VEGETATIVE REPRODUCTION IN NEW ZEALAND MOSSES.

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From time to time there have been brought to my notice unreported instances of asexual reproduction in New Zealand mosses or additional facts about already known cases which deserve record. This method of reproduction, i.e. by means of buds, protonema, etc., is especially common amongst the mosses, and its study, whether from a morphological or a physiological standpoint, is full of interest. In a work of the highest excellence on the subject Correns[3] occupies himself mainly with the morphology of the various organs of asexual reproduction, and also describes numerous cultural experiments made by him to ascertain the manner of their development. Correns was strongly of opinion that the organs in question could be turned to account in systematic bryology, but systematists generally show little inclination to do so. In the following notes the bracketed words in inverted commas are part of the terminology employed by Correns to describe the organ or tissue mentioned. The distribution of the species dealt with is according to Brotherus[1] and Dixon,[5] supplemented by my own observations and records. The following notes do not pretend to furnish a full and accurate account of the brood-organs mentioned or of their development.

CAMPYLOPUS CLAVATUS (R.Br.) H.f. & W.

Distribution.—Common in Australia and New Zealand.

Material examined.—Leg.: G.O.K.S.; October, 1933; on earth, near Wairoa, Hawkes Bay, North Island; fruiting.

This species is dioicous, but fruits freely. Asexual reproduction where present is brought about by brittle buds (" bruchknospen ") at the end of a stem or branch.

Each annual growing period ends with the production of such a bud, the next year's growth being provided for by an innovating shoot which commences usually immediately under the break in the stem or branch. When the plant fruits the terminal cluster of shoots consists of branches or branchlets ending either in female flowers or in bruchknospen. It appears therefore that fertility in this species does not influence the asexual propagation one way or the other. Where the bruchknospen are present the young innovations form the club-shaped branches from which the specific name is derived; where they are absent we have the form known as *C. appressifolius* Mitt. In some seasons the bruchknospen are very plentifully produced, and the detached buds can be seen in the spring conspicuously scattered over the surface of the tufts. Vertical sections through the bud and stem show that the brittle tissue at the place of fracture ("trennschicht") consists, as is usual, of an area of short cells which in this particular instance are dark in colour. The bud consists of from ten to twenty leaves, and from its basal part rhizoids freely germinate in contact with the soil, a new plant resulting by continuation of the growing point. The leaves of the bud do not differ in size or structure from those of the ordinary branches. The inner tissue of the bud is rich in oil-drops; this is a common occurrence in brood-organs, and is a provision for the storage of nutriment. The shortening of the cells is explained as a device for mitigating the loss of living substance from the stem when the break takes place.[(3), p. 372] Often, also, these cells are thinner walled, thus facilitating the fracture, but I have not noticed that they are so in *C. clavatus*. Occasionally the brittle bud, though broken off, escapes displacement from the parent branch, and in this case it puts out rhizoids and grows epiphytically, forming a pseudo-branch which is very easily detached. A similar method of reproduction apparently takes place in the European *C. schimperi* Milde,[(3), p. 38] which, unlike our species, practically never fruits.

CAMPYLOPUS TORQUATUS (Mitt.) Jaeg.

Distribution.—Tasmania and New Zealand.

Material examined.—Leg.: K. W. Allison; No. 555; October 18, 1932; on Sphagnum mound in swamp near Atiamuri, North Island; fruiting. Leg.: E. A. Hodgson; No. 673; October 10, 1932; on old burnt-out Totara

stump, in remnant of bush, near Wairoa, North Island; barren.

The brood-organs present here are deciduous leaves of simplified structure ("brutblätter"). I have not found them *in situ* in Mr. Allison's specimen, though they are present in small quantity in the detritus. In Mrs. Hodgson's gathering the detached brutblätter are strikingly numerous, and the material throughout provides but few stems bearing only normal leaves, as against a vast majority where brutblätter or leaves of intermediate structure are present in abundance. The brutblätter are borne on thin branches which are either produced singly here and there from the stem or terminate it in a cluster of three or four. The branches themselves are not deciduous, but the leaves are extremely so. The detritus furnishes brutblätter of all lengths from 0·5 mm. or less to about 3 mm., the normal leaves being about 4 mm. in length. Apart from structural differences the brutblätter are readily distinguishable by being conduplicate, much more shortly pointed, and more or less bent forward at the middle in the shape of a boomerang. The supra-basal part of the lamina in this species consists of a small area of oblong hyaline cells, which soon gives place above to shorter and more obscure ones. In the brutblätter the area of oblong cells is continued far up the leaf, and the cross walls of the cells are conspicuously thickened. This renders more striking still the difference in its appearance. Oil-drops are abundant in the tissue of the nerve, and sections through it show that its development has been arrested at an early stage, in the same way as that described[(3), p. 39] in two European species, *C. fragilis* B. & S. and *C. turfaceus* (*Bry. eur.*). The undivided branches which bear the brutblätter, the thickening of the cell walls mentioned above, and the structure of the nerve are all interesting points of resemblance between the New Zealand species and, in particular, *C. turfaceus*. In the European mosses mentioned the reproduction is effected by the further development of special thin-walled cells ("initials") which are present on the surface of the nerve of the brood-leaf and which produce a protonema from which new plants arise. These initials which, as they function specially for the propagation of new plants, are called *nematogones* are reported by Correns to be rare and difficult to find in the species investigated. I have failed to find them in *C. torquatus*, but have little doubt that they are present.

Rhizoid initials, i.e. those that develop from the nerve or lamina of the ordinary leaves the rhizoids which are so common on moss stems, are present plentifully on the nerve surface of the ordinary leaves of the New Zealand species, as they are in the case of the two European species. I have failed to find in the detritus any brutblätter showing germinating nematogones. In *C. fragilis* germination is infrequent, and confined to the large brutblätter.[(3), p. 41] Apparently the production of young plants from the resulting protonema has not been observed.

PLEURIDIUM NERVOSUM (Hook.) Par.

Distribution.—Australasia.

Material examined.—Leg. : G.O.K.S. ; October 23, 1927 ; on bare earth in open pasture, near Wairoa, Hawkes Bay, North Island ; barren.

The exact taxonomic position of this plant is doubtful. The habit indicated an *Anomobryum*, but a stem that I found (and subsequently mislaid, unfortunately) showed a lateral perichætium of typical *P. nervosum* character, and as this species also grows abundantly near Wairoa in an exactly similar habitat it is probable that our plant belongs there. As in *Campylopus clavatus*, the adaptation for reproduction is here a deciduous terminal bud. The very slender julaceous stems are usually simple, but in the rare cases where a single branch is produced it, as well as the stem, ends with a bud and is then incapable of further development. The stem leaves for the greater part are bluntly acute and entire, tightly packed round the slender stem. The nerve vanishes below the leaf apex, and the cells of the lamina are subquadrate and thin-walled. At the apex of the stem, i.e. immediately under the deciduous terminal bud, and on the bud itself, the leaves are more sharply acute, mostly nerveless, with the cells longer, somewhat sinuate, and distinctly incrassate. The axis of the bud is appreciably thickened, and this, with the yellowish tinge of its leaves, makes it quite conspicuous. The moss is only about 5 mm. long, and longitudinal sections through the stem and bud are somewhat difficult to make, but I have been able to ascertain from a fairly satisfactory section that there is a distinct trennschicht consisting of a decrease in the diameter of the stem with an area of short cells. The thickening of the axis of the bud is obviously an adaptation for storage of nutriment, and the lax internal cells contain a

strikingly large number of oil-drops. Rhizoid initials are present at the base of the bud, and though I have not observed it there can be no doubt that a new plant originates by growth of rhizoids at the base and further development of the apical growing point, as in *Campylopus clavatus*. If this plant really belongs to *P. nervosum*, it furnishes an interesting case of dimorphism in the fertile and brood-plants respectively, because the leaves of the latter, as already mentioned, are bluntly acute and weakly nerved, whilst in the former it is only the lowest rudimentary stem leaves that exhibit these characters, the other leaves being ovate-lanceolate with a strong excurrent nerve.

HOLOMITRIUM PERICHÆTIALE (Hook.) Brid.

Distribution.—Australasia, and some Pacific islands.

Material examined.—Leg. : G.O.K.S. ; January 1, 1932 ; Ketetahi, Mt. Tongariro, North Island ; barren. Leg. : O. Buchanan ; March, 1935 ; on bark, Tangiwai, near Mt. Ruapehu, North Island ; fruiting sparingly.

Flagellate shoots (" bruchäste "), which often terminate the stem and the innovating branches in clusters of three or four or more, are present in these specimens, and occur, too, on some of the fruiting stems of Mrs. Buchanan's gathering. The shoots are brittle throughout their length, and usually break just above the insertion of a leaf. The brittleness is not greatly pronounced, however. The leaves of the bruchäste are very small, and being unaltered when dry and appressed to the stem of the shoot, contrast strongly with the larger curled leaves of the normal branches. Correns[3], p. 7 cites several authors from whose statements it would appear that brittle flagellate branches occur in other species of *Holomitrium*, but no plants of the genus were examined by him. Another dicranaceous moss, however (*Dicranum flagellare* Hedw., a European species), was investigated and the bruchäste and leaves fully described. In *D. flagellare* the bruchäste are clothed with leaves which, though thickened in the middle, have no differentiated nerve, and which contain oil as reserve nutriment. The leaves, unlike the ordinary ones, are conspicuously distichous. The shoot breaks readily into as many fragments as there are leaves, and reproduction is brought about by the outgrowth of protonemal filaments from nematogones on the surface of the internodes. The young plants arise on the protonema at some distance from the broken-off fragments. There is a defined trennschicht

at the place of fracture. In *Holomitrium perichætiale* the process of differentiation has not gone nearly so far as that above described by Correns. As a corollary with the decreased brittleness of the shoot a defined trennschicht is not present. The arrangement of the leaves on the flagellate shoot, instead of being distichous, is the same as that of the ordinary leaves. In the latter the deuter cells of the nerve are usually six in number, and there is a layer of three to four stereid cells above and below them. In the leaf-nerve of the brittle shoot the deuter cells have usually on each side one row only of sub-stereid cells, and, corresponding to the decrease in size of the leaf, its nerve is reduced to about half the width of that of the ordinary leaf. The leaves of the bruchäste are not adapted for storage of nutriment; they contain no oil, and are merely reduced in size and structure without acquiring any special properties for the furtherance of reproduction. Initials are plentiful on the surface of the internodes, and are readily distinguishable by the colourless and thin outer wall, the other peripheral cells having the same wall thicker and red-brown in colour. The detritus shows numerous cases where these initials have produced protonemal threads, and they can often be seen on flagellæ *in situ*. Cultural experiments would be required to show whether the development proceeds further to the formation of new plants on the protonema, or whether on the other hand the reproductive process is not yet sufficiently evolved to allow of this. In *D. bonjeani* De Not. there is a somewhat similar approach to the bruchäste of *D. flagellare*.[3], p. 13

DICRANOLOMA MENZIESII (H.f. & W.) Par. var *rigidum* (H.f. & W.) Par.

Distribution.—Australasia, Chile, Norfolk Island, Chatham Islands and subantarctic islands.

Material examined.—Leg.: Simpson and Thomson; No. 232; August 5, 1933; on tree-fern, Morrison's Creek, near Dunedin, South Island; barren.

In *D. robustum* (H.f. & W.) Par. var. *setosum* (H.f. & W.) Sainsb., broken-off portions of the leaf subula occasionally produce a protonema of rhizoid nature as an outgrowth from the deuter cells at the broken end.[10] The same thing happens in the above variety of *D. Menziesii*, and, as in *D. robustum*, the capacity to produce a protonema is practically confined to the basal end of the fragment.

The leaves in the variety *rigidum* are more or less brittle, and are very finely setaceous. They are evidently " bruchblätter ", i.e. brittle leaves which serve to propagate the moss by the formation of young plants on the protonema. The species is usually fertile, but I have never seen any but barren plants of the variety, so presume that the capacity to form fruit has been totally suppressed here in favour of asexual reproduction.

DICRANUM TRICHOPODUM Mitt.

Distribution.—New Zealand and Tasmania.

Material examined.—Leg. : G.O.K.S. ; April, 1931 ; on bark of subalpine scrub, Waiopehu, Tararua Mountains, *ca.* 3,000 ft., North Island ; barren.

In this specimen there are present very striking bruchäste which probably generate new plants. The upper part of the stem bears numerous exceedingly long and very brittle branchlets whose leaves have long filiform prolongations of the nerve. The branchlets are readily broken into small fragments, the place of fracture, as in *Holomitrium perichætiale*, being usually just above a leaf insertion. There does not appear to be any consistently defined trennschicht, but the superficial cells of the stem are often shortened just above the leaf insertion where the break takes place, and this points to a stage of evolution towards a specialised tissue. Initials are plentiful on the surface of the internode, and can be found developing protonemal threads both on the plants and on the broken-off fragments. It is probable that young plants germinate on the protonema as in other species of *Dicranum*. In addition to the long prolongation of the nerve the leaf of the brittle branch differs from the ordinary leaf in being narrower and having a narrower nerve, but there is no adaptation for storage of nutriment.

FISSIDENS ASPLENIOIDES (Sw.) Hedw.

Distribution.—Sub-tropical parts of the Southern Hemisphere. Common throughout north island of New Zealand.

Material examined.—Leg. : J. H. McMahon ; 1928 ; Marlborough, South Island. Comm. : E. A. Hodgson ; No. 264 ; fruiting.

According to Correns,[3], p. 54 adaptations for asexual reproduction are, in the Fissidentaceæ, either unreported or very rare. Multicellular bodies borne on rhizoids from

the stem ("wurzelknollchen") are mentioned as having been observed by him on one occasion in the European *F. taxifolius* Hedw., and he cites Lorentz[9] as having described them from that species. I have not had access to the latter's account, and am unable to say in what respect the bulbils there dealt with differ from those I have found in the Marlborough plant. At any rate they have in common the somewhat significant character of being produced *above* the ground, and not as a subterranean organ, as is usually the case with wurzelknollchen. In Correns's opinion[3], p. 337 the subterranean variety at any rate can only be considered as a food reservoir, and not as an organ of reproduction; he expresses, moreover, the view that even where the bulbils are produced above the ground it is only those of *Bryum erythrocarpum* Schwaegr.—which are homologous with reduced moss-plants themselves—that can be definitely recognised as being capable of functioning as true brood-organs. Obviously, therefore, it would be unsafe to draw any conclusion about the wurzelknollchen in *F. asplenioides* without clear evidence of their function. They are produced on long, plentifully-branched stem rhizoids which mat the plants together for a great part of their length. The Marlborough plant is the only gathering that I have seen from the mainland of the South Island, and in none of the numerous North Island specimens examined are the stems at all densely beset with rhizoids. The bulbils are about 0·1 mm. long, oval or obovate or sub-globular, narrowed at the base to a stalk consisting of two thin-walled cells, the upper of which is much shorter than the lower. The bulbils, like the rhizoids, are ruby red in colour. The surface is boldly reticulated. Here and there one or two cells at the apex have the outer wall nearly colourless, and this is usually also the case with the basal cell surmounting the stalk. I have occasionally found that these cells have commenced to germinate with the protrusion of the outer wall, but whether the germination would result in the formation of a reproductive protonema or merely in the multiplication of the cells of the organism is quite uncertain. The facts that differentiated outer cells occur and that the bulbils are readily detached from the rhizoids go to show that reproduction from them is a possibility, but until something more is known of them it would be unsafe to form any definite opinion. I have found starch and oil present at times in the bulbils, but

this is as consistent with the nature of a food-reservoir as with that of a brood-organ.

LEUCOBRYUM CANDIDUM (Brid.) H.f. & W.

Distribution.—Australasia.

Material examined.—Leg.: K. W. Allison: April 4, 1931; on forest floor, Mt. Messenger, Taranaki, North Island; fruiting. Leg.: G.O.K.S.; January, 1935; near Dawson Falls, Mt. Egmont, North Island; fruiting.

In the mosses not only specialised deciduous leaves (" brutblätter "), but also the ordinary leaves, or portions of them, can often reproduce the plant by functioning as slips or cuttings. Such detached leaves or fragments produce, from the lamina or nerve, rhizoid growth on which young plants are subsequently formed by direct budding on the filaments. The stimulus to reproduce, however, is furnished by separation from the stem, and although the leaf, when still attached, often produces a protonema, the resultant growth rarely generates new plants except indirectly through the prior formation of brood-bodies. The family of Leucobryaceæ supplies some interesting exceptions to this general rule. Correns[3], p. 50 describes in *Ochrobryum Gardnerianum* Mitt. the formation on the leaf apices of a rhizoid mat on which appear rudimentary plants that simultaneously produce multicellular brood-bodies. Dixon[6] says of *Leucobryum glaucum* Schp. that " the apical leaves often produce at their tips a tuft of radicles, whence are developed a cluster of minute plants, these subsequently falling off and giving rise to new colonies ". Something resembling the latter form of propagation takes place in *L. candidum*, though I think quite infrequently, because I have only seen evidence of it in the two specimens above mentioned, and even there in but a few stems. What happens is that young plants are produced on rhizoid growth from the inner (ventral) surface of leaves borne on short branchlets. The leaves in question were of normal shape and structure and not at all deciduous, as they sometimes are in the species. The rhizoids on which the new plants germinate usually, but not invariably, have their origin in the lower part of the leaf. In *Leucobryum* the leaf consists almost entirely of a modified nerve formed by layers of hyaline cells which enclose a central layer of individually isolated and narrow chlorophyllose cells. In *L. candidum* some of the latter often run out to the surface towards the tip

of the leaf on the inner face, and then function as initials which develop a rhizoid growth that can usually be seen on leaves of the older part of the stem. A similar extrusion of chlorophyllose cells also frequently occurs towards the base of the leaf on the same face. One would expect, therefore, that the rhizoids on which the young plants are formed would originate only from these exposed chlorophyllose cells, but I cannot feel sure as to this, because the rhizoid filaments penetrate the hyaline cells in every direction and it is difficult to trace them to their starting points. With regard to the deciduous leaves that are occasionally met with in this species, I have not found that they differ from the ordinary leaves in any way, and do not know whether they are capable of generating a reproductive protonema when detached.

TORTULA ABRUPTINERVIS Dixon.

Distribution.—New Zealand.

Material examined.—Leg.: E. A. Hodgson; October, 1928; on bark, near Wairoa, Hawkes Bay, North Island.

This species has never been found in fruit. The remarkable brood-body present here is stated in the diagnosis[(5), p. 150] to be axillary, but Mrs. Hodgson ascertained that it originates at the apex of the nerve. It has been described and figured by her.[(8)] The brood-body is evidently a metamorphosed nerve arista, and I find that nematogones are numerous on its surface. They are sunk below the level of the other superficial cells and are readily distinguishable, especially in transverse section, by their outer walls being colourless and only slightly papillose. The only germinating brood-body found in the detritus showed two embryonic plants budding directly out from the surface, one near one end and the other near the other. The protonemal outgrowth from the nematogones has evidently been reduced here to one or two cells. The method of propagation in this species—by means of a modified nerve arista—is quite different from anything hitherto observed in the genus *Tortula*, or indeed in any other moss, except certain species of *Macromitrium*.

MACROMITRIUM CADUCIPILUM Lindb.

Distribution.—New Zealand.

Material examined.—Leg.: G.O.K.S.; December, 1934; on bark, Tangiwai, near Mt. Ruapehu, North Island.

Leg. : Simpson and Thomson ; No. 189 ; July, 1933 on bark, Otago, South Island.

As in the last-mentioned species, there is here a striking adaptation of the leaf arista as a brood-organ. Correns[3], p. 121 describes and figures it from the original material. The deciduous arista, which is often even longer than the leaf itself, breaks off at the leaf apex through a trennschicht of small, thin-walled cells. Correns found the arista to be frequently brittle throughout its length, but I suspect that this may be due to the age of the material examined, which was at least fifty years old. In my specimens the great majority of detached aristas are entire, and there is no marked fragility. Examination of fresh material also supplements his observations by showing that the tissue of the arista (when the latter is *in situ*) is green and chlorophyllose, in fact strikingly so, and that starch is present in it. Nematogones are plentiful on its surface, and Correns's confident assumption that rhizoid protonemata would be produced from these cells is borne out by the commencements of such growth that I have found in the detritus. In each case the only nematogones to germinate were situated in the lower central part of the arista. *M. caducipilum* has not been found in fruit.

MACROMITRIUM RETUSUM H.f. & W.

Distribution.—New Zealand.

Material examined.—Leg. : O. Buchanan ; March, 1935 ; on bark, Tangiwai, near Mt. Ruapehu, North Island.

This species is close to *M. caducipilum*, though separable by fairly satisfactory characters. The same peculiar thickened arista is present, and here, as in that species, it is quickly shed by all but the youngest leaves, so that the end of the branch usually shows a characteristic penicillate tuft. As in the last species, the arista breaks off at the leaf apex (where there is a similar trennschicht), and in all other respects I have found an exact agreement between the two species so far as the brood-body is concerned. Also in the only germinating arista found in the detritus there were several short rhizoid filaments situated in its lower central part. *M. retusum* has not been found in fruit, but it is doubtful whether it is specifically distinct from the fertile *M. gracile* (Hook.) Schwaeg.[5], p. 367 So far as the brood-body is concerned there is a closer connection with *M. caducipilum*.

MACROMITRIUM GRACILE (Hook.) Schwaegr.

Distribution.—New Zealand.

Material examined.—Leg. : G.O.K.S. ; September, 1931 ; on bark, Lake Waikaremoana, Hawkes Bay, North Island ; var. *proboscideum* Dixon ; barren. Leg. : R. Mundy ; Ohakune, near Mt. Ruapehu, North Island ; fruiting.

In the two last-mentioned species of *Macromitrium* there is no pronounced fragility of the leaf lamina, and the term " bruchblätter " is not so fitly applicable to their leaves as it is in the present species. Here the nerve is, except in the variety *proboscideum*, seldom very far excurrent. The leaf is brittle, especially in its upper portion, and the detritus usually contains a varied assortment of leaf fragments. Initials are present both in the excurrent nerve and also, more frequently, adjacent to it in the upper part of the leaf subula. The cells in question are distinguishable by their colourless outer walls, less papillose than those of the ordinary cells. I have not been able to find any trace of outgrowth from the initials in any of my specimens, so am unable to say whether the leaves are true bruchblätter or not.

BRYUM INCURVIFOLIUM C.M.

Distribution.—South Island.

Material examined.—Leg. : J. H. McMahon ; Marlborough. Comm. : E. A. Hodgson. Det. : H. N. Dixon ; No. 617 in Herb. G. O. K. Sainsbury.

I submitted this interesting plant to Mr. Dixon, who determined it as above somewhat doubtfully, so its systematic position must be considered as uncertain. The species may in any event come within the scope of the variable *B. lævigatum* H.f. & W.[(5), p. 216] Amongst the leaves, especially in the upper part of the stem, are conspicuously long brown filaments which in the terminal tuft nearly reach the leaf apices. It will be found that these brood-filaments (" brutfäden ") are borne on single or branched stalks which are produced from the leaf axils throughout the length of the stem. The cylindrical brood-filaments consist of up to twenty or more cells, which are divided by transverse walls. They are dark brown, papillose and obscure, and contain oil-drops. The terminal cell is rounded and colourless, but, being papillose too, is somewhat obscure. The cells usually vary in length from one and a half times to twice their

thickness, but towards the apex of the filament they become shorter and relatively wider. The filament is connected with the stalk by a very short brittle cell (" brachytmema ") whose function is to bring about the dehiscence of the filament. This disc-like cell is only about one-sixth the length of the adjoining basal cell of the filament. When the fracture takes place the remnants of the wall of the brachytmema remain attached to the adjoining cells of the stalk and filament respectively. Occasionally a filament can be found in the detritus showing an internal cell conspicuously shorter than its neighbours, but I am doubtful whether such a cell is a brachytmema or the dormant foundation cell of a branch. The cells of the stalk usually resemble those of the filament, being also brown and papillose, with transverse walls. They are, however, somewhat longer, and often show forms of transition to the ordinary stem rhizoids which are much thinner, faintly papillose only, and composed of much longer cells with slanting walls. Owing to the earlier dehiscence of the filaments in the lower and older part of the stem they are only to be found *in situ* in the upper part. I have not found any trace of germination in the filaments, but there can be no doubt that the terminal rounded cell can function as a nematogone, and probably the basal cell also, to judge by what happens in the European species *B. capillare* L.,[(3), p. 185] where the form and development of the brutfäden are, in the main, very similar. In that species either one or both of the terminal cells of the filament were found to be capable of developing protonemal growth on which young plants arose. In the detritus of Mr. McMahon's specimen there are numerous rudimentary buds (" bruchknospen ") and also red multicellular bodies resembling the wurzelknollchen before described in *Fissidens asplenioides*. Unlike the latter, however, they often show traces of development at the apex, in the shape of what appear to be leaf-foundations. Oil-drops are plentiful in their tissue. These bodies have evidently been produced on a protonema, but the remnants of the threads, where present, are in too bad a condition to show whether the bodies have originated on ordinary stem rhizoids or on a protonema of a reproductive nature. In any event their appearance indicates that they are wurzelknollchen of the kind produced by *B. erythrocarpum* Schwaegr., and capable of development into new moss plants. If, then, they originated in the specimen itself, we should have in this

plant the occurrence of two forms of asexual reproduction, which could only be matched by the bryoid moss *Leptobryum pyriforme* (L.) Wils., where brood-filaments and bulbils have been found on the same plant.[(3), p. 150] The bruchknospen, which are in the form of bulbils 0·3 mm. to 0·4 mm. long and crowned by more or less well-developed leaves, are of the type often met with in bryoid mosses. They must have been produced from leaf axils to which they were attached by a very brittle basal tissue. They contain starch as reserve nutriment, and would evidently develop into new plants by an extension of the growing point coupled with the outgrowth of rhizoids from the initials that are clearly visible at the base. The occurrence of *three* forms of asexual reproduction in a moss plant (and fertile at that) would be too remarkable to justify such a conclusion from the presence in the detritus of the organs in question, but it must be conceded that their being found loose in the packet is very puzzling, more especially as both kinds of brood-organ are practically confined to bryoid mosses. A careful search failed to reveal either bruchknospen or wurzelknollchen in organic attachment to the plant. It is possible that the knollchen have been formed on a protonema originating from the germination of nematogones in the brood-filaments. In that case they would be "secondary" brood-bodies, i.e. those that are occasionally produced directly from other brood-bodies,[(3), p. 348] but nothing resembling this particular case seems to have been recorded. It is perhaps too much to hope that further material will be found to throw light on this interesting specimen.

ERIOPUS CRISTATUS (Hedw.) Jaeg.

Distribution.—New Zealand, and possibly Tasmania.

Material examined.—Leg.: G.O.K.S.; October, 1934; on damp rock in dense shade, Marumaru Caves, near Wairoa, Hawkes Bay, North Island; fruiting.

The vegetative plant of this species consists of a dorsiventral flattened shoot, the leaves being closely imbricated as in many other Hookeriaceous mosses. I have not found brood-organs in any gathering other than the above. They are present here in the form of brood-filaments which dehisce by typical brachytmema from long branched virgate stalks that spring in dense tufts from the dorsal side of the stem. Some of the plants are densely beset with the stalks, whilst others have but few, and others

again none at all. The stalks are coloured light brown, except in their lower part, where they tend to become more red. The outer walls are thin, and the cell division walls all more or less transverse. The brood-filament has a peculiar appearance, being always approximately L-shaped. When mature it attains 0·3 mm. or more in length. When it is not strictly L-shaped the lower limb slopes down at an obtuse angle. The main limb consists of five or six cells, which are long in relation to their breadth. The lower limb or branch is developed from the cell on the main limb next above the brachytmema when the brood-body is still attached to the stalk. Probably the branch does not always attain its full growth, i.e. three to four cells, before the brood-body breaks off, but the greater part of its development certainly takes place before separation. A further interesting and curious extension of the brood-filament consists of the outgrowth from the first cell of the branch (next to the angle cell of the " L ") of yet another branch which grows out vertically to the plane of the filament and thus forms a second " L " with the original branch as its main limb. I have not been able to ascertain whether this secondary development ever commences when the brood-body is attached to the stalk. The remains of the wall of the brachytmema can be seen attached to the somewhat truncate basal cell of the filament in the form of a projecting rim or collar. The cells are usually densely packed with chloroplasts, and contain large quantities of starch grains but no oil. The apical cells of the main limb and branches are bluntly tapered and much more translucent. No further development was observed. A somewhat similar L-shaped brood-filament is shortly described by Correns[3], p. 235 in the case of an East Indian species *E. remotifolius* C.M., where the method of reproduction on stalks from the stem appears to be exactly the same, but where the branch of the filament constantly slopes down at a wide angle from the limb, and, moreover, frequently equals the latter in length. No particulars of the number of cells are given, but it is mentioned that they too are long for their width. Nothing is said of the formation of a secondary " L " which takes place not only in *E. cristatus* but also in the Hookeriaceous moss *Pterygophyllum dentatum* next dealt with. Correns states that he has observed no trace of germination of the filament, but that probably the apical cells of both limbs are capable of development.

PTERYGOPHYLLUM DENTATUM (H.f. & W.) Mitt.

Distribution.—Australasia, southern parts of South America, and subantarctic islands.

Material examined.—Leg. : V. D. Zotor ; September 3, 1933 ; Tararua Mountains ; No. 6914 in Herb. New Zealand Plant Research Station ; barren. Leg. : K. W. Allison ; No. 92 ; August 23, 1928 ; very rotten logs and earth, Puaiti Bush, near Rotorua, North Island ; fruiting. Leg. : E. A. Hodgson ; No. 533 ; September, 1930 ; Puketitiri, Hawkes Bay, North Island ; fruiting.

The brood-organs in this species were first mentioned by Colenso[2] in the publication of his *Hookeria obtusata* which is not separable from *Pterygophyllum dentatum*. He refers to them as follows : " Leaves often fringed at or within the margins on the under side with minute jointed cylindrical cellular bodies ". From the context it might seem that he considered them to be foreign bodies. Their true nature is recognized by Dixon,[5], p. 289 who mentions that they stand out on the leaf usually round the margin, and are frequently so abundant as to form a perfect *cheval de frise*. I find that they are produced on either surface of the leaf from initials that are separated from the margin by only one or two cells, and that they occur on fruiting as well as on barren plants. The initials are readily recognisable by their small size, the diameter being only about one-half of that of the adjoining cells of the lamina. When present in the leaf at all they may be in any number from a few scattered groups towards the apex to a continuous band within the margin. From the initials are produced short brood-filaments of the L-shape of those of *Eriopus cristatus*, an interesting point of resemblance in two species of related genera. The likeness is accentuated by the lower limb of the filament being often set on at a similarly wide angle, and still more so by the later development of a subsidiary limb. The main limb consists of a cylinder of four to six cells, whilst the lower limb has one to three. The cells are if anything rather broader than their length, instead of being narrower as in *Eriopus cristatus*, so although the number of cells is approximately the same as there, the brood-body in *Pterygophyllum dentatum* is much shorter, i.e. scarcely 2 mm., with a proportionately far wider diameter, and its appearance is altered accordingly. It tends to be short and squat rather than long and slender. The cells contain chloroplasts and oil-drops, but only a trace of starch.

The organism grows directly out of the initial from the surface of the leaf, cuts off the brachytmema from its base by a dividing wall, and ultimately dehisces by rupture of the brachytmema, the remains of whose walls can be seen as a collar or ridge on the outside of the initial and of the basal cell of the main limb. The lower limb is apparently often fully developed, by lateral outgrowth of the basal cell, before dehiscence. Where it is seen to consist of but one cell this is probably due to immaturity. The basal cell of the main limb is somewhat truncate, but the apical cells of both limbs are bluntly tapered, contain fewer chloroplasts, and are more translucent. They are capable of functioning as nematogones, but nevertheless do not germinate at once in the further development of the brood-filament, because the first cell to bud is nearly always the angle cell of the lower limb adjacent to the basal cell, and the commencement of this growth often takes place before the filament dehisces. The same peculiar double L-form results from this process as has been described in *Eriopus cristatus*. Subsequent commencements of protonemal growth in a straight line from the apical cells of either limb were noticed here and there in detached brood-bodies in the detritus. The only embryonic plant seen appeared to have developed on the branch of the *secondary* " L ", and there was in this case a very short extension of both limbs by protonemal growth. In the specimens examined the older leaves sometimes showed quite a vigorous rhizoid growth from the initials, but I cannot say whether the same initials had already produced brood-filaments which had broken off when the plant was younger. The brood-bodies are evidently therefore metamorphosed rhizoids which in their phylogenetic development have retained the distinctive shape of the modified stem-rhizoids that form the brood-filaments in *Eriopus cristatus*.

GLYPHOTHECIUM ALARE Dix. & Sainsb.

Distribution.—New Zealand.

Material examined.—Leg. : G.O.K.S. ; November, 1933 ; on bark of small trees, Panikeri Range, Lake Waikaremoana, Hawkes Bay, North Island ; barren. January, 1935 ; on bark of twigs and small branches ; near Dawson Falls, Mt. Egmont, North Island ; fruiting.

The position of this interesting moss is very doubtful, and it may have to form the type of a new genus.[7] The brood-filaments present are densely tufted in great

quantities in the axils of the upper leaves. They are borne on short stalks, formed of two to four cells, which are either simple or branched at the base. The stalks in the lower section of the gemniferous part of the stem tend to be of rhizoid character, with thickened and coloured outer walls and oblique inner walls. They resemble there the short axillary rhizoids that sometimes appear still lower down. Higher up the stem, however, towards the apex, the stalks have their outer walls thinner and more faintly coloured, and their cells approximate, both in structure and contents, to those of the brood-filaments. The latter are separated from the stalks by a disc-like brachytmema about 4μ long. The filament is slightly tapered from the middle to both ends. Mature filaments are composed of from twenty to twenty-five cells which vary from 45μ to 90μ in length by 20μ to 30μ wide. Their walls are transverse or slightly oblique and quite colourless, contrasting strongly with the green chlorophyllose cell contents. The apical cell is as a rule nearly hyaline, and its tapered distal end has a thickened wall. Treatment with suitable reagents discloses the presence of oil-drops in the cells. In the detritus, especially that of the Lake Waikaremoana specimen, a number of germinating filaments were found. In one case a long branch consisting of similar cells had grown out from about the middle. In other cases a colourless and thin rhizoid protonema had been produced from cells in various parts of the filament. Although the apical cell had sometimes put out two or three such protonemal threads, it did not seem that the capacity to produce them was accentuated in this part of the filament. No doubt cultural experiments would show that young plants arise on the protonema.

TETRAPHIDOPSIS PUSILLA (H.f. & W.) Dixon.

Distribution.—New Zealand.

Material examined.—Leg.: K. W. Allison; No. 155; January 21, 1929; Puaiti Bush, near Rotorua, North Island; on dead trunks; fruiting.

This remarkable moss was described and figured by Dixon[4] as *T. novæ-seelandiæ* Broth. & Dix., but later it was found to be the same thing as *Meteorium pusillum* H.f. & W., so the specific name reverted accordingly. The short brood-filaments present are densely crowded on a capitulum terminating the stem or branch, and are sometimes also axillary in the upper leaves. As the

description states, they are fusiform or narrowly clavate, and consist of four to six chlorophyllose cells. I can add from my observations that the filament, which is often slightly curved, is borne on a stalk consisting of a single thin-walled colourless cell from which it dehisces by a brachytmema. Reserve nutriment is present in the form of oil-drops. As is often the case where a brood-filament separates by the rupture of a brachytmema, the stalk here appears to be capable of growing up through the broken wall of the brachytmema and forming another brood-organ. The filaments are evidently metamorphosed stem-rhizoids, as are those of *Glyphothecium alare*, and this is an interesting link between the two mosses, which belong to related genera. The only germinating filament found in the detritus had put out the commencement of protonemal growth at a right angle from the apical cell.

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