of a laminar expansion, the food-materials for sporangial development would not be manufactured locally, but brought from a distance. As the vascular bundles of the fertile pinnae are often decurrent in the petiole for some distance, there are grounds for supposing the reserves of the stem to be the source of the requisite substances. In the case under consideration these substances may have been present in the stem when the rudiment of the leaf was formed, but gradually destroyed in connexion with respiratory processes while the plant remained packed up and shorn of its leaves. Or perhaps only the supply of these materials to the developing leaf was prevented by the previous drying of some of the conducting tissues in the stem.

There is no need to try to explain the production of nothing but normal sterile leaves by the other rhizome. It may have previously produced no rudiments of fertile leaves, or none sufficiently far advanced to determine the form of the pinnae.

It should be pointed out that, although the production of an anomalous leaf immediately after the plant had been subjected to very unusual conditions may be a mere coincidence, a series of cultural experiments would probably decide the point, and might lead to very interesting results.

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THE VASCULAR STRUCTURE OF THE 'FLOWERS' OF THE GNETACEAE:—With a view to determining how much nearer, if at all, the vascular structure of the 'flowers' of the Gnetaceae approaches to the more primitive type of the Cycadaceae than do the vegetative parts of these plants, I made a careful examination of the axes and foliar members of the flowers of all three genera, with the following results.

The bracts (both those of the general inflorescence and individual flowers) exhibit practically the vascular structure of the foliage leaves of the same plant, viz. a collateral bundle with transfusion-tissue fairly well developed occurring in a lateral position. In the bract of the female inflorescence of *Ephedra distachya*, however, I distinctly observed a few tracheides of *centripetal xylem* on the ventral side of the bundle, and, as I have noted in other plants, there occurs more immediately in the *median* ventral position a second group of proto-xylem, although very slight in amount, belonging to the centripetal

xylem. Hence, there is found in the foliar organs of these female inflorescences what I regard as a relic of the more primitive structure of the older types of Coniferae and of the Cycads, and which is not found in the vegetative foliar organs of the plants concerned.

The male sporophylls (on the view which I prefer taking of them) of the three genera are constituted according to the *radially-symmetrical* type. In *Ephedra* they are grouped intimately together so as to form a single columnar structure bearing the pollen-sacs at the apex. In *Welwitschia* they are fused, at least at the base, three and three together, into two groups on opposite sides of the flower. In *Gnetum* two sporophylls are intimately united together to form, as in *Ephedra*, a single column. In accordance with the radial or cylindrical structure the vascular bundle of the sporophyll in all three genera consists of what I must regard as a reduced *concentric* structure of which only the few small, central, spiral tracheides, forming a circular group, remain, the phloëm being absent or quite undistinguishable from the surrounding parenchymatous tissue. In this structure of the sporophyll we find a primitive type, which has been lost in Coniferae and modern Cycads, but which occurs in the fossil genus *Bennettites*, as also in *Ginkgo*¹. It is remarkable that this ancient type of sporophyll, with its corresponding vascular structure, should have been preserved in the otherwise advanced group of the Gnetaceae.

In the peduncle and axis of the female 'cone' of *Welwitschia* a most interesting structure obtains. The bundles of the innermost ring or central cylinder, twenty-five or so in number, frequently have an *inverted* strand attached to their dorsal side; the same phenomenon precisely which I have observed in the peduncle of some Cycadean cones²; this inverted strand may sometimes be so fused laterally with the main strand as to form a concentric structure of which the phloëm occupies the centre. But the most remarkable part of the whole structure consists in the presence of a number (about twelve) of rather widely-separated strands which belong for the most part to the *concentric* type of structure, although in reality only some two or three, in any one transverse section, possess this structure in perfect form, the others being more or less curved or horse-shoe-shaped; or, again,

¹ Worsdell, 'The Affinities of the Mesozoic Fossil *Bennettites Gibsonianus* Carr.' Ann. Bot., December, 1900.

² The Vascular Structure of the Sporophylls of the Cycadaceae. Ann. Bot., vol. xii, 1898, Plate XVII, Figs. 2 and 4.

two or three bundles are approximated together with their xylems mutually directed towards each other, to produce what is really the same result, viz. a *concentric* strand; in fact, all the strands are variations of one and the same type of structure, viz. the *concentric*. The bundles mostly exhibit, like those of the central cylinder, an *inverted* portion on their dorsal side, and this latter in its turn may have a small normally-orientated strand in close proximity to its outer face. Bundles, usually of collateral structure, are seen here and there between the two rings: these are the connecting-strands between the central cylinder and the outer concentric bundles¹.

Fig. 10. *Welwitschia mirabilis*, Hk.—Part of transverse section of the stalk of the female inflorescence, showing the concentric strands of the second vascular cylinder, r^2 (Diagrammatic). r^1 , central cylinder. x , xylem, ph , phloem.

Here and there is a very small bundle, collateral in structure and with normal orientation, lying *within* the central cylinder in the pith.

Another striking part of the structure consists in the presence and enormous development of what I feel, although with some hesitation, inclined to regard as the representative of *centripetal xylem*; it occurs

¹ For similar strands connecting two cylinders see my paper: 'The Comparative Anatomy of certain species of *Encephalartos*,' Trans. Linn. Soc., vol. v, pt. 14, 1900, Fig. 2.

opposite the protoxylem of very many of the bundles of the central cylinder in the form of very small, lignified elements equalling in size the innermost primary tracheides of the bundles. In many places these small elements are seen to pass gradually over into larger and larger lignified cells which, in transverse section, are seen to be scattered on all sides, around the bundle and far out into the pith, as reticulate elements of the same shape as the adjacent parenchyma-cells. As seen in longitudinal section, the smallest of these presumably centripetal tracheides, viz. those nearest the protoxylem of the cylinder, are very faintly and indistinctly outlined as compared with the tracheides farther out in the pith, which fact points to their representing a tissue on the way towards becoming effete. It is true all these tracheides bear but little resemblance to the centripetal xylem known to us in other plants, for they possess *simple* pits, and thus in appearance suggest the idea of ordinary sclerotic cells; but the typical sclerotic cells of the plant occur side by side with them, and curious, slightly-lignified groups of fibres are also scattered throughout pith and cortex. Moreover, I can detect no difference between the character of the pitting of these elements and that of the secondary tracheides of the bundle itself; and further, the gradual transition existing between the much elongated, narrow elements adjoining the protoxylem of the cylinder, and the short, reticulate, parenchyma-like elements of the more distant region, is precisely the same phenomenon met with in the foliar bundles of Cycads and Coniferae which exhibit centripetal xylem, and is unlike anything we should expect to find in a system of sclerides. In fact, I conclude that we may have here, as in the similar instance of the stem of *Cephalotaxus* (*Podocarpus*) *koraiana* observed by Rothert¹, and the peduncle of *Stangeria*, &c.², a case in which the centripetal xylem of the bundles of the *axis*, instead of becoming, as in the great majority of cases, entirely suppressed and extinct, is retained either as a mechanical tissue or as a mechanical and conducting tissue combined; but the pitting of whose elements, in the case before us, has become modified, and which has become extended throughout the ground-tissue, as in the case of the centripetal xylem

¹ Rothert, W., 'Ueber parenchymatische Tracheiden und Harzgänge im Mark von *Cephalotaxus*-Arten.' Berichte d. deutsch. bot. Gesell., Bd. xvii, 1899.

² Scott, D. H., 'The Anatomical characters presented by the Peduncle of Cycadaceae.' Ann. Bot., vol. xi, 1897, Plate XX, Fig. 2, and Plate XXI, Figs. 8 and 9.

of Coniferae, a relic of an ancient, ancestral character. But I am still quite willing to admit that this view of the tissue concerned may be an erroneous one. The *quasi* centripetal xylem of the inverted strands permeates the cortex in the same way as does that of the central cylinder the pith.

But there is another interesting point exhibited by the primitive floral axis of *Welwitschia*. I recognize an ancestral type of structure in the presence of the concentric, or partially-concentric, strands outside the central cylinder. These strands are, however, as must necessarily follow from the fact that they eventually supply lateral axes, *primary* in origin; but I nevertheless regard them as homologous and comparable with the strands composing the second cylinder in the vegetative axes of four genera of Cycads and of *Welwitschia* itself, which are not primary but *secondary* in origin.

I do not myself consider it necessary, as regards the phylum of plants with which we are dealing, but, on the contrary, rather misleading, to lay much stress on the difference between primary and secondary structures; for the various cylinders, where they occur, all have, with the exception of the insignificant and often transitory protoxylem and protophloem of the former, exactly the same constitution and appearance. In fact, it seems to me that the *only* difference between them, and that an unimportant one, lies in the *varying periods* at which they are formed. *All* the cylinders, from the innermost primary one outward, must be homologous one with another. The phenomenon here exhibited by *Welwitschia* I believe, however, to be parallel with the case of *Medullosa Leuckarti*, Göpp. and Stenz.¹, in whose stem *two* primary cylinders have been described; with that of *Ceratozamia mexicana*, Brongn., and *C. latifolia*, Miq.², in the axes of whose male cones I have myself described what I believe to be the rudiment of an *intrafascicular* primary cylinder of bundles; and, finally, with that of *Encephalartos*³, the male and female cones of which exhibit in their axes *two* cylinders of *primary* bundles, the outermost of which supplies the sporophylls, and, in consequence, dwindles in the extent of its development towards the apex of the cone; in both *Welwitschia*

¹ Weber und Sterzel, 'Beiträge zur Kenntniss der Medulloseae,' p. 42, and Plate IV, Fig. 2, 1896.

² Worsdell, 'Contributions to the Comparative Anatomy of the Cycadaceae,' Trans. Linn. Soc., vol. vi, pt. 2, p. 117, and Plate XVI, Figs. 10 and 11, 1901.

³ Ibid., p. 116, and Plate XV, Figs. 7 and 9.

and *Encephalartos* the collaterally-constructed extrafascicular strands of the vegetative axis reappear in the more primitive axis of the cone as more or less concentrically-constructed strands. The explanation of the fact that the second cylinder of the cone is primary, while that of the vegetative axis is secondary in origin, may be found in the fact that in the former case the strands of the outer cylinder are formed quite early, and assume the function of supplying the sporophylls, whereas, in the latter case, it is the inner cylinder alone which, in the first instance, supplies the leaves, and which goes on developing in thickness for some time before the formation of a second cylinder is demanded, in order to assist in the general conductive function of the stem, and, like the subsequent cylinders, to take a part in supplying the leaves. The late period at which the second cylinder arises necessitates its earliest beginnings being inaugurated by a *cambium*; but this differing mode of origin cannot in the least affect the fact that this 'secondary' extrafascicular cylinder of the vegetative axis is directly homologous with the 'primary' extrafascicular cylinder of the peduncle of *Encephalartos*. Nevertheless, the possibility remains, which is not improbable, that this latter is equivalent to the innermost or primary cylinder of the vegetative stem of the same plant, and that the innermost cylinder of the peduncle represents an intrafascicular one, such as that existing in the cases above mentioned.

In *Welwitschia* and the other plants which exhibit it we may regard the concentric structure as having been retained in the second cylinder of strands, owing to the fact that there has been, in the region where they occur, less demand for a modification of the structure to suit the strengthening and other requirements of the plant, and it is just in those regions of the axis where, *a priori*, we should expect primitive ancestral characters to turn up that they actually do occur.

I am, of course, aware that the one or two extra rings of bundles found in the peduncle and axis of the cone, and which have been clearly figured by Strasburger¹ both for *Welwitschia* and *Gnetum* (to whose striking figure of the cone-axis of the former plant I would direct special attention), are of only local and thus transitory occurrence, for they are the strands supplying the flowers axillary to the bracts, and in the region of the axis above the uppermost flowers are

¹ Die Coniferen und Gnetaceen, Plate XX, Fig. 49 (*Welwitschia*); Plate XXI, Figs. 17-22, and 36-7 (*Gnetum*), 1872.

no longer present. For all that, I hold these transitory, incompact extrafascicular rings of bundles to be homologous with the more fixed and permanent extrafascicular rings of bundles in the vegetative axes both of this plant and of Cycads; the indefinite, strong, vegetative growth of the axes in the latter case being the cause of the greater fixity, compactness, and stronger development of the extrafascicular strands there occurring. The fact that the extrafascicular concentric strands of *Welwitschia* become all used up in supplying the flowers does not appear to me to affect the question of their homologies in the least; the collateral extrafascicular strands of the vegetative axes of Cycads are dependent for their existence on the presence of the foliage-leaves, and take a large part in supplying them with vascular tissue; and they are not present at the apex of the stem above the last incoming leaf-traces.

If the concentric strands composing the outer ring in the axis of the cone of *Welwitschia* do not represent a relic of the same ancient structure which prevails in the cauline organs of Cycads, what, I would ask, has induced the concentric structure of these strands to appear at all? why do we not find a ring of ordinary endarch strands such as compose the central cylinder? The arrangement and composition of these peculiar strands is far too irregular to admit of the possibility of their being governed solely by the structural symmetry or other characters of the floral axes which they supply; and, moreover, they do not pass obliquely outward to these axes as is the case with the steles supplying lateral branches in most axial organs, but form a constituent part of the vascular structure throughout the peduncle.

The small bundles occasionally found within the central cylinder may be the sole remnants of a third innermost cylinder of bundles.

In a peduncle of a female cone of *Gnetum* which I examined, essentially the same structure, as regards the presence of the medullary lignified tissue, is exhibited; but the second ring of strands is in this plant reduced to a small, incomplete concentric strand, or an arc-shaped row of strands, or a single endarch bundle lying, here and there, immediately outside one of the bundles of the central cylinder. The inverted strands are almost entirely absent.

The male cones present no striking features.

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