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TAXONOMY OF THE INDIAN MEMBERS OF FAMILY "ASPLENIACEAE"

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ABSTRACT

Taxonomic problems of family "Aspleniaceae" are discussed and confusions have been cleared about *Asplenium dalhousiae*, *A. laciniatum*, and *A. planicaule*, *Athyrium boryanum*, *Diplazium polypodioides*, and *D. asperum*. Comments have been made on the generic status of *Ceterachopsis*, *Athyrium*, *Diplazium* and *Cornopteris*. It has been proposed that *Digrammaria* may be recognised as a sub-genus within large and comprehensive genus *Diplazium* Swartz so as to represent such elements as *Diplazium esculentum* that show peculiar venation and anatomical structure not seen in any other species of the genus. Various taxonomic criteria have been enumerated with instances from amongst the "Aspleniaceae". Salient features of six new ferns discovered from the Himalayas, are given.

INTRODUCTION

Diels (1898-1900) was the first to introduce the modern usage of family as a formal category. His family Asplenieae is a heterogeneous group of 15 genera comprised of two subdivisions as Aspleninae and Blechninae. Later on, Bower (1928) separated these two sections as Asplenioid and Blechnoid ferns. The former group was sub-divided into two sections consisting of 'sori indusiate' (*Asplenium*, *Athyrium*, *Diplazium* and *Diplaziopsis*) and 'sori exindusiate' (*Ceterach* and *Pleurosorus*). Bower was a great morphologist no doubt, but he assembled *Asplenium* and *Athyrium* (also *Diplazium* and *Diplaziopsis*) in the same group of his indusiate Asplenioid ferns though these genera apart from other details, differed markedly in the matter of vascular supply to sorus.

Christensen (1938) and Ching (1940) utilised the information afforded by Bower and segregated these two genera namely, *Asplenium* and *Athyrium* and their allies in sections or tribes but in the same group. Ching (1940) was perhaps the first to construe the word Aspleniaceae for a family though he attributed the family name to Presl who used this name as a tribus. The correct citation should, therefore, be family Aspleniaceae (Presl) Ching. This of course includes both the tribes or groups as represented by *Asplenium* and *Athyrium*. Dickason's (1946) approach was practically the same as that of Ching. Copeland (1947) and Holttum (1946, 1949) almost simultaneously segregated the two elements of Ching's family Aspleniaceae. The former author removed, though unnaturally, *Athyrium* and its allied genera to his family Aspidiaceae while the latter created a sub-family Athyrioideae of his family Dennstaedtiaceae for these, which, of course, is a better proposition. Alston (1956) raised Holttum's sub-family Athyrioideae to a family rank as Athyriaceae Alston, the position of Aspleniaceae being the same (now only composed of *Asplenium* and its allies). Recently Pichi-Sermolli (1958, 1959) placed these two families Aspleniaceae (cf. Copeland, 1947) and Athyriaceae (cf. Alston, 1956) in order Aspidiales of sub-class Filicideae but without assignment of various genera.

DELIMITATION OF GENERA

At present the more acceptable view is to split the conventional family "Aspleniaceae" into two and to segregate *Asplenium* and *Athyrium* group of fern genera into separate families.

Broadly speaking, the present day family Aspleniaceae as defined by Copeland (1947) and Alston (1956) is limited only to 'Group A' of Christensen's (1938) sub-family Asplenioideae or Tribe Asplenieae of Ching's (1940) family Aspleniaceae or sub-family Asplenioideae of Holttum (1946, 1949) and is typified by *Asplenium* Linn. Similarly, family Athyriaceae (of Alston, 1956) includes only 'Group B' of Christensen's (1938) sub-family Asplenioideae or Tribe Athyrieae of Ching's (1940) family Aspleniaceae or sub-family Athyrioideae of Holttum (1946, 1949) and *Athyrium* Röth typifies it.

As yet divergent viwes are held about the composition of these two families. The true Asplenioid ferns, *Asplenium* and its derivative genera are markedly different from *Athyrium* and its allies. These two diverse elements which were previously grouped together, have developed from different sources. These differ apart from chromosome number, in scale structure, supply to sorus, outline of leaf traces in petiole and rachis and finally in the structure of meristele.

Now the main interest centres around the question of delimitation of genera in these two families. The degree of variance to which different genera have been treated by various systematists, will be clear from comparison (cf. Table I) of the various systems of classification. The sequence of enumeration of genera is the same as mentioned by each author.

In India these two families are represented by only seven genera as enumerated below:

(i) Family Aspleniaceae: *Asplenium* Linn. and *Ceterach* Garsault

(ii) Family Athyriaceae:- *Athyrium* Röth, *Diplazium* Swartz, *Diplaziopsis* C. Chr., *Cystopteris* Bernh. and *Cornopteris* Nakai

An interesting point revealed by perusal of Table I is the controversy about the status and limits of various genera.

TABLE I

Showing the position of genera of family Aspleniaceae (sensu lato)

Bower (1928)	Christensen (1938)	Ching (1940)	Holttum (1946, '49)	Copeland (1947)	Alston (1956)
Asplenioid Ferns (a) Indusiate : *Asplenium* Linn. *Athyrium* Röth *Diplazium* Sw. *Diplaziopsis* C. Chr. (b) Exindusiate : *Ceterach* Garsault *Pleurosorus* Fe'e	Sub Family *Asplenioideae* Group A : Asplenieae *Asplenium* Linn. *Ceterach* Garsault *Pleurosorus* Fe'e *Phyllitis* Ludwig *Camptosorus* Link *Diplora* Baker *Pleurosoriopsis* Fomin Group B : Athyrieae *Athyrium* Röth *Diplazium* Sw. *Diplaziopsis* C. Chr. * *Cystopteris* Bernh. *Stenolepia* v.A.v.R.	Family Aspleniaceae Tribe Asplenieae (a) Sori indusiate *Phyllitis* Ludwig *Boniniella* Hyata *Camptosorus* Link *Diplora* Baker *Neottopteris* J. Sm. *Loxoscaphe* Moore *Asplenium* Linn. *Holodictyum* Maxon *Ceterachopsis* Ching (b) Sori exindusiate *Ceterach* Garsault *Pleurosorus* Fe'e ** *Pleurosoriopsis* Fomin Tribe *Athyrieae* *Diplazium* Sw. *Cornopteris* Nakai *Diplaziopsis* C. Chr. *Athyrium* Röth *Deparia* H. & G. *Cystopteris* Bernh. *Acystopteris* Nakai *Stenolepia* v.A.v.R. *Gymnocarpium* Newman (= *Currania* Copel.)	Sub Family *Asplenioideae* *Asplenium* Linn. *Phyllitis* Ludwig *Diplora* Baker *Camptosorus* Link *Ceterach* Garsault *Pleurosorus* Fe'e *Pleurosoriopsis* (?) Fomin Sub Family *Athyrioideae* *Athyrium* Röth (including *Diplazium* Sw.) *Cystopteris* Bernh.	Family Aspleniaceae *Asplenium* Linn. *Loxoscaphe* Moore *Diellia* Brack. *Ceterach* Garsault *Pleurosorus* Fe'e *Holodictyum* Maxon *Camptosorus* Link *Antigramme* Presl *Schaffneria* Fe'e Family *Aspidiaceae* (in part) *Currania* Copel. *Cystopteris* Bernh. *Athyrium* Röth (including *Diplazium* Sw ; *Deparia* H. & G. and *Cornopteris* Nakai) *Diplaziopsis* C. Chr. *Callipteris* Bory *Hemidictyum* Presl *Anisocampium* Presl	Family *Aspleniaceae* *Asplenium* Linn. Family *Athyriaceae* *Athyrium* R th. *Diplazium* Sw. *Matteucia* Todaro *Woodsia* R. Br. *Stenolepia* v.A.v.R. *Cheilanthiopsis* Hieron. *Cystopteris* Bernh.

* Treated as genus 'Insertae Sedis' by Bower (1928).
** Placed in family Pteridaceae by Copeland (1947). I have examined the Japanese material of Pleurosoriopsis makinoi (Maxim.) Fomin. The scale, sorus and spore characters indicate th t it belongs to family Aspleniaceae.

It may be mentioned that the genus *Asplenium* Linn. includes *Neottopteris* J. Smith, (*Thamnopteris* Presl), *Asplenidictyum* J. Smith, *Ceterachopsis* (J. Smith) Ching, *Caenopteris* Berg. (*Darea* Juss.), and *Phyllitis* Ludwig (*Scolopendrium* Adanson). In addition, out of the genera enumerated above in Table I, three more namely, *Gymnocarpium* New., *Mettucia* Todaro and *Woodsia* R. Br. are also met with in India. These have not been included above because in my opinion these are not at all related to the groups to which these have been referred to by various systematists. *Gymnocarpium* is *Lastrea* (cf. Copeland, 1947). Similarly, in *Mettucia* the fronds are dimorphic with sori practically terminal on the veinlets whereas in *Woodsia* the sori are sub-terminal or dorsal on the veins with basal indusium. All of these have nothing in common with Athyrioid genera.

TAXONOMIC COMPLEXES

(1) *Asplenium dalhousiae* Hook. *Christensen* (1906) transferred this fern under genus *Ceterach* as *C. dalhousiae* (Hook.) C. Chr. and since then in the recent literature on Indian ferns it has been referred to as such by Mehra (1939), and Stewart (1942, 1945, 1957). Wagner (1954) has also used this name during his studies on the genus *Diellia*. This is perhaps because of its very close external resemblance with *Ceterach officinarum* Lam. & DC. which is also met with in the North Western Himalayas. It may be pointed out that none of the generic characters of *Ceterach* such as exindusiate sori, fused veinlets and presence of scales on the under surface of pinna lobes are exhibited by *A. dalhousiae*. The earlier name *Asplenium alternans** by Wallich is a nomen nudum being not validly published at all and therefore should not be used any longer. It will be totally unjustifiable to include it in *Ceterach*.

Ceterachopsis was established by J. Smith as early as 1875 (Hist. Fil. 317) and in all probability was typified by *A. dalhousiae*. However, Christensen (1906) did not recognise it but merged with *Ceterach*. Later on, Ching (Bull. Fan. Mem. Insti.

* This name was considered as valid in an earlier paper (cf. Bir, 1959) due to oversight.

Biol. Bot. Ser. 10:9.1940) revived and revised the genus *Ceterachopsis* and made *Asplenium dalhousiae*, the type species. He attributed only two representatives to this genus, being distributed in the Himalayas, China and Abyssinia. The other one is *Asplenium paucivenosum* (Ching) S. S. Bir, comb. nov.

Basionym: *Caterach paucivenosa* Ching in Bull. Fan Mem. Inst. Biol. 2:210. t. 28. 1931.

Synonym: *Caterachopsis paucivenosa* Ching in Bull. Fan Mem. Inst. Biol. Bot. Ser. 10: 9. 1940.

In my earlier papers (cf. Bir, 1959, 1960) I was wrong in attributing the transfer of the name *Paucivenosa* from genus *Caterach* to *Asplenium* to Copeland (Genera Filicum, 169, 1947) who had only suggested that *Caterach paucivenosa* Ching is an *Asplenium* and had not actually proposed a new combination for it under *Asplenium*.

In the Herbarium of Lloyd Botanic Garden, Darjeeling and Forest Research Institute, Dehra Dun, (India), I have examined specimens of *Asplenium paucivenosum* from the Eastern Himalayas labelled as A. *alternans* Wall. (=A. *dalhousiae* Hook.) which is met within the North Western Himalayas with Nainital as the eastern limit. Panigrahi's (1960) recent report of *A. alternans* from Eastern India is probably based on specimens of *A. paucivenosum* which is extremely allied to the other fern. *Asplenium paucivenosum* differs from *A. dalhousiae* by its rather broad pinna lobes, with conspicuously hyaline and cretaceous margin and well developed, persistant indusia at maturity. (Figs. 1-4).

The genus *Ceterachopsis* cannot be recognised simply on the basis of some supposed resemblance of minor characters with *Ceterach*. The best course would be to accord sub-generic rank to *Ceterachopsis* representing elements consisting of *A. dalhousiae* and *A. paucivenosum* within the large comprehensive genus *Asplenium* because with Copeland's (1947) concept of *Asplenium* there is no alternative but to recognise few sub-genera representing different evolutionary tendencies of morphological nature. These two species of *Asplenium* provide a clue how *Ceterach* has evolved from *Asplenium* through loss of indusium and webbing of veins (cf. Bir, 1963).

(2) *Asplenium laciniatum* Don & *A. planicaule* Wall. The herbarium specimens of these two 'spleenworts' have often confused the taxonomist. A study of available literature shows that *A. planicaule* Wall. has mostly been treated as synonym of *A. laciniatum* Don by Clarke (1880), Beddome (1892), Mehra (1939) and very recently by Panigrahi (1960). Christensen (1906) in his Index Filicum considered this species as a variety of *A. laciniatum* and latter on in 1934 (Index Filicum, Supplm. III. 36) he recognised *Asplenium planicaule* Wall. as a separate species. Thus a state of uncertainty exists about the status of this specis. Dickason (1946) and Kachroo (1953) while enumerating ferns of Burma and Assam respectively, only listed separately these two ferns but without any details of differences. Extensive collections in the field show that these species though closely similar are distinct from each other in the following characters:—

(i) The scales in *A. laciniatum* have a distinctly hyaline margin while this is not the case in *A. planicaule* (Figs. 5-6).

(ii) Lobes in *A. planicaule* are pointed while these are blunt in *A. laciniatum*. The texture in *A. laciniatum* is fleshy which is not the case in the other species.

(iii) The sori in *A. laciniatum* are swollen, short and confined to the middle portion of veinlet while in *A. planicaule* these are elongated and more or less reach the margin of the pinnae (Figs. 7-8).

(iv) Indusium in *A. laciniatum* is thick and conspicuous but in other species it is membranaceous.

(v) In *A. laciniatum* vegetative buds are present on the pinnae, arising on upper side in the vicinity of veinlet. These are absent in *A. planicaule*.

Asplenium laciniatum is confined only to the Eastern Himalayas and has never been collected west of Nainital whereas *A. planicaule* is represented throughout the Himalayas from Dalhousie to Khasya Hills.

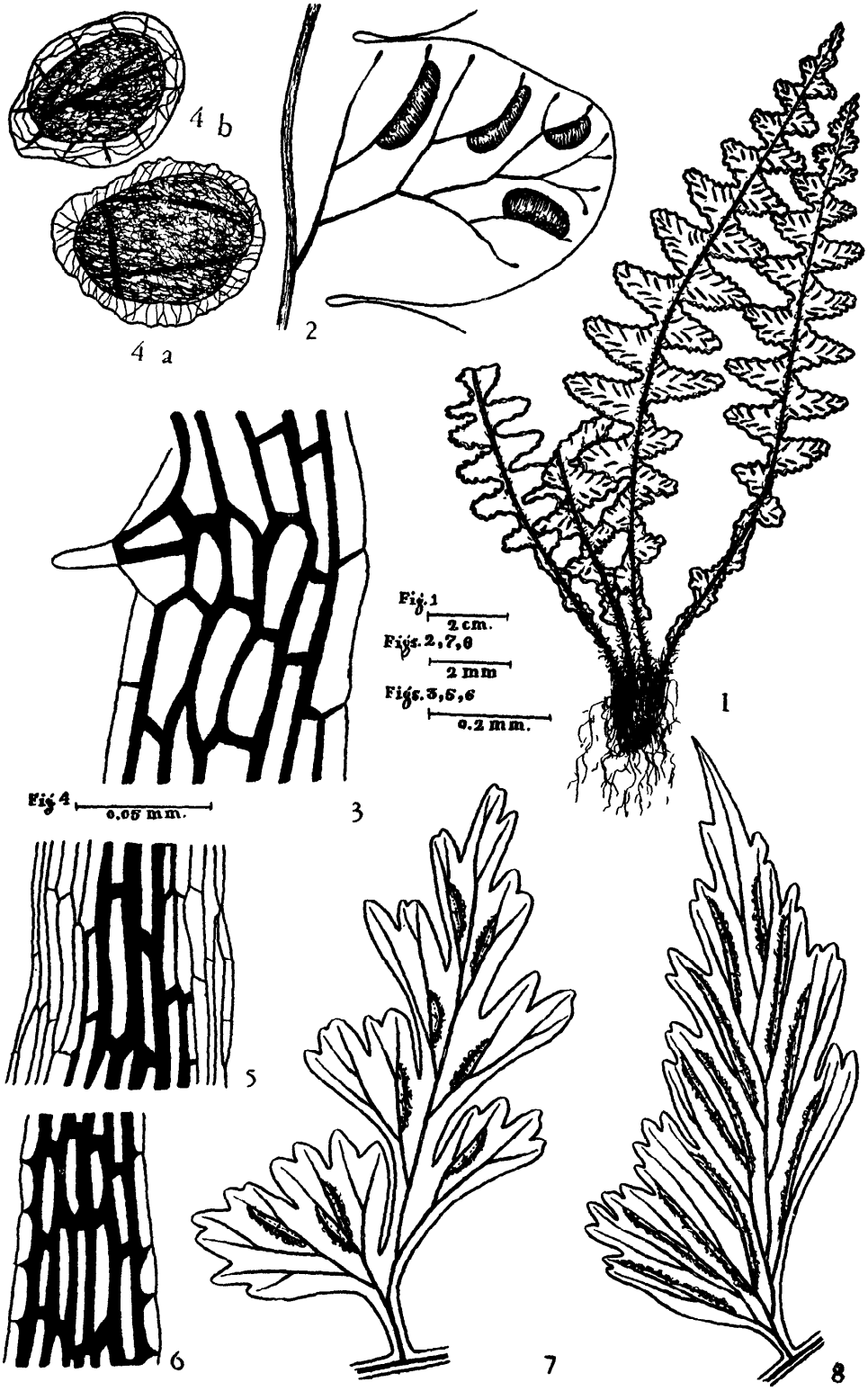
From Darjeeling and Sikkim State one new variety each of *A. laciniatum* and *A. planicaule* have been discovered.

(a) *Asplenium laciniatum* Don var. *acutipinna* Bir. Plants are large as the type; pinnae 3 cm. long, 0.6-0.8 cm. wide, narrower than the type, apex acute, margin obliquely cut into well-spread lobes which are seldom bifid, upper margin auricled at the base, lower one slightly truncate; sori linear, on the general surface of the pinnae rather than the lobes (Fig. 9).

In contrast to the type, specimens of the pinnae of varieties *sub-integrifolium* and *acutipinna* are not incised into clear cut acroscopic basal and marginal lobes. In variety *sub-integrifolium* the pinnae have a broader aspect than either the type or var. *acutipinna*.

(b) *Asplenium planicaule* Wall. var. *obtusum* Bir. Pinnae generally broader with obtuse apex, the apices of the incisions blunt. There is also formed a basioscopic smaller lobe which is absent in the type. The acroscopic superior lobe is well developed than the type (Fig. 10).

(3) Distinctness of *Athyrium* Röth and *Diplazium* Swartz. Copeland (1947) following Milde (Bot. Ziet. 373. 1866) merged *Diplazium* with *Athyrium* and this view was accepted by Holttum (1954). But recently accumulated cytological data (cf. Manton & Sledge, 1954; Manton, 1954, 1959; Mehra & Verma, 1957; Mehra & Bir, 1960; Brownlie, 1958; and Bir, 1958, 1959, 1960, 1961 a,b,



Figs. 1-4. *Asplenium paucivenosum* (Ching) Copel.

1, Habit ; 2, pinna lobe ; 3, portion of scale showing marginal projection ; 4a, spore (octaploid race) ; 4b, spore (tetraploid race).

Fig. 5. Scale from rhizome apex of *Asplenium laciniatum* Don. Note the hyaline margin.

Fig. 6. Scale from rhizome apex of *Asplenium planicaule* Wall.

Fig. 7-8. Pinna of *Asplenium luciniatum* and *A. planicaule* respectively.

1962b) has clearly indicated that *Athyrium* is based on $x=40$, and *Diplazium*, $x=41$ and are distinct genera. This conclusion arrived at on cytological ground has been supported by other morphological characters brought out by the author during his studies on Indian members. Both these genera differ in scale structure markedly. The scales are prominently toothed and black-edged, the marginal cells having thickened walls than the rest in *Diplazium*, whereas in *Athyrium* these are usually smooth-edged and marginal cells never thickened (Figs. 11-14). It will be pertinent to point out that with the sole exception of a fern commonly called *Diplazium japonicum* (Thbg.) Bedd., all the Himalayan species of *Diplazium* and *Athyrium* identified in the field on the basis of soral characters, have yielded cytological results and details of scale structure in conformity with the above mentioned distinctness. Therefore, it is stressed that the shape of the sorus, its structure and indusium are dependable characters in identification of atleast the Indian members of these two genera.

(4) *Athyrium boryanum* (Willd.) Tagawa. This fern has met with many vissitudes of taxonomic position and has often been referred to quite a different and wide apart genera. Originally it was described as *Aspidium boryanum* by Willdenow (in Linn., Spec. Pl. ed. 4, V: 285, 1810) and later on called *Phegopteris kingii* by Beddome (Handb. Supplm. 84. 1892), *Polypodium tripinnatum* by Clarke (Trans. Linn. Soc. Bot. London 1:545. 1880) and *Dryopteris boryana* by Christensen (Index Filicum 225. 1906). Firstly, Tagawa (Acta Phytotax. et Geobot. 4:144. 1935) and then Ching (Lignan Sci. Jour. 15:296. 1936) transferred it to genus *Athyrium*. Copeland (1947) recently added this to genus *Ctenitis* primarily on the basis of presence of articulated hairs. Holttum (1954) relying more on anatomical features justified Tagawa's and Ching's treatment. It differs markedly from *Dryopteris* and *Ctenitis* in the structure of stipe in always having only 2 vascular strands, whereas in the other two genera the number of vascular strands in stipe is always more than two. The cytological studies by Mehra & Verma (1957) and by the author on this fern from various parts of the Eastern Himalayas Bir, (unpublished), have revealed that this is a diploid species with $n=40$. So the cytological evidence supported the earlier conclusions arrived at on the basis of anatomy etc. in relegating it to the genus *Athyrium* (Mehra & Verma, loc. cit.). Both *Ctenitis* and *Dryopteris* are based on x=41, while *Athyrium* (s.s.) species have invariably been shown to have $x=40$.

Madame Tardieu Blot (1958) considered the similarity of this fern with genus *Cornopteris* and proposed a new combination under that genus. Commenting upon Malayasian Ferns Holttum (1958) compared the morphology of *Athyrium boryanum* with *Cornopteris opaca* (Don) Tagawa and concluded that this fern does not belong to *Cornopteris* as that genus has been redescribed by Ching (Lingnan Sci. Journ. 21:32. 1945) to show characteristically "exindusiate, elongated sori". Both these characters are absent in *Athyrium boryanum* which shows rounded sori covered with small reniform, fugacious indusium. Holttum (1958) proposed a new genus *Parathyrium* typified by this fern. However, some time later in 1959, Holttum (personal communication) abandoned his genus *Parathyrium* since Ching had already established genus *Dryoathyrium* for this species in 1941. There are other species of *Athyrium* namely, *A. japonicum* (Thbg.) Copel. and *A. thelypteroides* (Michx.) Desv. which share with *A. boryanum* the character of presence of lax, septate, hairs, but these have elongated sori, few of which are typical athyrioid and have been shown to be based on $x=40$ (cf. Bir, 1961b). *Athyrium japonicum* and *A. boryanum* also resemble in the similar structure of spores. It is evident that *Athyrium boryanum* is an aberrant species possessing rounded sori and thus showing a link with *Dryopteris-Ctenitis* series of Aspidiaceous stock. Since this fern combines the *Ahyrioid* and *Dryopteroid* characters, therefore, the best solution is to follow Ching in placing it in a separate genus *Dryoathyrium* (Ching in Bull. Fan. Mem. Inst. Biol. 9:81. 1941), which it typifies and in future it may be referred as *Dryoathyrium boryanum* (Willd.) Ching.

(5) *Diplazium polypodioides* Bl. and *D. asperum* Bl. [=*D. sikkimense* (Clarke) C. Chr.] are very closely allied to each other and have often been confused especially the dry herbarium material. Clarke (1880) and Beddome (1892) treated both these species separately and v.A.v.R.* has also suggested their distinctness. But recently Holttum (1954) followed Raciborski* and united *D. polypodioides* Bl. with *D. asperum* Bl. under genus *Athyrium*. The study of fresh material of both these species has revealed that though apparently looking alike, these two species can be segregated on the basis of the following differences:

(i) The rhizome is ascending in *D. polypodioides* but erect and arborescent in *D. asperum*.

(ii) The upper portion of the stipe and primary and secondary rachises are naked and straw-coloured in *D. polypodioides*, while these are densely scaly, prickly and dark-brown in *D. asperum* (Figs. 15-16).

(iii) The segments are relatively narrow and deeply cut in *D. asperum* as compared to the other species.

(iv) Perisporium on the spores of *D. asperum* is lacking, while it is present in *D. polypodioides* (Figs. 17-18).

(6) *Diplazium esculentum* (Retz.) Sw. It was originally described as *Hemionitis esculenta* by

* Not consulted in original. Reference from Holttum (1954).

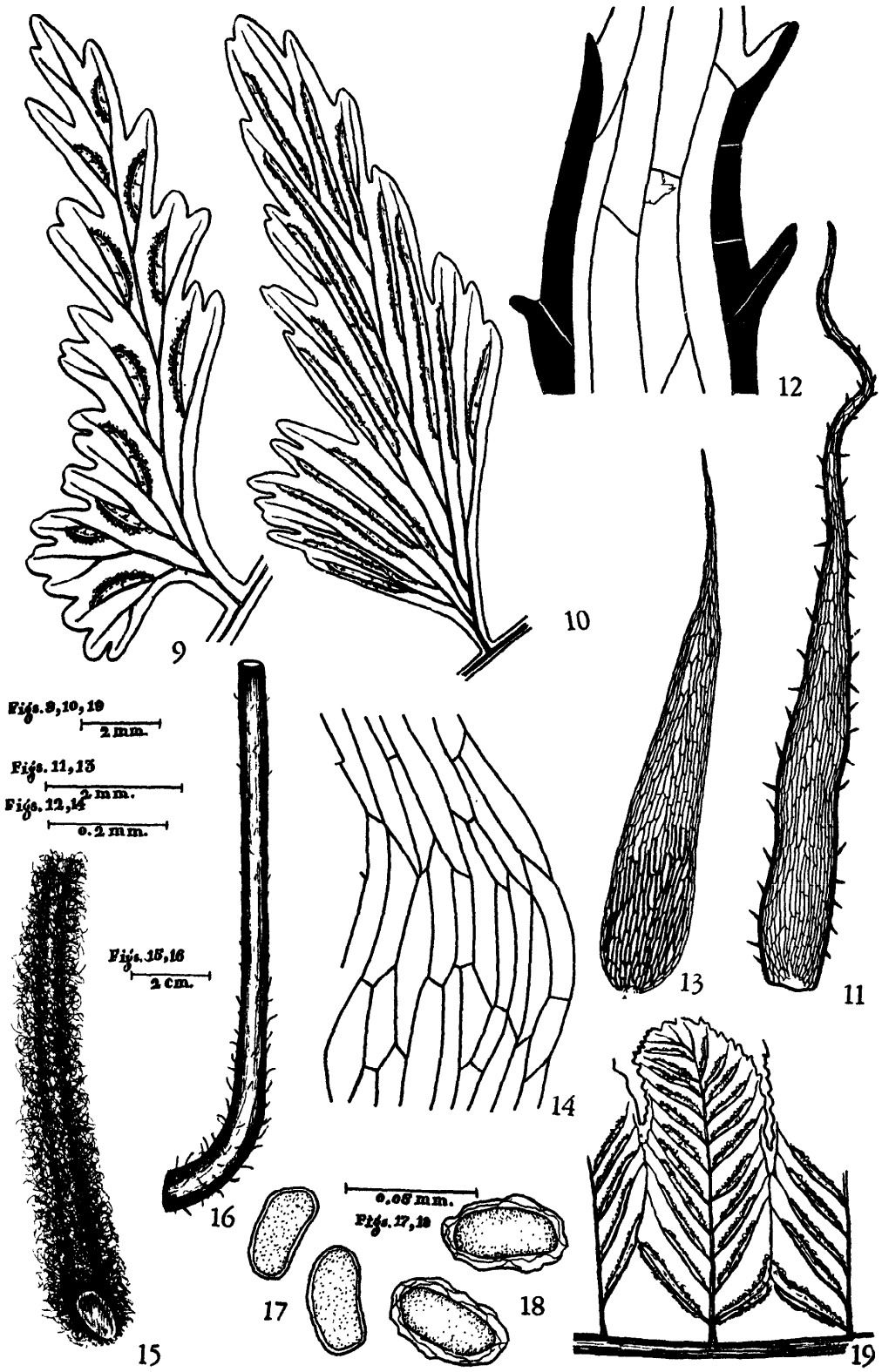


Fig. 9. Pinna of *A. laciniatum* Don var. *acutipinna* Bir Fig. 10. Pinna of *A. planicaule* Wall. var. *obtusum* Bir Figs. 11-12. Scale structure in *Diplazium* Sw. 11, Scale of *D. asperum* Bl. ; 12, Portion of scale of *D. stolickae* Bedd. with prominently thickened marginal cells. Figs. 13-14. Scale structure in *Athyrium* Röth 13, A scale from rhizome of *A. mehrae* Bir ; 14, Portion of scale of *A. mehrae*. Here all the cells are uniformly thickened. Figs. 15-16. Lower portion of stipe of *Diplazium asperum* Bl. and *D. polypodioides* Bl. respectively. Figs. 17-18. Spores of *D. asperum* and *D. polypodioides* respectively. Fig. 19. A portion of pinna of *Diplazium esculentum* (Retz.) Sw. showing venation.

Retzius (Obs. Bot. 6:38. 1791) and since then it has been afflicted with different names under *Asplenium, Diplazium, Anisogonium, Microstegia, Digrammaria, Callipteris, Gymnogramme* and *Athyrium*. Recently Copeland (1947) while defining various genera of ferns merged *Diplazium, Anisogonium, Microstegia* and *Digrammaria* with *Athyrium*. Exceptionally long list of synonyms can be compiled up for this species. But now its name as *Diplazium esculentum* (Retz.) Sw. or *Athyrium esculentum* (Retz.) Copel. is more or less widely used. The species has been cytologically investigated from Malaya by Manton (1954) and the Himalayas by Bir (1961b). It has been found to possess $n=41$. Therefore, the cytological evidence favours the view that it does not belong to *Athyrium* as earlier thought by Copeland (1947) and Holttum (1954). *Diplazium esculentum* shows special features of interest as enumerated below:

(i) It possesses a peculiar type of venation which is hardly seen in any other species of genus *Diplazium*. The lower 2-3 pairs of veinlets of adjacent groups form an excurrent veinlet by fusion towards the sinus between two lobes (Fig. 19). This excurrent veinlet in this species is similar to that seen in *Cyclosorus*.

(ii) The internal structure of *Diplazium esculentum* is very interesting. The anatomy was worked out by Ogura (1927). The details were also studied by the author few years ago, being totally unaware of the earlier work. But this reinvestigation has revealed more details concerning departure of leaf traces. The rhizome is dictyostelic with medullary bundles. The outer ring consists of 3-6 meristeles often ensheathed with sclerenchymatous patches. The medullary bundles are small in size and often appear independently in the pith. In addition, these medullary bundles also arise by means of internal thickenings of the meristele especially in young plants. The medullary bundles present near the leaf bases become fused with the two bundles of the leaf trace forming a U-shaped structure at the base of the petiole, though higher up it consists of only two leaf strands which fuse into one in rachis (Figs. 20-23). The details are intended to be published elsewhere. In young individuals the medullary bundles may be absent. Their appearance at least in independent fashion in the pith depends upon the size of the rhizome which is usually wide creeping with fronds borne on all the sides but under cultivation tends to become suberect or sub-arborescent.

To the best of my knowledge such medullary bundles are not reported from any other species of *Diplazium*, except in *D. marginatum* (L.) Diels (cf. Stenzel, 1861), which is the type and sole species of the genus *Hemidictyum* Presl with far more complicated anastomosis of veins (forming areolae all ending in a conspicuous intramarginal vein) than seen in this species. The presence of medullary bundles in *Diplazium esculentum* reminds us of their occurence in *Cyathea spinulosa* and other members of family Cyatheaceae.

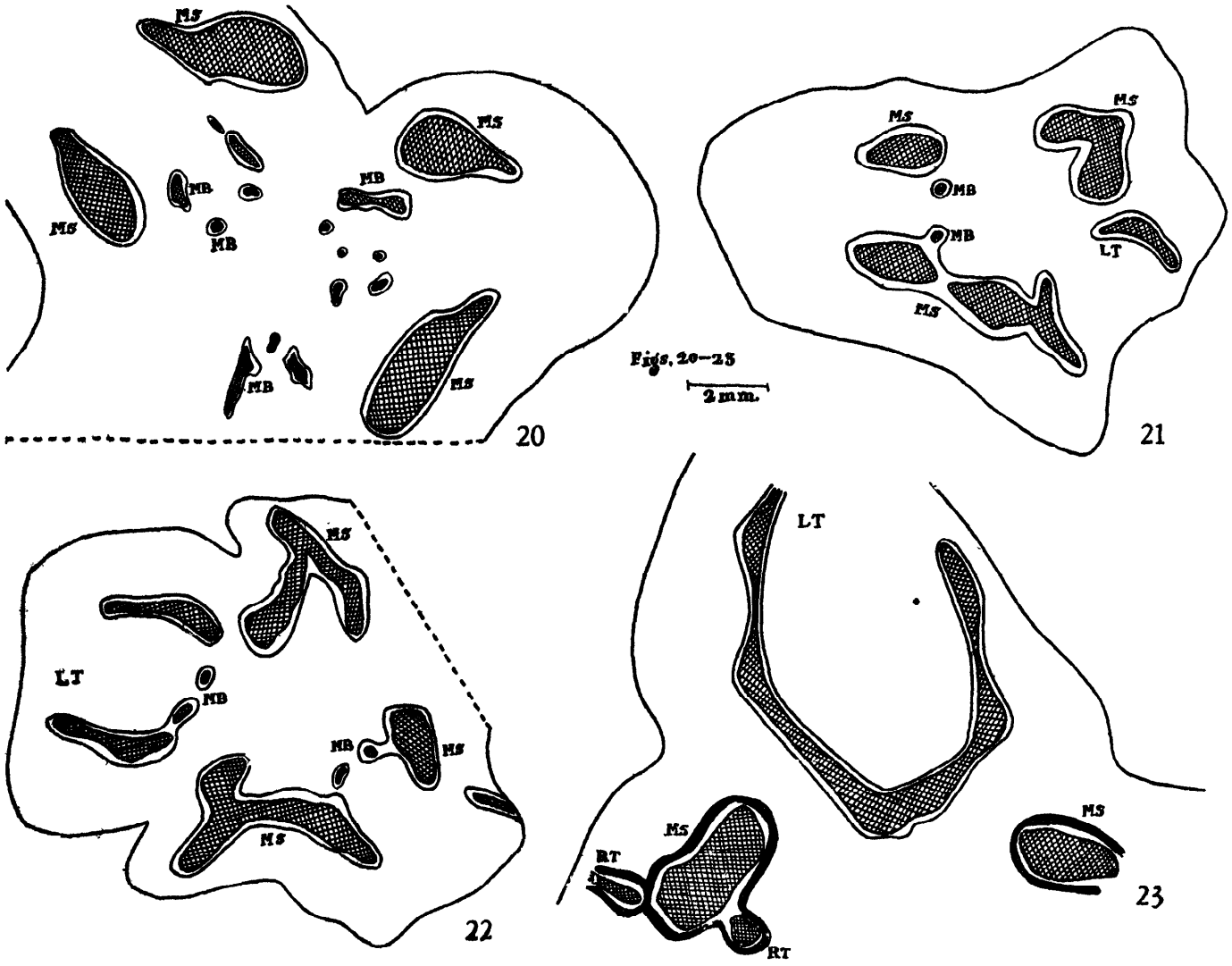
Nomenclatural considerations: As this species markedly differs from other members of genus *Diplazium* Swartz in venation and anatomical characters, so this needs to be egregated from rest of the species of *Diplazium* whether as a genus or sub-genus, and now the next question arises as to what should be the suitable name for it.

Presl (Tent. Pterid. 116. 1836) listed *Diplazium esculentum*. He had referred to *Anisogonium* very heterogenous group of ferns, some as *A. integrifolium* and *A. cordifolium* showing 'aerolate' type of anastomosis of veinlets near the margin and that too casually rather than regularly. The genus *Anisogonium* was a mixture as first described (Copeland, 1947) and none of the species mentioned by Prest, typifies it. The pattern of venation in *Callipteris* Bory is also different where this fern cannot be referred to. In the type species, *C. prolifera* Bory [=*Athyrium accedens* (Bl.) Milde] the lateral veinlets of adjacent groups anastomose and produce a series of parallelogram shaped areolae while the small veins near the edge of the lamina also fuse irregularly. Such condition of venation is never seen in *Diplazium esculentum*. The third genus, *Microstegia* Presl, to which this fern has been referred to, has been irregularly described and its type species *M. sylvatica* has usually free veins whereas in this the veins are fused.

The next genus is *Digrammaria* in which the present fern has been placed. Presl (Tent. Pterid. 117. 1836) had probably this fern, *D. esculentum* in mind when he established his genus *Digrammaria* because the two synonyms, namely *Asplenium ambiguum* Sw. and *Diplazium malabaricum* Spr. mentioned for the sole species, *Digrammaria ambigua* of this genus, are *Diplazium esculentum* (Retz.) Sw. His illustrations of *Digrammaria* (Tent. Pterid 117. t. 4. figs 12 & 17. 1836) are of different fern which he later on (Presl Emp. Bot. 142. 1849) described again as *Heterogonium aspidioides* Presl, a fern with Tectarioid venation and typifying the genus *Heterogonium* Presl. As *Digrammaria ambigua* Presl was illustrated by a wrong figure, so this name cannot be considered to have been validly published. Hence this name cannot be applied here.

Hooker (1840) and Fée (1850-52) accepted Presl's genus *Digrammaria* and proposed two names, *D. ambigua* Hook. and *D. esculenta* Fée respectively for the species in question. So the correct reference of this fern to *Digrammaria* dates back to these taxonomists. However, Fée's name has priority because it is based on specific epithet *'esculenta'* under which this fern was described first of all as *Hemionitis esculenta* by Retzius in 1791.

Copeland's (1947) objection regarding recognition of *Digrammaria* is that the fusion of veinlets is not



Figs. 20-23. T. S. Rhizome of *Diplazium esculentum*.

20, shows an outer ring of four meristeles (MS) and large number of medullary bundles (MB) ; 21, shows the origin of medullary bundles (MB) as internal thickenings of meristeles. The two bundles of leaf trace (LT) have almost departed from meristeles on the right hand side ; 22, shows the fusion of medullary bundles (MB) with the leaf bundles near the leaf base on left hand side. Two medullary bundles are also seen departing from meristeles ; 23, shows U-shaped structure near the leaf base formed as a result of fusion of medullary bundles with the two bundles of the leaf trace. (RT—Root Trace).

a constant character especially so in New Guinea and Fiji populations. I have examined a large material of *Diplazium esculentum* from various regions of its distribution and of various ages and have found that the character of fusion of adjacent veinlets of two groups is a constant feature and presence of some free veins may possibly be an aberration. At the same time Copeland (1947) had also hinted at recognition of *Digrammaria* with *D. esculenta* as the sole representative.

Though on the basis of peculiar venation and anatomical structure, not seen in any other species of *Diplazium*, the present fern requires to be segregated into a separate genus yet I am of the opinion that the multiplicity of genera should be avoided. It has already been made amply clear in the foregoing account that genus *Digrammaria* Presl was typified by this fern and *D. esculenta* Fée is the only valid name for it under that genus. Therefore, it is suggested that *Digrammaria* Presl with *D. esculenta* Fée (=*Diplazium esculentum*) as the sole representative may be recognised as a subgenus within large genus *Diplazium* Swartz. By this new arrangement it will be possible to segregate such elements as represented by *Diplazium esculentum* within *Diplazium* that show advancement in venation and anatomical structure over the rest of the species of the genus. The retention of *Digrammaria** as a sub-genus within *Diplazium* is supported by the fact that it possesses the same chromosome number (x=41) and broadly speaking, the same structure of stipe, scale, sorus and sporangium as various species of *Diplazium*.

(7) Genus *Cornopteris* Nakai. It was described by Nakai (Bot. Mag. Tokyo 44: 7. 1930) from Japan and was typified by *C. decurrenti-alata* Nakai which is *Gymnogramme decurrenti-alata* of Hooker, *Athyrium decurrenti-alatum* of Copeland, and *Dryopteris decurrenti-alata* of Christensen. Ching (1940) maintained the identity of this genus and ascribed 13 species to it, practically all distributed in East Asia. A few years later, Ching (Lingnan Sci. Journ. 21:32. 1945) very carefully redescribed this genus and he stated that in this case the 'sori are elongated and ex-indusiate'. Later on, Copeland (1947) merged this genus with *Athyrium* and considered the type species, *C. decurrenti-alata* to be closely allied to *Athyrium japonicum* (Thbg.) Copel. The author (cf. Bir., 1961a) has shown that *A. japonicum* and *C. decurrenti-alata* (*Athyrium decurrenti-alatum* Copel.) are not at all related to each other. Apart from morphological differences (of cutting of lamina, sori and spore structure) both differ markedly cytologically too. *Athyrium japonicum* is based on x=40 (cf. Bir. 1961a) while *Cornopteris* on x=41.

Tardieu-Blot (1958) has transferred nine more ferns to this genus, out of which *Cornopteris boryana* (Willd.) Tard.-Blot, *C. Macdonelli* (Beddome) Tard.-Blot, and *C. tenuisecta* (Bl.) Tard.-Blot, are represented in India. In my opinion the first typifies *Dryoathyrium* Ching, the second belongs to genus *Athyrium* Röth and the last one is *Cystopteris* Bernh. Every one of these is indusiate and not related to true *Cornopteris*. Cytological data is also contrary to Tardieu-Bolt's conclusion. The Eastern Himalayan populations of the last one, *Cystopteris tenuisecta* (Bl.) Mett. are triploid and tetraploid with 2n=126 and n=84 respectively, based on x=42 (cf. Bir. 1961b).

In the recent years the concept of the genus *Cornopteris* has been greatly misunderstood and all the ferns with a typical *Athyrium* sori have been transferred to this genus. Tagawa (1959) has illustrated four different species of the genus from Japan alone.

Recent cytological observations on the Himalayan members of family "Aspleniaceae" by the author (cf. Bir, 1958, 1961a, 1961b) have shown that *Cornopteris* is based on x=41, whereas *Athyrium* on x=40. This cytological distinctness of the genus and other typical morphological characters as elongated or oblong but never 'hippocrepiform' exindusiate sori justify the generic status for *Cornopteris* and it cannot be merged with *Athyrium* as earlier done by Copeland (1947).

In India we have got two species of *Cornopteris*, namely, *C. opaca* (Don) Tagawa (*Leptogramma* or *Gymnogramme opaca*) and *C. birii* Ching. The former is very common in the Eastern Himalayas from Nepal to Bhotan, 1,200-2,100 metres and eastward to Khasya, while the latter is a new species described by the author from Sikkim State and named so by Prof. R. C. Ching. *Cornopteris birii* Ching is a tetraploid sexual species with $n=82$ (cf. Bir, 1961a, b) and is closely allied to *Athyrium japonicum* (Thbg.) Copel. in external look and outline of the frond but can be distinguished by: (i) comparatively narrow sinus in between the segments; (ii) naked sori which are never 'hippocroform' or horse-shoe-shaped or even double. (iii) Spores with smooth, broad transparent perispore, devoid of any thickenings; and (iv) finally, different cytological status. *Athyrium japonicum* has indusiate sori, often double or horse-shoe-shaped and spores with tuberculate thickenings.

TAXONOMIC CRITERIA AND THEIR EVALUATION

No doubt, the evidence from sori, their development, structure, shape and position is of great significance and this forms the basis of identification of different genera of ferns, but among the characters which with most likely give indications

* *Diplazium* Swartz (Schrader's Journal. "1800". 61. 1801) sub-genus *Digrammaria* (Presl) Bir, comb. et stat. nov. based on *Digrammaria* Presl, Tent. Pterid 117. 1836. The emended description for the sub-genus *Digrammaria* will be published elsewhere.

of affinity and are helpful in detailed taxonomy and which have not been fully exploited to that end, the following have proved to be of special significance during my studies on "Aspleniaceae." (i) Symmetry of the rhizome ; (ii) microscopical details of the dermal appendages (hairs and scales) ; (iii) external form and internal structure of petiole, rachises and leaflets of lamina ; (iv) sporangia and spore structure; and finally (v) cytology which is of fundamental importance. Now I will discuss briefly how the above mentioned criteria have helped in clearing some taxonomic tangles in "Aspleniaceae":

(a) **Rhizome:** So far, practically no emphasis has been laid on the rhizome characters, whether radial or dorsi-ventral in symmetry, creeping or short and ascending. This is a good character in preparing a key to the species and is of special importance in the case of genus *Athyrium*.

Two species, namely, *Athyrium schimperi* Moug and *A. polyspora* (Clarke) Ching are considered very closely allied or rather identical with each other, but these can be distinguished on the basis of widely creeping rhizome in *A. schimperi* and ascending in *A. polyspora*. Similarly *Athyrium rubricaule* (Edw.) Bir is very similar to *A. schimperi* in outline of lamina and cuttings of pinnae and pinnules, but it widely differs in possessing an ascending and short rhizome.

Another Western Himalayan fern that has often been confused with *A. schimperi* in the herbaria is *A. rupicola* (Hope) C. Chr. However, these can be easily separated if the rhizome is present with the herbarium specimen. *Athyrium rupicola* has small ascending rhizome with apex densely clothed in scales. Again, *Athyrium clarkei* Bedd. and *A. schimperi* Moug the two very closely similar ferns, can be separated on the basis of rhizome which is ascending in the former and creeping in the latter.

(b) **Dermal appendages—scales, hairs etc.:** The scales of *Asplenium* and *Athyrium* group of genera are different. These are clathrate in the former and non-clathrate in the latter (See Figs. 9 & 15). These are also helpful in distinguishing the genus *Diplazium* from *Athyrium*. Almost all the Himalayan representatives of *Diplazium* have black-edged scales with marginal cells thickened, whereas those of *Athyrium* have scales with marginal cells never thickened (cf. Figs. 13 & 15). The scales are very useful in distinguishing *Asplenium planicaule* from *A. laciniatum* as already referred to. *Asplenium crinicaule* Hance var. *sikkimensis* Bir is very much similar to *Asplenium planicaule* in appearance. But both have different types of scales. The rachis in *A. planicaule* is very sparsely covered with smooth margined scales, whereas in the other fern it is densely fibrillose with brown setaceous scales with marginal projections. The apical cell of the scale may or may not be glandular in various species. Such details can thus prove useful in distinguishing species.

The hairs are usually absent in various species of *Asplenium* except *Asplenium pumilum* Sw. var. *hymenophylloides* (Fée) Clarke. These bring out the resemblances of *Athyrium thelypteroides* (Michx.) Desv., *A. japonicum* (Thbg.) Copel. and *Dryoathyrium boryanum* (Willd.) Ching. The short pointed setae of *Athyrium setiferum* C. Chr., *A. proliferum* Moore and *A. pectinatum* (Wall.) Presl also serve as basis of specific diagnosis.

Another important criterion is the presence or absence of vegetative buds. One of the important characters of segregating *Athyrium schimperi* and *A. clarkei* is the presence of apical vegetative buds in *A. clarkei*. The presence of buds on the upper surface of old pinnae of *Asplenium laciniatum* is a specific character.

(c) **External form of the petiole:** According to Holttum (1958) the significant feature of the *Athyrium* (including *Diplazium*) rachis is the deep groove on the upper surface, this groove being open to admit the groove of a branch of higher order, the decurrent basioscopic edge of the latter being raised ; midribs of leaflets are also grooved. In *Diplazium* the edges of this rachis groove, at the junctions, are winged (see Holttum, 1954 p. 542, fig. 320), while in *Cornopteris opaca* (Don) Tagawa the wings are hardly present but the arrangement of the grooves is the same, the difference being the presence of fleshy horn-shaped outgrowths (whence the name *Cornopteris*) at the junctions of main rachis with its branches (Fig. 24). In case of *Dryoathyrium boryanum* (Willd.) Ching the structure of

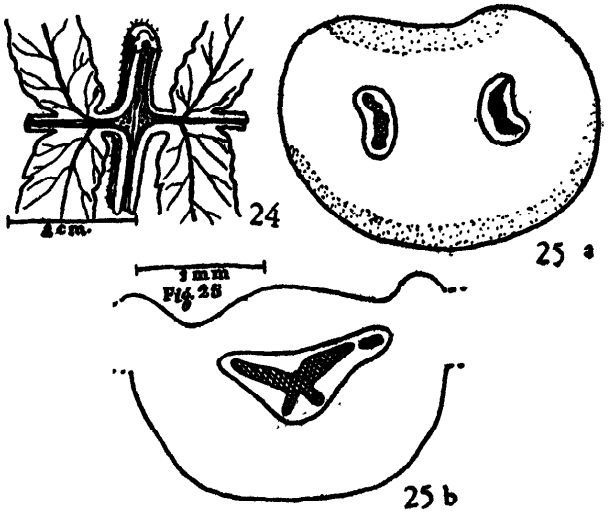


Fig. 24. *Cornopteris opaca* (Don) Tagawa, part of main rachis with bases of pinnae (after Holttum, 1958).

Fig. 25. *Asplenium nidus* Linn. a, T. S. stipe ; b, T. S. rachis showing x-shaped single strand.

rachis is very much as in *Ctenitis*, the rachises are slightly grooved but the grooves are not open at the junction of the branch. Such details of external form of the petiole can be very good generic or

specific feature and can indicate phylogeny. However, this aspect needs further careful study.

(d) **Anatomical details:** The stipe, rachis and meristele structure is a sure guide to identification of genera of *Asplenium* and *Athyrium* groups. *Asplenium* and *Ceterach* have two leaf strands in petiole fusing upwards in X-shaped fashion and the meristele is without xylem parenchyma intermixed with xylem elements, whereas in case of *Athyrium, Diplazium, Diplaziopsis, Cystopteris* and *Cornopteris* the two leaf strands fuse upwards in one V- or U-shaped strand in rachis and the admixture of xylem parenchyma with xylem element is a regular feature (Fig. 25-27). The presence of perforations towards the host side in the basal portion of rhizome of *Asplenium ensiforme* Wall. is a diagnostic feature and similarly presence of a single leaf trace in the petiole of *Asplenium trichomanes* Linn. and *A. varians* Hook. et Grev. is a specific character (cf. Bir, 1957). The stipe anatomy has also been useful in locating a form of *Diplazium polypodioides* Bl. from Lebong forest, Darjeeling with multiple leaf trace. The taxonomic status of this fern is being assessed. Similarly another species of *Diplazium* was discovered from near Lachen in North Sikkim which in all probability is a new species and in which the two leaf strands at the base of the petiole divide into four independent strands arranged in

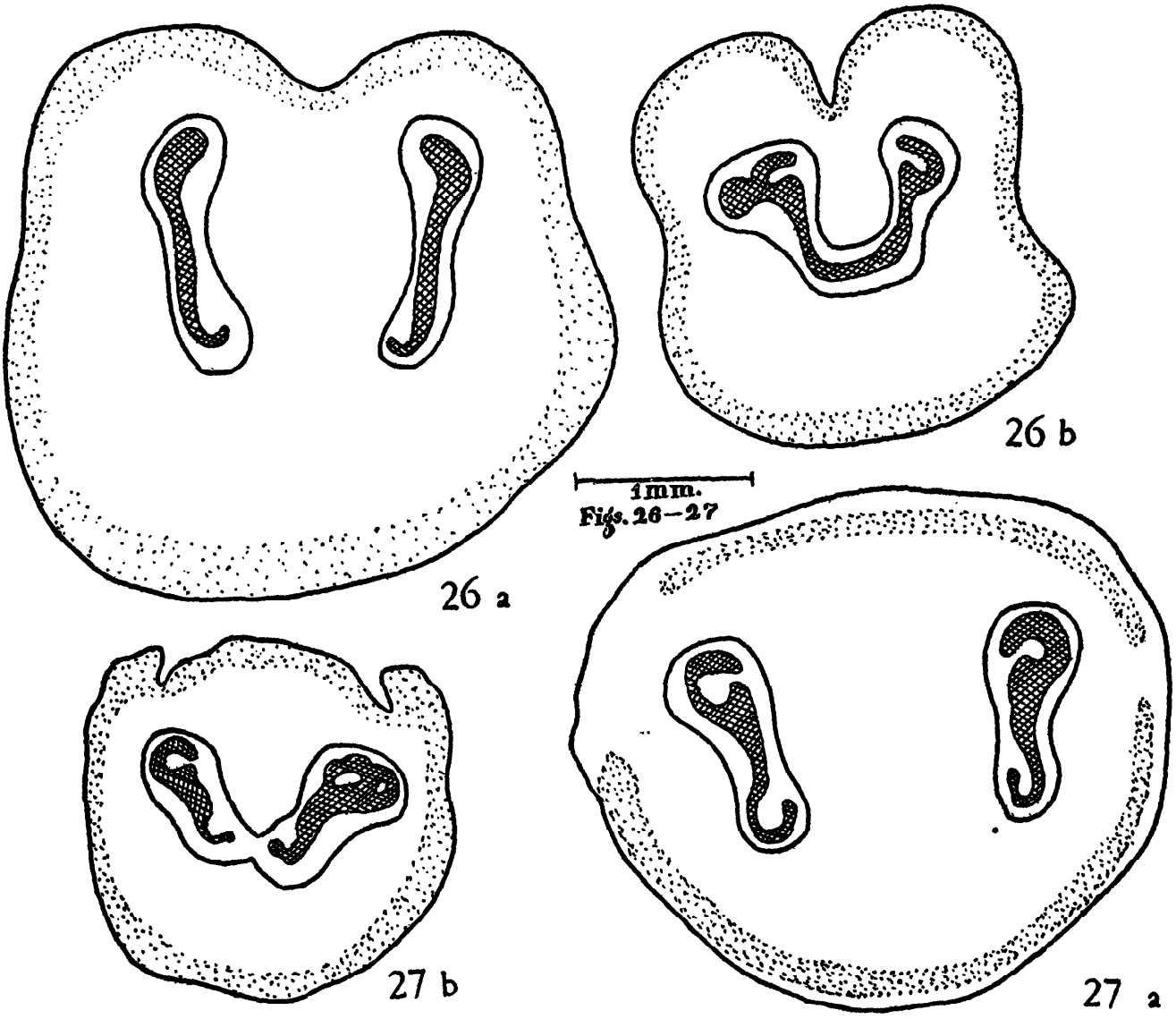


Fig. 26. *Diplaziopsis javanica* C. Chr. a, T. S. stipe showing two strape-shaped leaf strands ; b, T. S. rachis showing U-shaped single strand.

Fig. 27. *Diplazium stolickae* Bedd. var. *hirsutipes* Bedd. a, T. S. stipe at base ; b, T. S. rachis. Here the two strape-shaped leaf strands present in the stipe have fused into one U-shaped strand.

a ring (Fig. 28). This fern does not match with any other species present in our herbaria.

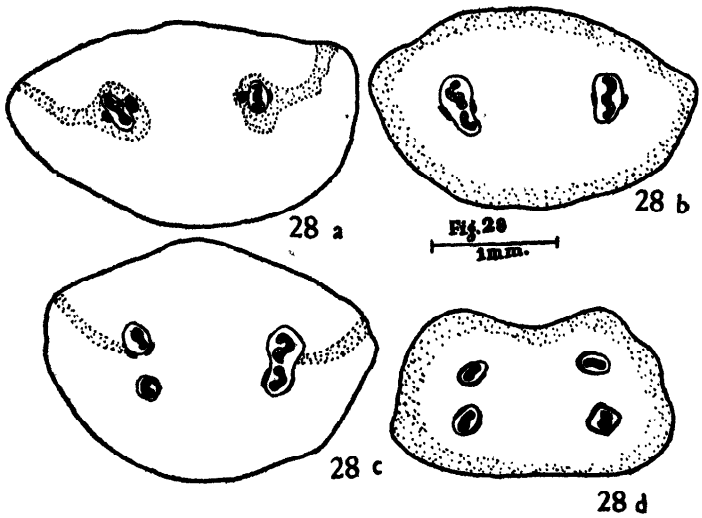


Fig. 28. T. S. petiole of *Diplazium* species (new) collected from Sikkim State. a-d, sections successively cut from base of the petiole upwards. These show division of each leaf strand into two thus giving a total of four strands upwards.

The roll of anatomy in elucidating the taxonomic status of *Diplazium esculentum* and *Athyrium boryanum* has already been discussed.

(e) **Sporangia and spores:** The sporangia of *Asplenium* have got long stalk consisting of a single row of cells, while in case of *Diplazium* and *Athyrium* the sporangial stalks are comparatively short and consist of usually 3 or seldom 2 rows of cells. The presence of unicellular glands at the base of sporangium of *Athyrium japonicum* (Thbg.) Copel. is a good specific character.

The study of spore has lately assumed great importance. Very significant contributions have been made by Knox (1951) and Hagenah (1961) on the European and North American representatives of Aspleniaceae and Athyriaceae. The spore output can be a conclusive guide to find out whether the particular species is apogamous or not. The leptosporangiate sexual species have usually got 64 spores, whereas the apogamous 32 (cf. Mehra & Bir, 1960b).

In taxonomic study of *Athyrium, Diplazium* and *Cystopteris* the details of spore structure—presence or absence of perisporium, have proved fruitful. The difference in spore structure of *Diplazium polypodioides* Bl. and *D. asperum* Bl. is striking. The former is perisporiate, while the latter non-perisporiate. *Athyrium attenuatum* (Clarke) Tagawa and *A. rupicola* (Hope) C. Chr. are very closely looking ferns, but both can be separated on the basis of non-perisporiate spores in *A. attenuatum* and broadly perisporiate in the other. Similarly we can separate *Athyrium rubricaule* (Edgw.) Bir and *A. schimperi* Moug, often confusing species. *A. rubricaule* has spores totally devoid of perisporium, while these are broadly perisporiate in the other species (Fig. 29).

Spores of different species of *Cystopteris* have also diagnostic features; those of *C. tenuisecta* (Bl.) Mett. are minutely rugulose, those of *C. sikkimensis* Ching are broadly perisporiate with perisporium thrown into many folds, while in case of *C. sudetica* A. Br. the spores are heavily tuberculated and spiny (Fig. 30).

(f) **Chromosome Numbers:** The roll of cytology in taxonomy of ferns needs no emphasis. The chromosome number has been very helpful in deciding a controversy about *Athyrium, Diplazium* and *Cornopteris*. Now these are regarded as distinct genera. Bir (1961a) has shown that the fern called *Diplazium japonicum* (Thbg.) Bedd. should be referred to as *Athyrium japonicum* (Thbg.) Copel. since it has been found to be based on x=40, not x=41 as earlier data showed. Three cytological races, diploid (n=40), tetraploid (n=80) and pentaploid hybrid (2n=200) have been discovered from the Himalayas in this species complex.

The taxonomic status of some specimens of *Asplenium laciniatum* Don from Darjeeling which are intermediate between var. *subintegrifolium* and the type, has now been decided because these have been found to be hybrids with 2n=144 (cf. Bir, 1960). Similarly some specimens of *Diplazium* intermediate between *D. polypodioides* and *D. asperum* are now found to be hybrid between these two species with an=82 (cf. Bir, 1961b).

(g) **Gametophytes:** The reproductive structures of various genera of "Aspleniaceae" are of typical leptosporangiate type and they do not give adequate evidence of relationships. Moreover, the study of gametophyte of ferns is much time consuming and laborious and as such its value in taxonomy has limited scope. However, critical observations concerning the presence or absence of emergences on the prothalli of allied species have yielded good results. So far, very little work has been done on the gametophytes of various members of family "Aspleniaceae." The genus *Asplenium* contains some species with prothallial trichomes 'papillae' such as *A. adiantum-nigrum, A. ruta-muraria,* and *A. septentionale,* whereas other species lack them such as *A. trichomanes, A. viride* and *A. marinum* (cf. Lagerberg, 1908 and Faegri, 1934). Similar conclusion has also been reached by the author concerning the Indian members. The epiphytic species, namely, *Asplenium finlaysonianum, A. ensiforme* and *A. nidus* show marginal papillae (glandular in case of *A. finlaysonianum*) on the prothalli. In strong contrast to it these papillae are absent on the prothalli of *Asplenium varians, A. trichomanes* and *A. cheilosorum* which are terrestrial or lithophytic (Fig. 31). Wagner (1954) has shown the presence of secretory hairs on the prothallus of *Asplenium dalhousiae* (named as *Ceterach*

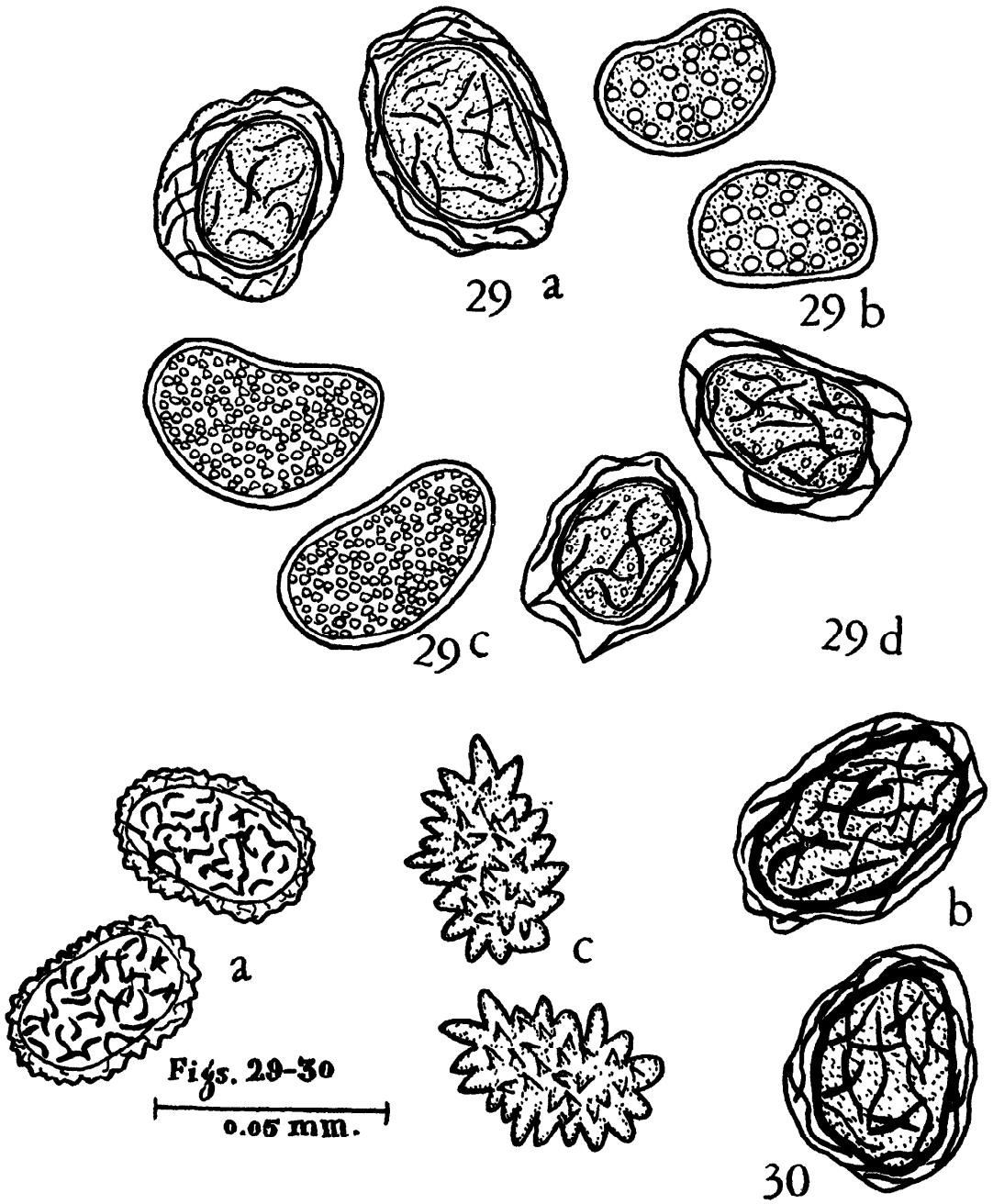


Fig. 29. Spores of different species of *Athyrium* Röth from the Himalayas. a, *A. rupicola* (Hope) C. Chr. ; b, *A. attenuatum* (Clarke) Tagawa ; c, *A. rubricaule* (Edgw.) Bir; d, *A. schimperi* Moug.

Fig. 30. Spores of different species of *Cystopteris* Bernh. from Sikkim State, Eastern Himalayas. a, *C. tenuisecta* (Bl.) Mett. ; b, *C. sikkimensis* Ching ; c, *C. sudetica* A. Br.

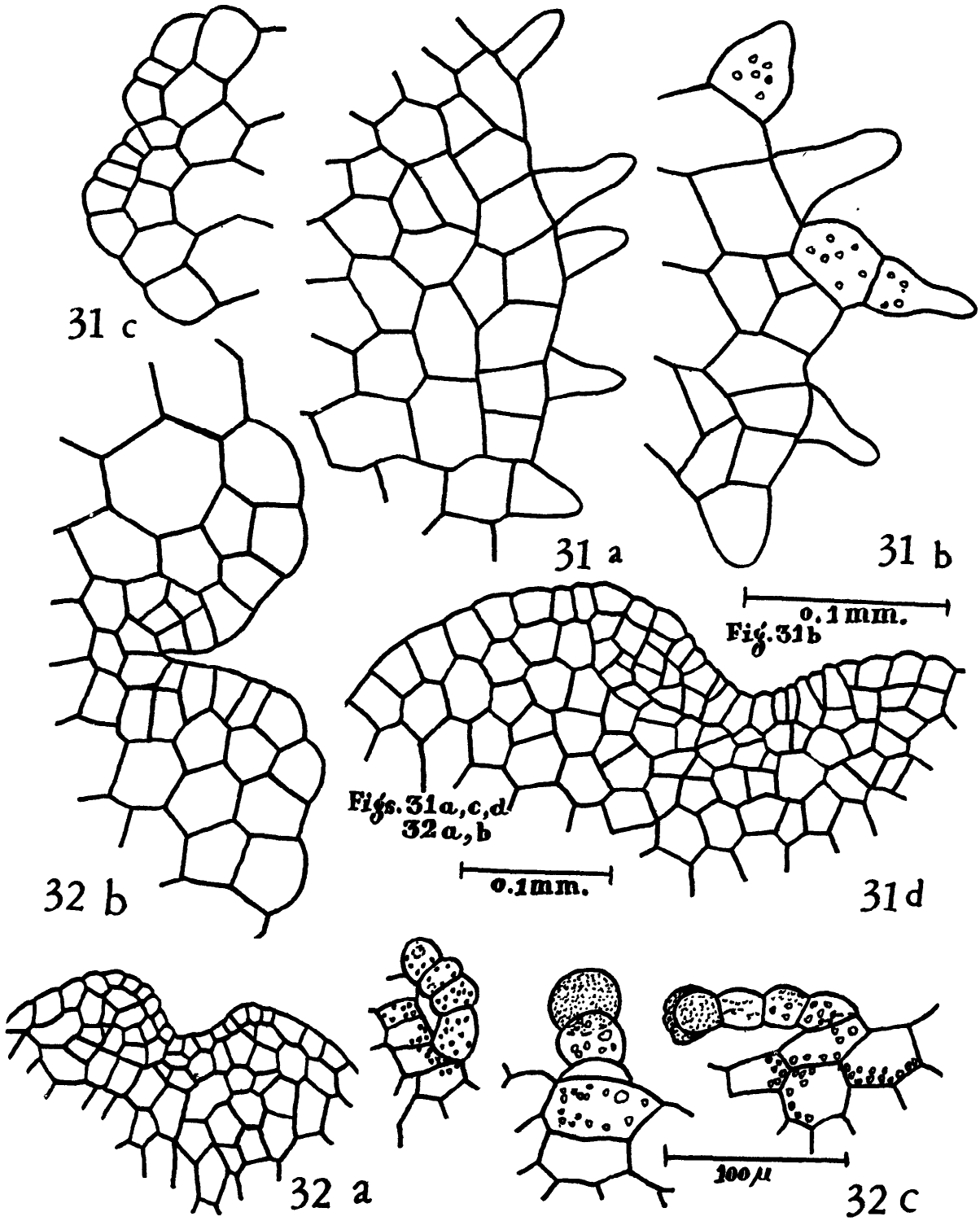


Fig. 31. Margin of prothalli of some Himalayan species of *Asplenium*. a, *A. nidus* Linn. ; b, *A. ensiforme* Wall ; c, *A. tri-chomanes* Linn. d, *A. cheilosorum* Kunze.

Fig. 32. a & b, Margin of prothalli of *Asplenium dalhousiae* Hook. and *Ceterach officinarum* Lam. and DC. respectively raised from spores of plants collected from the Western Himalayas. In these cases no hairs are present on the Margin ; c, Margin of prothallus of *Ceterach dalhousiae* (Hook.) C. Chr. (*Asplenium dalhousiae* Hook.), here glandular hairs are preseut along the margin (after Wagner, 1954. Gametophytes raised from spores of plants at the University of California Botanical Garden).

Dalhousiae by Wagner). But my observation on the spores from the Himalayas have shown that the prothalli in *Asplenium dalhousiae* are totally devoid of any outgrowths at all stages of development (Bir, unpublished). Similarly my observations of *Ceterach officinarum* also differ from those of Döpp (1927) in the fact that there are no papillae or secretory hairs on the prothalli raised from spores collected from Kulu in Western Himalayas (Fig. 32). In such cases of differences in observations the authenticity of material is very important. The Himalayan samples of the two ferns were identified by Mr. A. H. G. Alston (British Museum). The material on which observations of Döpp (1927) and Wagner (1954) were based, has not been available to me for comparison. One possible explanation for variation in the presence or absence of outgrowths can be that these variations may be due to difference in habitat or climatic conditions, although it seems improbable.

A Suggestion to the Collectors: In case of ferns attempt should always be made as far as possible to collect complete plant, failing which nature of the rhizome, size of the frond, degree of division of lamina must be recorded at the time of collection. Field notes are very important which should include information concerning (i) presence or absence of scales, hairs or other dermal appendages. (ii) nature of indusium whether present or not. Young sorus must be studied because often the indusium is fugacious at maturity. The scales in many cases are deciduous and seldom preserved in the herbarium specimens. Many wrong references of ferns to other genera are due to incomplete records. *Diplazium* species have often been referred to *Gymnogramme* because in many cases the indusium disappears at an early stage.

NEW FERNS

The distinguishing characters of *Asplenium laciniatum* Don var. *acutipinna* Bir, *A. planicaule* Wall. var. *obtusum* Bir and *Cornopteris birii* Ching have already been dealt with. The others are:

(1) *Athyrium mehrae* Bir (Nova Hedwigia 4: 165-167. figs. 1-5. 1962a). This species belongs to the group of '*Athyrium filix-foemina* complex'. The striking features are the usually fragile and stramineous stipe, firm but herbaceous fronds and flattened rachis which is winged above. The lower pinnae are gradually reduced to mere auricles and the falcate segments are the other peculiarities of this fern. The nearest relative is *Athyrium attenuatum* (Clarke) Tagawa, but the two can be readily distinguished, among other characters, mainly by spore structure. These are pale brown and broadly perisporiate in *A. mehrae*, while non-perisporiate and light yellowish in *A. attenuatum*. Collected from near Thangu, 12,000 ft. alt., N. Sikkim. Terrestrial and grows under *Rhododendron* trees, quite rare.

(2) *Athyrium sub-triangulare* (Hook.) Bedd. var. *sikkimense* Bir (Nova Hedwigia 4: 168, figs. 9-11. 1962a). Beddome (1892) and Christensen (1906) have merged *A. subtriangulare* with *A. spinulosum* (Michx.) Maxim. It is, however, distinct from *A. spinulosum* in having (i) ovate or sub-deltoid lamina; (ii) breadth shorter than length; (iii) lower pinnae ascending, the pinnules close together, strictly sessile and inciso-serrate into short spinulose teeth. Common in Lachen valley 10,000-13,000 ft. alt., N. Sikkim.

The variety *sikkimense* differs from the type in the smaller size, smooth margin of the segments, except from the apex which is irregularly dentate and in larger spore size. Common near Thangu, 13,000 ft. alt., N. Sikkim. It also differs from the type in being diploid with $n=40$. The type is tetraploid with $n=80$ (cf. Mehra & Bir, 1960a).

(3) *Cystopteris sikkimensis* Ching (in edit).

This species is very much similar to *C. fragilis* (L.) Bernh., but differs conspicuously in spore character and chromosome number. *C. sikkimensis* is octaploid with $n=168$, whereas Himalayan samples of *C. fragilis* are tetraploid with $n=84$. (cf. Bir, 1961*b*). The plants are ordinarily larger in size with dark ebenaceous stipes, whereas in *C. fragilis* the stipe is only yellowish brown and not ebenaceous. The spores of *C. fragilis* are heavily spiny, but in this case the spores are broadly perisporiate, the perisporium wrinkled and totally lacking in spines. In mature condition the indusium is absent. Common in rock crevices near Thangu, 13,000 ft. alt., N. Sikkim.

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