, under the names of *Calamodendron commune*, *Volkmannia Binneyi*, and *Calamostachys Binneyana*, is then investigated. The above authors had associated it with *Calamites*; but its internal structure is shown to have nothing in common with that type; it consists of alternating verticils of barren and fertile appendages. The former are nodal disks bearing protective leaves; the others are verticils of sporangiophores, usually six in each verticil, and which closely resemble those of the recent Equisetaceæ; they project at right angles from the central axis, and expand at their outer extremities into shield-like disks, which sustain a circle of sporangia on the inner surface of each shield. The sporangia consist of a very peculiar modification of spiral cells; they are filled with spores which have been described as provided with elaters, like those of *Equisetum*; but the author rejects this interpretation, regarding the so-called elaters as merely the torn fragments of the ruptured mother cells in which the true spores have been developed. The vascular axis is shown to be *solid*, and without any cellular elements, being wholly different from that of *Calamites*, in which the vascular axis is a *hollow* cylinder containing an immensely large, cellular, and fistular pith. In one fine example of *Calamostachys Binneyana* the author has found the central fibro-vascular bundle surrounded by an exogenous ring. This, too, exhibits no resemblance whatever to the corresponding growths of *Calamites*; on the other hand, it corresponds closely with conditions occurring in some parts of *Asterophyllites*, with which group the author believes the fruit to be related, notwithstanding the peculiarity of its sporangia and sporangiophores. The author is confirmed in his conclusion that this fruit is not Calamitean by his having already described the structure of a true Calamitean strobilus, from an example in which the central axis retains most accurately the arrangements of tissues characteristic of Calamitean stems (Manchester Transactions, 1870). A type of stem to which the author had previously assigned the provisional generic name of *Amyelon* is now shown to be the root or subterranean axis of *Asterophyllites*, specimens being described in which clusters of rootlets are given off, in irregular order, from various points of the exterior of the branching roots. The latter have no medulla; but in the centres of several of them the author

finds the peculiar triangular fibro-vascular bundle so characteristic of *Asterophyllites*; and in all remains of the same trifid origin of the vascular layers may be traced in the peculiar curvatures assumed by the vascular laminæ as they proceed from within outwards. The bark consists of two layers: the inner one is composed of ordinary parenchymatous cells, often of considerable size; the outer one consists of irregular piles or columns of cells, disposed perpendicularly to the surface of the bark, and with their tangential septa in close contact and in parallel planes. The lateral or radial boundaries of these piles of cells are more strongly defined than the transverse septa. In tangential sections of this outer bark, each of these radially disposed columns of parallel-sided cells appears as a single thick-walled parenchymatous cell, whose aspect, in common with that of its neighbours, is that of ordinary coarse parenchyma. Such sections exhibit no indication of the radial elongation of these cells seen in radial and transverse ones. On reexamining the inner bark, we discover the explanation of these appearances. Many of the larger and more peripheral of the cells of the latter are seen to be undergoing division by the development within their walls of secondary cell-partitions, which are parallel with those of the radially disposed columns. It appears obvious that each of the latter was primarily one of the cells of the inner bark, which has become elongated radially, and at the same time divided into a linear series of compressed cells by the growth of a succession of secondary divisions, all of which were more or less tangential to the periphery of the stem.

The author directs special attention to the genetic activity of this inner bark; the cells of its inner surface were obviously instrumental in producing the successive circumferential additions to the primary vascular axis, whilst those of its outer surface increased the diameter of the outer bark in the way just described.

After comparing these plants with living forms, the conclusion is arrived at that the nearest parallel to the structure of their stems is to be found in *Psilotum triquetrum*; whilst their general affinities are regarded by the author as Lycopodiaceous rather than Equisetaceous. The exogenous aspect of their successive vascular growths is, if possible, more conspicuous than in most of the other Carboniferous Cryptogams.

The structure of the stems described is identical with that of those found at Autun by Prof. Renault, and assigned by him to *Sphenophyllum*; thus the close affinity of this genus with *Asterophyllites* appears to be finally established. The *Calamites verticillatus* of authors is probably the arborescent stem of one of these plants.