Contributions to the Life-History of *Callitris*.

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With Plates XLV and XLVI.

INTRODUCTION.

THE genus *Callitris* was incidentally referred to in two accounts of the life-history of *Widdringtonia* recently published by the writer (13, 16). The present study has been carried on conjointly with that of *Widdringtonia*, and, as was stated in the last published account of the latter genus (16), the facts there reported will be discussed in connexion with the corresponding phases in the life-history of *Callitris* in the present communication.

The methods employed are similar to those reported in the study of *Widdringtonia* (13) and need not be repeated here.

Callitris is an Australasian genus consisting of about a dozen closely allied species. So closely, in fact, do different species approximate that even with ample material it is no easy matter to discriminate between them. The material used has been collected entirely in the Government plantations in the neighbourhood of Cape Town, mainly in those at Tokai.

I desire to express my thanks to the following gentlemen who have assisted me in the collection of material, &c.:—

To Mr. J. J. Boocock for bringing material from the Tokai plantations on twelve occasions; to Mr. W. C. Worsdell, F.L.S., for collecting and fixing material for me on three occasions during a visit to the Tokai Forestry School; to Mr. G. A. Zahn for bringing material on two occasions from the Tokai plantations; to Mr. G. A. Wilmot, M.F., Forest officer in charge of the Tokai plantations, for giving me every facility for collecting material while staying at the Tokai Forestry School; to Mr. G. H. Ridley, curator of the Municipal Gardens, Cape Town, for germinating seed of *Callitris* and *Widdringtonia* for me in the municipal greenhouses.

Several species of *Callitris* have been examined from time to time. All are so much alike that it may safely be said that the following account would apply equally to any of these. That, however, which has been mainly studied is *Callitris verrucosa*, chiefly because it cones freely and contains a larger proportion of fertile ovules than most species. In a few cases material was fixed in the field, but more usually the cones were collected one afternoon, placed in moist packing material and fixed the following day, either morning or afternoon.

The preparations from such material proved quite as satisfactory as those from material fixed immediately.

DESCRIPTION.

1. *The Male Cone.* The sporophylls are arranged, like the leaves, in alternating whorls of three. Each sporophyll is peltate when mature, but when young the proximal part of the blade is curved inwards round the central sporangium (Pl. XLV, Fig. 1). A single vascular strand passes into each sporophyll and terminates a little beyond the large resin cavity. The wall of each sporangium (Fig. 2) consists of a single layer of cells; within this are two layers of tapetal cells probably formed by periclinal divisions in the sister-cells to those forming the wall. The mature sporangium closely resembles that of *Widdringtonia*, the output of spores being about the

P. 558, l. 21. For 500 read 5000 s, however, from that of *Widdringtonia* in bearing only three (rarely two or four) sporangia (Fig. 3).

2. *The Female Cone and the Ovule.* The young female 'cone' consists of six radiating sporophylls in two whorls. Each scale of the upper whorl bears about fifteen ovules. The scales of the lower whorl are considerably smaller, as a rule, and each bears about five ovules. Thus the total number of ovules in a cone is about sixty. The ovules are situated on the proximal part of the upper surface and close to the median ridge. Ovules prior to pollination have not been seen. The micropyle closing cells, like those of *Widdringtonia*, remain non-septate. The micropyle is more widely spreading than in *Widdringtonia*, as shown in Fig. 4, and its wall is either one or two cells wide, whereas that of *Widdringtonia* is three cells wide. A whole ovule in longitudinal section has the structure indicated in Fig. 4. (The asymmetric appearance of the section is due to it being nearly in the plane of the wings.)

Pollen tubes may be seen in the nucellus at this stage but have not been indicated in the figure. The position of the sporogenous tissue is shown.

3. *Megasporogenesis.* Only a very small number of megaspore mother-cells are found (one to three) and they lie about half-way down the nucellus (Fig. 4). Their structure is shown in Fig. 5. They are sharply differen-

tiated from the surrounding cells of the nucellus, having large and lightly staining nuclei and dense cytoplasm, while those of the nucellus have smaller, deeply staining nuclei and less dense cytoplasm.

Only a very limited number of preparations show at all clearly the stages following this. Neither of the reducing divisions has been seen. Fig. 6 indicates that the upper of the two megaspore mother-cells may develop, but as this represented the only preparation in which the point could be definitely ascertained, it is impossible to say if there is any constancy in the position of the functional mother-cell. This figure also shows that of a row of four megaspores the second from the top became functional. Other preparations indicate considerable variation in this respect (see Figs. 8 and 10).

A considerable proportion of ovules become abortive while quite young. The structure of the nucellus of such an ovule is shown in Fig. 7, about the same age as the normal ovule shown in Fig. 8. No pollen-tube is found and all the central tissue of the nucellus is made up of very large cells with scanty cytoplasm.

4. *The Female Gametophyte.* The general structure of the nucellus after the first division of the megaspore nucleus is shown in Fig. 8. In this case traces of sterile megaspores can be seen above but not below the prothallus; i. e. the lowest of the row of megaspores has become functional. The relative size of the pollen-tube is shown in the tip of the nucellus.

Instances are occasionally met with where more than one megaspore begins to develop. Such a case is drawn in Fig. 9. The upper embryo-sac here contains two nuclei, the lower contains four.

It could not be definitely ascertained whether these two megaspores developed from the same or different megaspore mother-cells.

The next figure (10) shows a somewhat older sac, containing sixteen nuclei. In this case the three sterile megaspores are below the embryo-sac, and it must therefore have been the uppermost which became functional.

At this time and throughout the development of the prothallus, the absence of any kind of tapetal layer is a noteworthy feature. Physiologically its place is possibly taken by the basal part of the nucellus, the cells of which are always densely packed with contents; growth of the nucellus takes place mainly in this basal part, as is indicated in Fig. 11. This represents the structure of the nucellus at a time when 128 nuclei are found in the prothallus. The basal meristematic tissue is shaded. It consists at this time of a number of exceedingly regular rows of tabular cells, somewhat resembling the 'Pavement tissue' in *Gnetum Gnemon* recently described by Coulter (4). The upper part of this tissue is absorbed later as the chalazal end of the sac penetrates more deeply into the base of the nucellus, but its basal part persists. As far as the species available to the writer are concerned this has proved a constant character. Cell-formation in the pro-

thallus of *Callitris* has not been seen, but doubtless takes place in the normal manner.

The archegonia are formed in a single group abutting on the side of the pollen-tube (Fig. 12), except where two pollen-tubes are present, when two such groups are organized. No other archegonia, not in contact with the pollen-tube, are found. The number of archegonia in a group is usually about seventeen to twenty. The archegonia are considerably smaller than those of *Widdringtonia*, but probably their development is the same. The neck soon disappears, and the adjacent part of the pollen-tube breaks down, so that the contents of the archegonium are freely exposed to those of the tube (Fig. 13). The oosphere nucleus has one, or sometimes two, large hollow nucleoli, and is situated near the base of the archegonium, no vacuole being present as a rule. Occasionally an aster-like structure is evident near the top of the archegonium (Fig. 13). This may possibly represent the remains of the ventral canal nucleus.

5. *The Male Gametophyte.* Some of the microspore mother-cells, probably shortly before division, are shown in Fig. 14. Unfortunately stages to illustrate microsporogenesis have been missed. The wall of the mother-cell is rather thick, and between this and the central nucleus is a space packed with starch grains (Fig. 14). The wall of the mature pollen grain is, however, much thicker than that of the mother-cell. As far as has been seen, the microspore nucleus does not divide before the spores are shed; this point has been investigated in *C. verrucosa* and *C. robusta*. It is not very easy to make out the structure of the mature grain owing to the thick hard wall, which is difficult to penetrate and to cut, but in the thousands of spores examined not one has appeared to contain a second nucleus.

This does not agree with the statement made by Coker (3) that two nuclei are present at the time of shedding in a species of *Callitris*, but no statement is made by him as to which species was the subject of investigation.

I have found it impossible at present to follow the early development of the pollen-tube. The nucellar beak seems to offer great resistance to the microtome knife, and it is comparatively seldom that a clear view even of the tube itself is obtained, much less of the contents. Later stages, after the cutting-off of the two sterile nuclei, are quite easy to follow. These two nuclei are invariably equal in size and staining-capacity and are usually abreast of one another in the tube (Fig. 15), so that it is impossible to distinguish between 'tube' and 'stalk' nuclei. They are always to be seen in the tube and do not tend to disappear as they do in *Widdringtonia*. When the male cells are formed, starch grains are found in the tube, contrary to what is the case in *Widdringtonia*.

The two male cells have very dense cytoplasm with a distinct limiting membrane or wall and a large central nucleus, with a single large, hollow or reticulate nucleolus (Fig. 16). In this figure the two sterile nuclei are quite

distinct, and, in addition, a large nucleus of quite a different character is present. This must represent some abnormal structure.

6. *Fertilization and Embryogeny.* Only one preparation has been obtained which undoubtedly shows the sexual nuclei in contact in two adjacent archegonia. (These are the lowest but one, and the lowest but two of the group of archegonia in Fig. 12.) One of these is shown in detail in Fig. 17. The structure of the two nuclei is exactly identical, each containing a large reticulate nucleolus. This figure closely resembles Lawson's (7) fig. 29 of *Thuja*, but in the present case a number of plasmic fibres may be seen radiating from the outside of both nuclei. These are a conspicuous feature in both the fertilized archegonia, although nothing of the kind has been described in similar stages of other Conifers. The male nucleus is also relatively larger here than in Lawson's figure cited above.

The cytoplasm is denser and more homogeneous towards the apex of the archegonium, probably due to the presence of the cytoplasm of the male cell. No starch can be seen in the archegonium. A comparison of Figures 13 (archegonium), 16 (male cells), and 17¹ (fertilization) will show that the size of male and female nuclei before fertilization is almost precisely identical, but the male nucleus seems to become a little smaller inside the archegonium.

Early stages of the proembryo are wanting. The mature proembryo, like that of *Widdringtonia*, completely fills the archegonium. The arrangement of the cells shows considerable variation. Two mature proembryos are shown in Fig. 18 in median longitudinal section, and another in tangential section in Fig. 19. More than eight cells are present in a mature proembryo.

A dividing nucleus from a mature proembryo is drawn in Fig. 20 (not all chromosomes shown). The large spindle and short chromosomes are in striking contrast to the much shorter spindle and long chromosomes of the divisions in the prothallus cells (Fig. 21, not all chromosomes shown). The latter are frequent at this time, giving rise to the typical bi- and multinucleate cells of the mature prothallus. In a former paper (13) the opinion was expressed that the number of chromosomes in gametophyte and sporophyte respectively were in the neighbourhood of 12 and 24. I am now convinced that the numbers are somewhat less than that, the thickness of the chromosomes tending to make the number appear more than is actually the case, and the estimation difficult. For the same reason it is impossible to represent more than a few of the chromosomes in a drawing. The numbers are probably nearer 10 and 20 or perhaps 8 and 16.

In the same paper (13) a comparison was provisionally suggested between the multinucleate prothallus cells of *Widdringtonia* and *Callitris*

¹ Figure 13 is drawn on a considerably larger scale than 16 and 17.

and those of *Welwitschia*. The origin of the latter has now been definitely ascertained (Pearson (11)), and is so radically different from that of the same cells in the former genera that any comparison between them must be abandoned.

It is certain that at least three separate embryos are derived from a single proembryo. From the material examined it has not been possible to determine precisely how this takes place, but it seems likely that the whole proembryo is inclined to partially separate into groups of two or three cells, of which the smallest becomes the embryo initial and a larger one the single suspensor cell. Indications of such a state of affairs are seen in the upper proembryo of Fig. 18, and especially in Fig. 22, which shows part of a proembryo in longitudinal section, in which two such groups, of three cells each, seem clearly indicated. It is merely suggested that this is what happens. The evidence is by no means conclusive. The next stage seen shows a tortuous mass of thick-walled suspensors below the crushed remains of the archegonia, the free ends of which protrude in all directions from this mass (except immediately above, and especially below). About a dozen of these embryos may be found in a single ovule. Since more than two pollen-tubes never reach maturity (usually only one) it is only possible for four archegonia to be fertilized. In confirmation of this inference (if any were required) four is the maximum number of proembryos found in an ovule. Hence the presence of a dozen or so embryos in an ovule proves conclusively that at least three must be formed from a single proembryo, as stated above.

The free tip of one of these conspicuous suspensors, bearing a four-celled embryo, is drawn in Fig. 23. The first two divisions of the embryo cell are constantly vertical, giving rise to a single tier of four cells. This is exactly the opposite to what occurs in *Pinus*, where the first division is always (?), and the second nearly always, transverse, but it agrees with *Sequoia*, as described by Arnoldi (1).

The next division in each cell is transverse, giving two tiers of four cells each. In its further development, which has been followed fairly closely, the embryo agrees essentially with that of *Pinus*, as recently described by the writer (14). The meristem which gives rise to embryonal tubes, root-cap, and periblem, appears perhaps a little earlier than in *Pinus*. The region traversed by the suspensors is also relatively shorter than in other conifers, this being probably a necessary consequence of the position of the archegonia. The part of the prothallus above the archegonia develops no further, and in advanced stages of the embryo very little can be seen of it.

Fig. 1, Pl. XLVI shows an embryo shortly after the differentiation of the cotyledons. The region in which starch is present is clearly shown. Fig. 24 is a drawing of a few cells just on the boundary line of the starch-containing

region, showing the persistently multinucleate cells of the prothallus. This character can be clearly seen in the photograph from which Fig. 1, Pl. XLVI is reproduced, but is not likely to be apparent in a half-tone reproduction.

The mature embryo has invariably been found to possess two cotyledons. The germination is of the same type as in *Widdringtonia*, but the seedling is very much more slender than in that genus. The succession of plumular leaves is also the same in the two genera; that of *Callitris* is shown in Fig. 2, Pl. XLVI.

7. *Abnormalities.* One case has already been mentioned where a supernumerary nucleus was present in the mature pollen-tube (Fig. 16), but the case shown in Fig. 25 is still more remarkable. Here the dilated tip of the pollen tube has put out a slender tube below, suggestive of a haustorial function, and in the swollen part are found five nuclei, all practically alike in size and structure. In the prothallus, surrounding the enlarged part of the tube, are a considerable number of archegonium initials.

Fig. 3, Pl. XLVI represents a prothallus which is only abnormal in the fact that no pollen-tube has yet penetrated it, and yet cell-division is complete and archegonium initials have appeared. The latter are clearly seen to be endogenous in origin. This figure will be referred to again later.

8. *Discussion and Conclusions.* As was stated above (p. 557) this discussion and the conclusions arrived at are based partly on the facts here reported, and partly on the corresponding facts in the life-history of *Widdringtonia*, as recently described by the writer.

The main conclusion reached from these studies is that *Callitris* and *Widdringtonia* must be placed in a tribe apart from those Cupressineae which have been fully investigated, and no longer included as a sub-tribe of Cupressineae.

Masters (8) has already separated these two genera together with *Tetraclinis* and *Actinostrobus* as the sub-tribe Callitrineae, but has included them in the tribe Cupressineae. Most other authors (e. g. Rendle (12)) have not recognized even the subtribal distinction.

The writer suggests that the Callitrineae as defined by Masters (loc. cit.) should be raised to the rank of a tribe, co-ordinate with the Cupressineae, although the inclusion of *Tetraclinis* and *Actinostrobus* must be merely provisional until their life-histories have been worked out.

It is hoped that at a future date material of these genera may be available for investigation in order to ascertain whether or not their life-history does conform to that of *Callitris* and *Widdringtonia*.

In Table I, showing the chief differences between the Callitrineae and the Cupressineae, it has been assumed that certain points only definitely ascertained for one genus will be found to hold good for both. It may be pointed out that where this is done (fertilization and post-fertilization stages) there is considerable evidence that the two genera will be found to agree,

but, the series not having been very close in either case, some stages are missing in the one genus which are present in the other and vice versa.

TABLE I.

<i>Organ or Stage.</i>	<i>Callitrineae.</i>	<i>Cupressineae.</i>
Female cone.	All cone scales fertile.	Some cone scales sterile.
Ovule.	<i>Widdringtonia</i> : many megaspore mother-cells. <i>Callitris</i> : very few megaspore mother-cells.	Very few megaspore mother-cells.
Prothallus.	Cells eventually bi- and multi-nucleate.	Cells finally uni-nucleate. Temporarily bi-nucleate in <i>Cryptomeria</i> . ¹
Archegonia.	Never situated at apex of prothallus. Number may be under 20 (<i>Callitris</i>) or over 100 (<i>Widdringtonia</i>).	Always situated at apex of prothallus. Number usually few (6-12). Rarely up to 20 or 30.
Jacket cells.	Seldom recognizable.	Usually well marked.
Fertilization.	Male and female nuclei almost identical in size.	Male nucleus smaller than female.
Proembryo.	Not more than five, possibly only two, free nuclei before wall-formation. Proembryo fills archegonium.	Eight free nuclei before wall-formation. Proembryo never fills archegonium.
Embryo.	Three or four from single proembryo.	One from each proembryo.

Of these differences the position of the archegonia and the development of the proembryo seem most important, while the bi- and multinucleate prothallus cells of Callitrineae also constitute an interesting feature. In a recent paper, Coulter (5), referring to the position of the archegonia in *Sequoia* as reported by Lawson (6), and in *Widdringtonia* as found by the writer (13), considers the point of only secondary importance on account of the fact that it is correlated with the position of the pollen-tube, but it seems scarcely reasonable to conclude that because two unusual features are correlated with one another, therefore they are of little importance. Moreover, it has been shown in *Callitris*, that while ordinarily the archegonia are organized in relation to the pollen-tube, yet, in the case of the pollen-tube being arrested in its development, the archegonia still develop in relation to the position which a normal pollen-tube would have occupied. It seems to the writer that this makes it probable that although,

¹ In certain other Conifers, e.g. in *Podocarpus* (Coker 2), multinucleate cells are formed in the prothallus.

in the individual development, the position of the archegonia is usually a correlated character, yet phylogenetically it may well have been otherwise. Nevertheless evidence from abnormalities is not always reliable, and may be easily used beyond its legitimate extent, so this suggestion is put forward with some hesitation.

The position of the archegonia in *Araucaria* and *Agathis*, especially in the latter, is similar to that here described, and Seward and Ford (17) regard this as a primitive character, with which view the present writer is entirely in agreement.

In this connexion something may be said in regard to the points of resemblance with *Sequoia sempervirens*, as worked out by Lawson (6). Other writers had previously mentioned some of the peculiarities in this remarkable Conifer, but the life-history was fully described for the first time by Lawson, and it is therefore found most convenient to refer to his account only.

Two points of resemblance stand out sharply. (i) The position of the archegonia, and (ii) the similarity in size and organization of male and female nuclei.

A possible relationship between *Sequoia* and the Cupressineae has been suggested before by Arnoldi (1), and in many respects the Callitrineae may be considered to supply the missing link, agreeing with Cupressineae in their more obvious, with *Sequoia* in some of their more recondite, characters.

This relationship, if admitted, would tend to the view that the Callitrineae represent a relatively ancient type as compared with the Cupressineae, and other considerations support this view. There can be no doubt that *Callitris* is more nearly related to the Cupressineae than in *Widdringtonia*, and there are many indications that *Callitris* is the more specialized type of the two. Evidence of this would be largely a repetition of Table II below (which see). It seems quite clear to the writer that specialization in the Cupressineae must have proceeded on similar lines, although a wide gap, as shown above, separates the two tribes. The main change must have been increase in the number of cone-scales, accompanied by sterilization of some of them, the culmination of the process being reached in *Cupressus*.

The second important conclusion is that, although fairly closely allied, the genera *Widdringtonia* and *Callitris* are quite distinct, and should undoubtedly be kept apart, as recently urged by the late Dr. Masters (9). It is unfortunate that, in the paper cited, a well-known species of *Callitris* should have been described by the author as a new species of *Widdringtonia*. The necessary correction was made by the author himself shortly after (10), but in the meantime it had been admitted in the first paper (*loc. cit.*) that the supposed new species to some extent broke down the distinction between the genera, and in consequence the conclusion lost much of its weight.

The writer has already expressed (13) the opinion that the two

genera should be kept apart, and has cited the opinions of some other botanists both for and against this view, which need not here be repeated. The evidence was not brought forward at that time, as it was thought better to postpone it until the life-history of *Callitris* had been more fully worked out.

Table II gives a list of the chief differences noted, including both those which are more obvious and those more recondite. Since not all the species of either genus have been examined, it may prove that not quite all of the differences given will prove constant, but it is highly improbable that many of the distinctions will be broken down.

TABLE II.

<i>Organ or Stage.</i>	<i>Widdringtonia.</i>	<i>Callitris.</i>
Leaves.	Opposite and decussate.	In alternating whorls of three.
Female cones.	Two decussate pairs of scales. All scales equally fertile.	Six scales in two alternating whorls. Outer scales smaller and bearing fewer ovules.
Ovules.	Not more than about thirty in a cone. Most develop up to free nuclear conditions of the prothallus (except when not pollinated).	About sixty in a cone. Many abort very early and appear merely as a flat scale, slightly thicker in the middle, and eventually of almost the same size as the fertile seed, but apparently containing no nucellus.
Megaspore mother-cells.	About sixty-four at base of nucellus.	One or very few half-way up the nucellus.
Young prothallus.	Appears in lower half of nucellus. No 'pavement tissue'.	Appears in upper half of nucellus. 'Pavement tissue' below.
Mature prothallus.	Relatively large.	Relatively small.
Archegonia.	More than twenty-five in more than one group.	Less than twenty-five in one group.
Seeds.	Relatively large. Wings not very broad or may be obsolete.	Relatively small. Wings broad.
Male cone.	Sporophylls in decussate pairs.	Sporophylls in alternating whorls of three.
Microsporophyll.	Bears four sporangia.	Bears three sporangia.
Chromosomes.	Six and twelve.	More than six and twelve. (Perhaps eight and sixteen).
Habitat.	South and Central Africa and Madagascar.	Australasia.

The anatomy of leaf and stem also shows considerable differences between the two genera. An account of this has been published elsewhere by the writer (15).

In a former paper (13) the name *Actinostrobeae* was used for the four genera here named *Callitrineae*. I had at that time failed to note that Masters (8) had already applied the latter name to the same four genera in preference to Endlicher's name which included also *Libocedrus*. In the same paper a comparison was provisionally suggested with the *Gnetales*, especially with *Welwitschia*, but further research has shown that the resemblances noted are apparent rather than real. Nevertheless it does seem likely that of all Conifers *Widdringtonia* come a trifle nearer the *Gnetales* (at any rate *Welwitschia* and *Gnetum*) than any other genus, at any rate in gametophyte characters. Coulter (5) regards the *Gnetales* as derived from the *Cupressineae*.

SUMMARY.

The microsporophylls are arranged in alternating whorls of three, and each bears three microsporangia.

The six megasporophylls are in two alternating whorls of three, the outer somewhat smaller and bearing fewer ovules.

The young embryo-sac is situated in the apical half of the nucellus.

The archegonia are never situated at the apex of the prothallus, but in a single group of about, or just under, twenty, arranged along the inner side of the pollen-tube near its apex. If two pollen-tubes are present, two such groups are organized.

The pollen grain is uninucleate at the time of shedding in *C. verrucosa* and *C. robusta*.

The later development of the male gametophyte is normal.

The proembryo completely fills the archegonium, but the arrangement of the cells is variable.

More than one embryo is formed from a single proembryo.

The first two walls in the embryo are longitudinal.

The mature embryo has two cotyledons.

The cells of the mature prothallus are all binucleate or multinucleate.

It is concluded that *Widdringtonia* and *Callitris* undoubtedly represent two distinct genera and must be made the types of a separate tribe of Coniferae, the *Callitrineae*, co-ordinate with *Cupressineae*. The characters of the *Callitrineae* are in many respects intermediate between those of *Cupressineae* and those of *Sequoia*.

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EXPLANATION OF FIGURES IN PLATES XLV AND XLVI.

Illustrating Mr. Saxton's Paper on *Callitris*.

All figures were drawn with Zeiss Camera lucida, microscope and lenses. In all:—

A = archesporium; *C* = micropyle-closing cells; *D* = megaspore mother-cells; *G* = Starch grains; *H* = integument; *K* = tapetum; *L* = suspensor; *N* = nucellus; *P* = prothallus; *Q* = body-cell nucleus; *R* = resin cavity; *S* = sterile nuclei; *T* = pollen-tube; *V* = vascular bundle; *W* = wall of microsporangium; ♂ = male nucleus; ♀ = Female nucleus.

PLATE XLV.

Fig. 1. Part of median longitudinal section of young male cone showing position of sporophyll microsporangium, resin cavity, and vascular bundle. × 135.

Fig. 2. Microsporangium from a similar cone. × 420.

- Fig. 3. Transverse section of mature microsporophyll, showing three microsporangia, resin cavity, and vascular bundle. $\times 40$.
- Fig. 4. Longitudinal section of a young ovule, almost in the plane of the wing. [Wing partly cut on right, missed on left, of figure.] $\times 58$.
- Fig. 5. Part of Fig. 4, showing the two megaspore mother-cells. $\times 930$.
- Fig. 6. A somewhat later stage showing the functional megaspore, one disorganizing megaspore above and two below, and the non-functional mother-cell below these. $\times 930$.
- Fig. 7. Median longitudinal section of the nucellus of an abortive ovule. About same age as Fig. 8. $\times 135$.
- Fig. 8. Median longitudinal section of normal nucellus after first division of megaspore nucleus. [cf. Fig. 7.] $\times 135$.
- Fig. 9. Development of two embryo-sacs. $\times 400$.
- Fig. 10. Embryo-sac with 16 nuclei, and 3 disorganizing megaspores below. $\times 230$.
- Fig. 11. Sketch of nucellus in longitudinal section when 128 nuclei are present in the embryo-sac, showing positions of pollen-tube, embryo-sac and 'pavement tissue'. $\times 40$.
- Fig. 12. Longitudinal section of upper two-thirds of prothallus, showing position of pollen-tube and archegonia. Two adjacent archegonia near the base have just been fertilized. $\times 58$.
- Fig. 13. Mature archegonium. The neck-cells have broken down, and the archegonium opens directly into the pollen-tube. $\times 930$.
- Fig. 14. Microspore mother-cells connected to form a net-work. $\times 930$.
- Fig. 15. Tip of fairly young pollen-tube. $\times 400$.
- Fig. 16. Contents of tip of mature pollen-tube. $\times 545$.
- Fig. 17. Archegonium after fertilization. [One of the archegonia of Fig. 12.] $\times 545$.
- Fig. 18. Two adjacent mature proembryos, in nearly median longitudinal section. $\times 400$.
- Fig. 19. Tangential section of a similar proembryo. $\times 400$.
- Fig. 20. Dividing sporophyte nucleus. Not all chromosomes shown. $\times 1,500$.
- Fig. 21. Dividing gametophyte nucleus from same series of sections. Not all chromosomes shown. $\times 1,500$.
- Fig. 22. Part of a single proembryo in longitudinal section. $\times 570$.
- Fig. 23. A suspensor bearing a four-celled (two in section) embryo. $\times 400$.
- Fig. 24. Multinucleate prothallus cells on the border of the starch-containing region.
- Fig. 25. Tip of abnormal pollen-tube. $\times 135$.

PLATE XLVI.

- Fig. 1. Longitudinal section of seed, showing embryo with cotyledons differentiated.
- Fig. 2. Transverse section of seedling, showing cotyledons and plumular leaves.
- Fig. 3. Longitudinal section of ovule, containing prothallus.

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