Systematic Sutudies on the Conducting Tissue of the Gametophyte in Musci

Sci. Rep. Kanazawa Univ.,
Vol. 15 No. 2, 71-98
December 1970

Systematic Studies on the Conducting Tissue of the Gametophyte in Musci

(1) On the Affinity Regarding the Conducting Tissue of the Stem in Some Species of Polytrichaceae

Isawo KAWAI and Kiku IKEDA*

Department of Biology, Faculty of Science, Kanazawa University

(Received Oct. 31, 1970)

Abstract In some species of the Musci we came to know that such anatomical characteristics of the stem as the number of cell layers of the epidermis, diameter of the stem, number of cell layers of the cortex, width of the cortex, diameter of the central strand, whether distinction between the hadrom and the leptom is clear or not, number of cell layers of the leptom, width of the leptom, number of cell layers of the hadrom, cell number of the hadrom, diameter of the hadrom are less variable, distinctly specific and peculiar to the species. We examined whether, in Polytrichaceae, these characteristics are peculiar to the species and whether there is something in common among the characteristics of the inner structure of the stem in the species belonging to the identical genus.

The species which we have considered here, are 16 species of Polytrichaceae. In all the species examined the stem is differentiated into the epidermis, the cortex, the endodermis, the leptom, the hadrom as VI-type, which is one of the six types of the stem. The distinction between the leptom and the hadrom is clear in *Polytrichum*, *Pogonatum* and *Atrichum*. In *Bartramiopsis* and *Oligotrichum*, it is not clear. Besides all characters of the stem are much alike. In *Pogonatum*, the number of cell layers of the hadrom are in all species 3-6 layers (B-type). In *Polytrichum* diameters of the central strand are always 150-370 μ (A-type). Number of cell layers of the epidermis is two (A-type) in *Pogonatum grandifolium* and

*Present adress: Nanbu Middle School, Komatsu-City, Ishikawa Pref.

Polytrichum formosum, but the other species have only one layer of the epidermis. In view of these facts, we conclude that the characteristics of the conducting tissue are to a great extent peculiar to the genus, so that the characteristics of the stem-structure are vitally important in the classification of the genus. In our future studies we have to consider the origin of each tissue of the stem. The leptom and the hadrom are expected to have different development of tissues specialized for the conduction. Before examining this points, however, we must know more about the physiology of conduction in bryophytes.

Introduction

In such genera as Mnium internal conduction is in the central strand of the stem and in the leaf midrib. The leaf lamina and the ground tissue of the stem are secondarily supplied from these sources. In such cases the differentiated tissues of the leaf midrib do not like up with the central strand of the stem, but end blindly in the ground tissue forming so-called false leaf traces. According to ZACHERL these act after the manner of wicks, and the passage of water from the central strand of the stem to the leaf base is thereby accomplished across the intervening ground tissue. In such a genus as *polytrichum*, by contrast, true leaf traces are continuous from the central strand of the stem out into the midribs of leaves. Here internal conduction is localized throughout in these specialized tissues. ZACHERL adds that conduction of water by way of the central strand of a stem is most rapid and direct to the uppermost leaves, and that the lower leaves are as a result often satisfied later than the shoot tips. In moss stems in which a central strand is either feebly developed or absent he holds that there is no internal conduction.

In *Funaria hygrometrica*, internal conduction in rhizoids, for example, is found to be slow, and the stem base seems normally to be reached much more rapidly by an external capillary path. Once the water is in the stem, however, the central strand is found to be important; but access to the leaves is more common by external channels (BOPP and STEHLE 1957).

On the whole, a delicate but perceptible cuticle is present on the leaves of those species in which the main water supply comes from below. They are called **endohydric mosses**. On the other hand, there are many mosses (**ectohydric mosses**), in which no cuticle can be demonstrated, and here the normal water supply is from above. A further group, combining in some measure the characteristics of these two, is said to be **myxohydric** (BUCH 1947).

Here, we would especially consider the **endohydric mosses**.

Acknowledgement

we extend our cordial thanks to Dr. T. OSADA, Professor of Yamanashi Woman University, who has given us several useful suggestions.

Materials and methods

Four years ago, scores of mosses which were taken back from a beech-wooded region in Mt. Hakusan, were cultivated in the Botanic Garden of Kanazawa University. The living materials used for this research are some of those species. And the dry materials comprise specimens of mosses collected from Japan and Germany. All the samples studied are deposited in the Moss Herbarium of Kanazawa University.

Atrichum undulatum (HEDW.) P. BEAUV.: Ishikiri Shizuoka Pref. (30508), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (33244), Omata, Shizuoka Pref. (30509), Jesteburg Bendestorf, Kreis Harbrug, Germany (30663), Mt. Kenzan, Tokushima Pref. (30505), Hittfeld, Kreis Harburg, Germany (30571), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32215), Ramelshoh-Harmstorf, Kreis Harburg, Germany (30063).

Oligotrichum parallelum (MITT.) KINDB.: Rokumanzan, Mt. Hakusan, Ishikawa Pref. (31913), Murodoo, Mt. Hakusan, Ishikawa Pref. (33275), Betsuzan, Mt. Hakusan, Ishikawa Pref. (33296).

Bartramiopsis lescurii (JAM.) CARD. et Ther.: Midagahara, Mt. Hakusan, Ishikawa Pref. (33259), Mt. Oodaigahara, Nara Pref. (34965), Mt. Kenzan, Tokushima Pref. (30492).

Pogonatum alpinum (HEDW.) ROEHL.: Shoogawa, Ooshirakawa, Gihu Pref. (11246), Murodoo, Mt. Hakusan, Ishikawa Pref. (33278), Midagahara, Mt. Hakusan, Ishikawa Pref. (35340), Oonanji, Mt. Hakusan, Ishikawa Pref. (33295), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32188), Shakadake Mt. Hakusan Ishikawa Pref. (34814), Gozengamine Mt. Hakusan Ishikawa Pref. (33256), Kankooshidoo, Mt. Hakusan. Ishikawa Pref. (35364), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (33250).

Pogonatum contortum MENZ.: Hujimiyaguchi, Mt. Hujisan, Shizuoka Pref. (30452), Rokumanzan Mt. Hakusan Ishikawa Pref. (32224). Nagoro, Mt. Kenzan, Tokushima Pref. (30448), Ichiu Mt. Kenzan, Tokushima Pref. (30451), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (35339), Murodoo, Mt. Hakusan, Ishikawa Pref. (35331).

Pogonatum grandifolium (LINDB.) JAEG.: Hujimiyaguchi, Mt. Hujisan, Shizuoka Pref. (30459), Ooshirakawa, Mt. Hakusan, Gihu Pref. (30911), Mt. Kenzan, Tokushima Pref. (30373), Sabooshindoo, Mt. Hakusan, Ishikawa Pref. (35328), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32026), Midagahara, Mt. Hakusan, Ishikawa Pref. (35330), Kami-ina, Nagano Pref. (35161), Mt. Ontake, Gihu Pref. (34960), Murodoo, Mt. Hakusan, Ishikawa Pref. (33276).

Pogonatum inflexum (LINDB.) PAR.: Unoya-Nomo, Ishikawa Pref. (11395), Keta-Omata, Shizuoka Pref. (10103), Nishiiyayama, Mt. Kenzan, Tokushima Pref. (30477),

Shoodoshima, Kankakei, Kagawa Pref. (15478), Ichiu, Mt. Kenzan, Tokushima Pref. (30462), Hakui Ishikawa Pref. (30822), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (31941), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (36323), Ishikiri, Shizuoka Pref. (30465).

Pogonatum nipponicum NOG. et OSA.: Omata, Shizuoka Pref. (30469), Ishikiri, Shizuoka Pref. (30468), Dookisawa, Shizuoka Pref. (30473), Yana, Aichi Pref. (35197), Mt. Jinkakugi, Ooita Pref. (35183).

Pogonatum spinulosum MITT.: Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32218), Kankakei, Shoodoshima, Kagawa Pref. (34618), Keta Shizuoka Pref. (30934), Ichinose, Mt. Hakusan, Ishikawa Pref. (31940).

Pogonatum urnigerum PAR.: Ooshirakawa, Gihu Pref. (30902), Hooeizan, Mt. Hujisan, shizuoka Pref. (30357), Oonanjimine, Mt. Hakusan, Ishikawa Pref. (33291), Keta, Shizuoka Pref. (30888), Hujimiyaguchi, Mt. Hujisan, Shizuoka Pref. (30485), Hunazuguchi, Mt. Hujisan, Yamanashi Pref. (30352), Kawamata, Mt. Kenzan, Tokushima Pref. (30383), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (35333), Murodoo, Mt. Hakusan, Ishikawa Pref. (35336), Gozenmine, Mt. Hakusan, Ishikawa Pref. (35335).

Polytrichum commune HEDW.: Mt. Chausu, Aichi Pref. (35128), Reinfeld, Holstein Bezirk, Germany (30172), Hamstedter Berge, Kreis Hardurg, Germany (33595), Murodoo, Mt. Hakusan, Ishikawa Pref. (33242), Midagahara, Mt. Hakusan, Ishikawa Pref. (33274), Goyoozaka, Mt. Hakusan, Ishikawa Pref. (33245), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32059), Gozenmine, Mt. Hakusan, Ishikawa Pref. (33265).

Polytrichum formosum HEDW.: Kankooshindoo, Mt. Hakusan Ishikawa Pref. (35362), Goyoozaka, Mt. Hakusan, Ishikawa Pref. (33270), Zinnosukedani, Mt. Hakusan, Ishikawa Pref. (33271), Murodoo, Mt. Hakusan, Ishikawa Pref. (33258), Ooshirakawa, Mt. Hakusan, Gihu Pref. (11989), Iwama, Mt. Hakusan, Ishikawa Pref. (34830), Sieverser Sunder, Kreis Harburg, Germany (30081), Rokumanzan, Mt. Hakusan, Ishikawa Pref. (32138), Sanpoogan, Mt. Hakusan, Gihu Pref. (33268), Horneburg, Holstein Bezirk, Germany (30091), Chuuguu, Mt. Hakusan, Ihikawa Pref. (30884), Ichiu Mt. Kenzan, Tokushima Pref. (30386), Wiedenthal, Kreis Harburg, Germany (33403), Sahoyama, Miyagi Pref. (34894).

Polytrichum gracile SM.: Goyoozaka, Mt. Hakusan, Ishikawa Pref. (35316).

Polytrichum juniperinum HEDW.: Chuuguu, Mt. Hakusan, Ishikawa Pref. (35369), Itzenbüttel, Kreis Harburg, Germany (34012), Wiedenthal, Kreis Harburg, Germany (30168), Sieverser Sunder, Kreis Harburg, Germany (30167), Metzendorf über Hittfeld, Kreis Harburg, Germany (30165), Hooeizan, Mt. Hujisan, Shizuoka Pref. (30356), Hujimiyaguchi, Shizuoka Pref. (30484).

Polytrichum ohioense REN. et CARD.: Kankooshindoo, Mt. Hakusan, Ishikawa Pref. (35365).

Polytrichum piliferum HEDW.: Evendorf-Rolfsen, Kreis Harburg, Germany (33413), Wiedenthal, Kreis Harburg, Germany (30159), Harburg, Kreis Harburg, Germany (30161), Hamstedter Berge, Kreis Harburg, Germany (30157), Jesteburg Bendestorf,

Kreis Harburg, Germany (33973), Reinfeld, Holstein Bezirk, Germany (30164), Murodoo, Mt. Hakusan, Ishikawa Pref. (33285), Hujimiyaguchi, Mt. Hujisan, Shizuoka Pref. (30489), Oonanji, Mt. Hakusan, Ishikawa Pref. (33283).

For anatomical studies, microtome sections of the fresh moss are prepared by the ethylalcohol-buthylalcohol-paraffin method, following BOUIN's fluid fixation. Before examination the dry moss is boiled in water for about half an hour. The inner structure of the stem of the gametophyte is studied from serial transverse sections having a thickness of 5 to 10μ. Fast green, acid fuchsin, fuchsin, "Jodjodkalium", "Gentianaviolett" are used for staining anatomical preparations.

Observation

In the species of Polytrichaceae the superficial layer of the stem is clearly differentiated as an epidermal layer. Inside the epidermis is the cortex. The peripheral cortical region consists of compact, elongated prosenchymatous cells, the inner cortex consists of elongated, thin-walled green parenchymatous cells. At the inner limit of these cortical layers is a layer, one cell thick. This layer resembles the endedermis. The cells of the endodermal layer and the thin-walled green parenchymatous cells of the inner cortex are much alike in characters such as shape, size and cell wall. The central strand, in which two tissues, hadrom and leptom, are distinct one from the other, consists of central part of the stem. The central portion, hadrom is a mass of cells, of which the walls are thicker than those of the outer layer (leptom). The hadrom consists of the hydrom and the stereom. The very thick-walled elongated cells are the stereids, as a whole being called stereom. Scattered among these stereids are elements which are often united in bands of 2 or 3, the cells of each band being separated by extremely delicate cellulose walls. These elements are named hydroids, and as a whole are called hydrom.

The cross section of the stem is considered from the following view points: that is, number of cell layers of the epidermis, diameter of the stem, number of cell layers of the cortex, width of the cortex, diameter of the central strand, whether distinction between the hadrom and the leptom is clear or not, number of cell layers of the leptom, width of the leptom, number of cell layers of the hadrom, cell number of the hadrom, diameter of the hadrom (Pl. I-VI). The diameters of the central strands are measured 370μ, 300μ, 270μ, 250μ, 200μ, 170μ, 150μ, 130μ, 120μ, 110μ, 80μ, 60μ. In *Polytrichum commune* it shows 370-300μ, in *Pogonatum inflexum* it is 300-170μ, in *Polytrichum formosum* it is 200-150μ (Tab. 1). So the diameter of the central strand, 370-150μ, is called A-type, and 140-60μ is called B-type.

Tab. 1 The similarity types of diameter of the central strand

Diameter of the central strand (μ)	
370 300 270 250 220 200 170 150	130 110 80 70
A-type	B-type

Tab. 2 The similarity types of diameter of the stem

Diameter of the stem (mm)		
1.3	0.9 0.8	0.6 0.5 0.4
A-type	B-type	C-type

Tab. 3 The similarity types of number of the cell layers of the epidermis

Number of the cell layers of the epidermis (layer)	
One layer of the epidermis	Two layers of the epidermis
A-type	B-type

Tab. 4 The similarity types of number of the cell layers of the hadrom

Number of the cell layers of the hadrom (layer)		
10 9	8 6 5 4	3
A-type	B-type	C-type

Tab. 5 The similarity types of distinction between the hadrom and the leptom

Distinction between hadrom and the leptom	
clear	not clear
A-type	B-type

Tab. 6 The similarity types of cell number of the hadrom

Cell number of the hadrom (cell)		
280 250 230	180 150 130 100	80 50 30
A-type	B-type	C-type

Tab. 7 The similarity types of width of the leptom

Width of the leptom (μ)								
70	50	40	35	30	25	20	12	7
A-type			B-type					

Tab. 8 The similarity types of number of the cell layers of the leptom

Number of the cell layers of the leptom (layer)				
5	4	3	2	1
A-type		B-type		

Tab. 9 The similarity types of number of the cell layers of the cortex

Number of the cell layers of the cortex (layer)												
17	16	15	14	13	12	11	10	9	8	7	6	5
A-type								B-type				

Tab. 10 The similarity types of width of the cortex

Width of the cortex (μ)									
400	300	270	250	220	170	150	120	100	70
A-type		B-type					C-type		

Tab. 11 The similarity types of diameter of the hadrom

Diameter of the hadrom (μ)										
250	220	200	170	150	120	100	80	70	60	50	30
A-type			B-type				C-type				

Thus as described above, numerical values of the character of the stem are classified into types. (Tab. 12). From this table (Tab. 12), it can be known the following that; in diameter of the central strand *Pogonatum spinulosum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum*

ohioense, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum*, *Polytrichum piliferum* and *Polytrichum commune* belong to the A-type and *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum urnigerum*, *Pogonatum alpinum* and *Pogonatum nipponicum* to the B-type; in diameter of the stem *Pogonatum grandifolium* belongs to the A-type, *Atrichum undulatum*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum*, *Polytrichum piliferum* and *Polytrichum commune* to the B-type and *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum spinulosum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum nipponicum*, *Pogonatum contortum*, *Pogonatum inflexum* and *Polytrichum ohioense* to the C-type; in number of the cell layers of the epidermis *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum spinulosum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum nipponicum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Atrichum undulatum*, *Polytrichum ohioense*, *Polytrichum gracile*, *Polytrichum juniperinum* *Polytrichum piliferum* and *Polytrichum commune* belong to the A-type, and *Pogonatum grandifolium* and *Polytrichum formosum* to the B-type, in number of the cell layers of the hadrom *Polytrichum commune* belongs to the A-type, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum nipponicum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum ohioense*, *Polytritum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum* to the B-type, and *Bartramiopsis lescurii*, *Oligotrichum parallelum* and *Polytrichum piliferum* to the C-type; in distinction between the hadrom and the leptom *Pogonatum spinulosum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum nipponicum*, *Pogonatum*, *contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum ohioense*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum*, *Polytrichum piliferum*, and *Polytrichum commune* belong to the A-type, and *Bartramiopsis lescurii* and *Oligotrichum parallelum* to the B-type; in cell number of the hadrom *Polytrichum commune* and *Pogonatum inflexum* belong to the A-type, *Pogonatum nipponicum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, and *Polytrichum formosum* to the B-type, *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Polytrichum ohioense*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum* and *Polytrichum piliferum* to the C-type; in width of the leptom *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum gracile*, *Polytrichum piliferum* and *Polytrichum commune* belongto the A-type, and *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum nipponicum*, *Polytrichum ohioense*, *Polytrichum formosum* and *Polytrichum juniperinum* to the B-type; in number of the cell layers of the leptom *Pogonatum nipponicum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum ohioense*, *Polytrichum gracile*, *Polytrichum piliferum* and *Polytrichum commune* belong to the A-type, *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Polytrichum formosum* and *Polytrichum juniperinum* to the B-type; in number of the cell layers of the cortex *Pogonatum urnigerum*, *Pogonatum*

Tab. 12 The anatomical characters of the stem and those similar types

	Number of the cells layers of the epidermis		Diameter of the stem		Number of the cell layers of the hadrom		Distinction between the hadrom and the leptom is clear (A-type) or not (B-type)	Diameter of the central strand		Cell number of the hadrom		Width of the leptom		Number of the cell layers of the leptom		Number of the cell layers of the cortex		Width of the cortex		Diameter of the hadrom	
	Layers	Types	mm	Types	Layers	Types		μ	Types	Cells	Types	μ	Types	Layers	Types	Layers	Types	μ	Types	μ	Types
Bartramiopsis lescurii	1	A	0.4	C	3	C	B	60	B	30	C	20	B	2(2-3)	B	8(8- 8)	B	100	C	30	C
Oligotrichum parallelum	1	A	0.4	C	3	C	B	110	B	30	C	30	B	3(3-4)	B	7(6- 7)	B	100	C	60	C
Pogonatum spinulosum	1	A	0.6	C	?	?	A	300	A	?	?	?	?	?	?	8(7- 9)	B	120	C	?	?
Pogonatum grandifolium	2	B	1.3	A	6	B	A	300	A	123	B	50	A	17(15-18)	A	17(15-18)	A	400	A	200	A
Pogonatum urnigerum	1	A	0.6	C	4	B	A	80	B	47	C	7	B	1(1-2)	B	16(15-18)	A	200	B	70	C
Pogonatum alpinum	1	A	0.6	C	4	B	A	120	B	54	C	25	B	3(2-3)	B	15(15-15)	A	220	B	100	B
Pogonatum nipponicum	1	A	0.4	C	6	B	A	130	B	119	B	30	B	4(3-5)	A	9(8-10)	B	100	C	80	C
Pogonatum contortum (1)	1	A	0.6	C	6	B	A	200	A	103	B	40	A	4(4-5)	A	10(9-12)	A	170	B	120	B
Pogonatuu contortum (2)	1	A	0.9	B	6	B	A	250	A	123	B	50	A	4(3-5)	A	11(11-12)	A	220	B	150	B
Pogonatum inflexum (1)	1	A	0.6	C	8	B	A	300	A	219	A	70	A	4(4-5)	A	12(10-13)	A	200	B	150	B
Pogonatum inflexum (2)	1	A	0.6	C	6	B	A	200	A	105	B	40	A	4(2-5)	A	11(10-12)	A	170	B	120	B
Pogonatum inflexum (3)	1	A	0.5	C	5	B	A	170	A	101	B	40	A	4(2-5)	A	12(10-13)	A	150	B	100	B
Atrichum undulatum	1	A	0.8	B	6	B	A	270	A	98	B	70	A	5(3-6)	A	10(7-13)	A	220	B	170	B
Polytrichum ohioense (1)	1	A	0.4	C	4	B	A	150	A	45	C	25	B	4(2-5)	A	6(5- 6)	B	70	C	100	B
Polytrichum ohioense (2)	1	A	0.5	C	4	B	A	200	A	53	C	35	B	4(3-5)	A	6 (5- 7)	B	100	C	100	B
Polytrichum formosum (1)	2	B	0.8	B	6	B	A	200	A	90	C	35	B	3(2-4)	B	16(14-17)	A	270	B	150	B
Polytrichum formosum (2)	2	B	0.8	B	4	B	A	150	A	52	C	12	B	2(2-3)	B	16(15-17)	A	270	B	120	B
Polytrichum gracile	1	A	0.9	B	4	B	A	220	A	45	C	50	A	4(3-5)	A	14(12-16)	A	250	B	120	B
Polytrichum juniperinum	1	A	0.8	B	6	B	A	170	A	79	C	25	B	3(2-4)	B	16(15-16)	A	270	B	120	B
Polytrichum piliferum	1	A	0.9	B	3	C	A	250	A	41	C	50	A	4(3-5)	A	17(16-17)	A	300	A	120	B
Polytrichum commune (1)	1	A	0.8	B	10	A	A	370	A	242	A	70	A	5(3-6)	A	11(9-13)	A	170	B	250	A
Polytrichum commune (2)	1	A	0.9	B	10	A	A	300	A	283	A	50	A	5(3-8)	A	15(15-15)	A	250	B	220	A
Polytrichum commune (3)	1	A	0.8	B	9	A	A	300	A	224	A	50	A	4(3-5)	A	16(15-16)	A	270	B	250	A

alpinum, *Pogonatum contortum* *Pogonatum inflexum*, *Pogonatum grandifolium*, *Atrichum undulatum*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum*, *Polytrichum piliferum*, and *Polytrichum commune* belong to the A-type, *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum spinulosum*, *Pogonatum nipponicum*, and *Polytrichum ohioense* to the B-type; inwidth of the cortex *Pogonatum grandifolium*, and *Polytrichum piliferum* belong to the A-type, *Pogonatum urnigerum*, *Pogonatum alpinum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Atrichum undulatum*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum* and *Polytrichum commune* to the B-type, and *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum spinulosum*, *Pogonatum nipponicum*, and *Polytrichum ohioense* to the C-type; in diameter of the hadrom *Pogonatum grandifolium* and *Polytrichum commune* belong to the A-type, *Pogonatum alpinum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Atrichum undulatum*, *Polytrichum ohioense*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum* and *Polytrichum piliferum* to the B-type and *Bartramiopsis lescurii*, *Oligotrichum parallelum*, *Pogonatum urnigerum* and *Pogonatum nipponicum* to the C-type.

The distinction between the hadrom and the leptom is clear in *Polytrichum*, *Pogonatum* and *Atrichum* but in *Bartramiopsis* and *Oligotrichum* is not clear, as well as all characters of the stem are much alike. In *Pogonatum* numbers of cell layers of the hadrom are all 3-6 layers (B-type). In *Polytrichum* diameters of the central strand are all 150-370μ (A-type).

Discussion

We have hithertofore studied placing our primary emphasis upon the characteristics of the inner structure of the stem in some species of the Musci. Thus we came to know that such characteristics of the stem as the number of cell layers of the epidermis, diameter of the stem, number of cell layers of the cortex, width of the cortex, diameter of the central strand, distinction between the hadrom and the leptom is clear or not, number of cell layers of the leptom, width of the leptom, number of cell layers of the hadrom, cell number of the hadrom, diameter of the hadrom are less variable, distinctly specific and peculiar to the species. Since then we have studied and taken a great interest in whether we can place our emphasis upon the characteristics of the inner structure of the stem in Musci in general. We examine, therefore whether these characteristics are peculiar to the species and whether there is something in common among the characteristics of the inner structures of the stem in the species belonging to the identical genus in Musci.

I. Significance of the stem in systematic botany of Musci

In some species of Musci, morphological differentiation of tissue in the stem showed some differences from species to species, and on the basis of affinity shown in morphological differentiation we are able to classify the inner structures of the stem into six types. The stem of Sphagnum grows by means of a tetrahedral apical cell with three cutting faces. The first cell division in the young segment, cut off from each face, is periclinal; the inner cell forms the axis of the stem and the outer gives

rise to the cortex and a single leaf. Thus each segment gives rise to a single leaf and the subtending portion of the stem. In the center of the stem there is an axial cylinder composed of layers of small, narrow, thick-walled, elongated prosenchymatous cells or, if thin-walled, of colourless, somewhat, elongated parenchymatous cells. The outermost region of the stem is the cortex. When formed, the cortex is some cells thick and its cells are small, forming a compact tissue (cf. Fig. I-1 *Sphagnum* and Fig. V-1, I-type: cortex- axial cylinder).

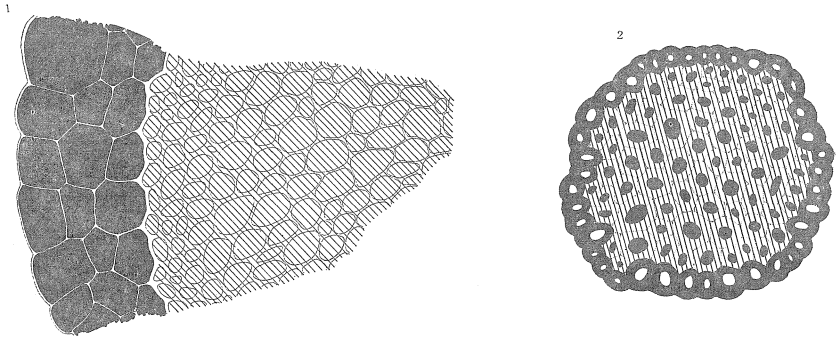

Fig. I Cross sections of the I-type (cortex-axial cylinder) and II-type (epidermis-axial cylinder)
1: *Sphagnum* sp. 2: *Andreaea* sp.

The stem of Andreaea in cross section shows an almost uniform structure without any internal differentiation into cortex and central conducting strand. The superficial layer may be somewhat thick-walled and dark-coloured than the deep-laying cells (cf. Fig. I-2 *Andreaea* and Fig. V-2, II-type: superficial layer-axial cylinder).

In the plant of *Fissidens adelphinus*, a cross section of the stem shows a differentiation of tissues into a central tissue, cortex and epidermis. The central tissue consists of long, narrow, thin-walled, colourless cells. The central tissue is surrounded by cortical tissue. The epidermis is usually one cell thick (cf. Fig. II *Fissidens adelphinus*, *Plagiothecium* sp., *Hylocomium cavifolium*, *Campylium* sp., *Hypnum o dhamii*, *Mnium microphyllum*, *Hookeria nipponensis*, *Thamnium plicatulum*, *Ctenidium hastile*, *Thuidium toyamae*, *Grimmia maritima*, *Grimmia plagiopodia*, *Grimmia brunnescens* f. *epilosa*, and Fig. V-3, III-type: epidermis-cortex-central tissue).

On the outside of the stem in *Grimmia ovalis* there is a superficial layer (epidermis) of thick-walled cells. Below the epidermis there are several layers of living cortical cells. The cells of the cortex in the inner part of the stem contain chloroplasts, but in the outer they are few. The outer cells of the cortex have thicker walls, while the cells of the inner cortex are thin-walled. At the inner limit of the cortex is a layer of radially elongated cells with thickenings on their radial and horizontal walls. This layer resembles the endodernnis. The central strand consists of thin-walled cells and doesn't differentiate into two tissues (cf. Fig. III *Grimmia ovalis*, *Grimmia laevigata*, *Grimmia gracile* f. *tenuis*, *Grimmia pulvinata* v. *africana*, *Grimmia incurva*, *Grimmia teretinervis*, *Grimmia decipiens*, *Grimmia anomala*, and Fig. V-4, IV-type: epidermis- cortex-endodermis-central strand).

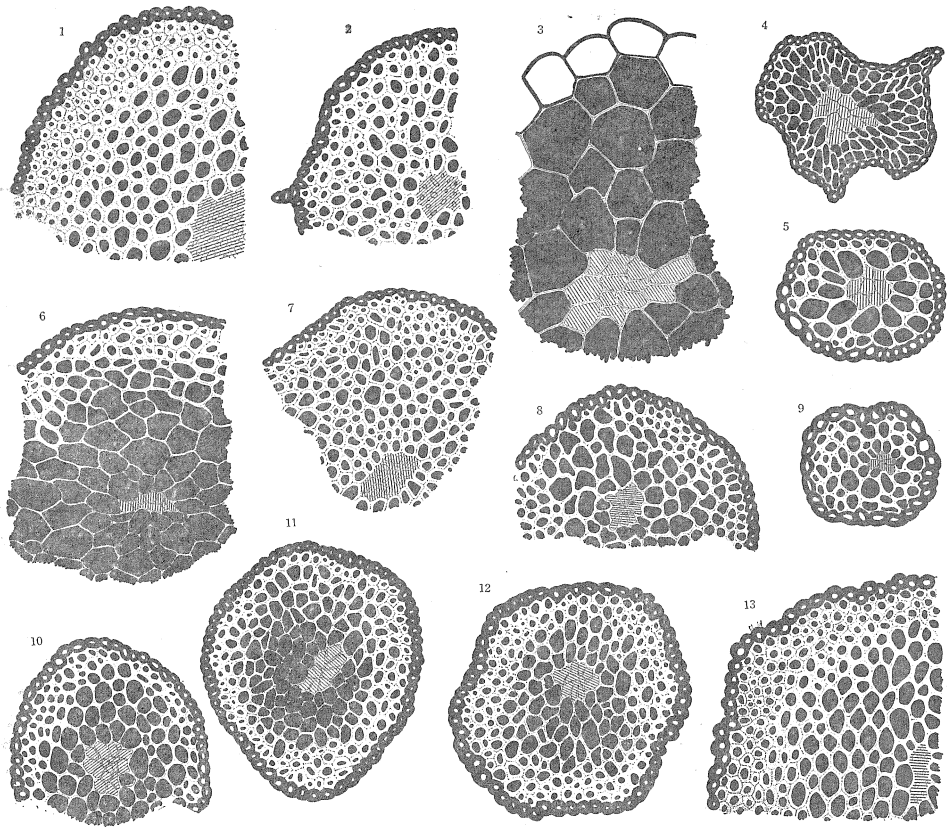

Fig. II Cross sections of the III-type stem (epidermis-cortex-central tissue)
1: *Thuidium toyamae* NOG. 2: *Ctenidium hastile* (MITT.) BROTH. 3: *Hookeria nipponensis* (BESCH.) BROTH. 4: *Mnium microphyllum* D. et M. 5: *Fissidens adelphinus* BESCH. 6: *Plagiothecium* sp. 7: *Thamnium plicatulum* LAC. 8: *Grimmia maritima* TURN. 9: *Grimmia plagiopodia* HEDW. 10: *Grimmia brunnescens* f. *epilosa* (SCHIFFN.) PAR. 11: *Hypnum oldhamii* (MITT.) JAEG. 12: *Campylium* sp. 13: *Hylocomium cavifolium* LAC.

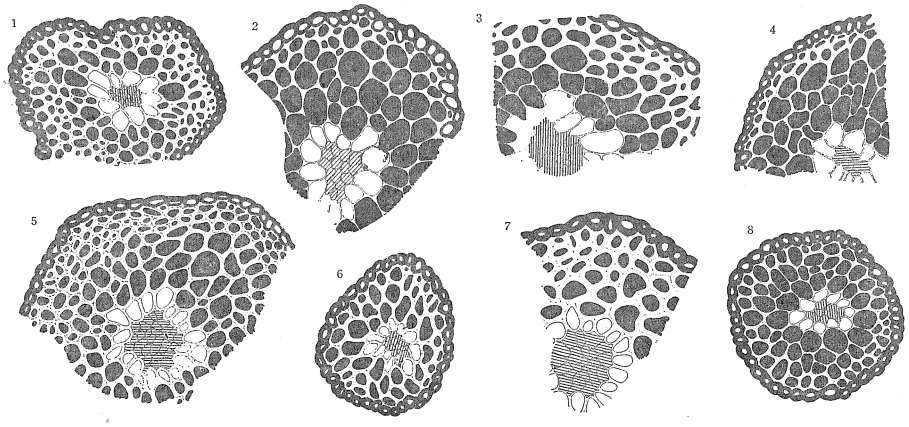

Fig. III Cross sections of the IV-type stem (epidermis-cortex-endodermis-central strand)
1: *Grimmia gracile* f. *tenuis* VILHL. 2: *Grimmia anomala* HAMP. 3: *Grimmia decipiens* (SCHULTZ.) LINDB. 4: *Grimmia laevigata* (BRID.) BRID. 5: *Grimmia ovalis* (HEDW). LINDB. 6: *Grimma incurva* SCHWAEGR. 7: *Grimmia pulvinata* v. *africana* (HEDW.) HOOK. 8: *Grimmia teretinervis* LIMPR.

V-type is a structure that is found in *Bartramiopsis lescurii* and *Oligotrichum parallelum*. The superficial layer of the stem is clearly defined as an epidermis. Inside the epidermis is the cortex. The peripheral cortical region consists of compact, elongated prosenchymatous cells, the inner cortex has a intercellular spaces. Inside the inner cortex there is a layer with abundant starchy contents. It seems to be the endodermis. Internal to this is a part composed of sieve tube-like cells. It is named the leptom. Inside the leptom is the hadrom, composed of several layers of cells with thick-walls. (cf. Pl. I *Bartramiopsis lescurii* and *Oligotrichum parallelum* and Fig. V-5, V-type: epidermis-cortex-endodermis-leptom-hadrom), and Fig. IV *Polytrichum commune*, *Pogonatum grandifolium*, *Polytrichum piliferum*, *Polytrichum juniperinum*, *Polytrichum formosum*, *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum nipponicum*; V′-type: epidermis-cortex-endodermis-hadrom-leptom).

In *Polytrichum* the stem is differentiated most to the greatest degree of all in the Musci, that is, into an epidermis of thick-walled cells, cortical sclerenchyma, cortical parenchyma, an endodermis and a central strand consisting of leptom and hadrom. The

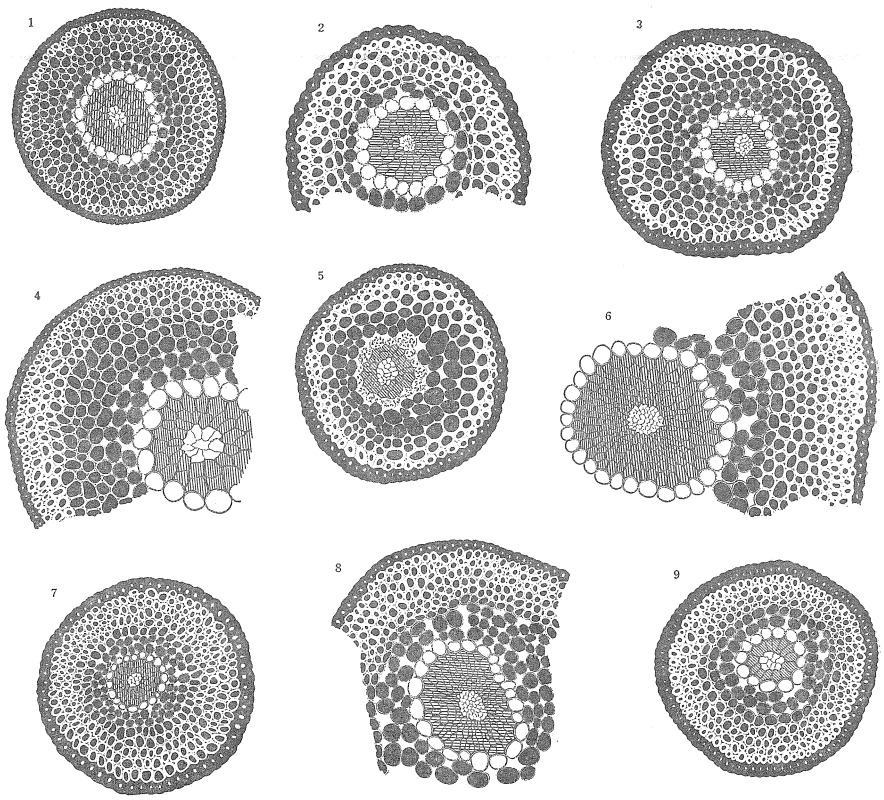

Fig. IV Cross sections of the V′-type seta (epidermis-cortex-endodermis-hadrom-leptom)
1: *Polytrichum piliferum* HEDW. 2: *Pogonatum grandifolium* (LINDB.) JAEG. 3: *Pogonatum contortum* (SCHWAEGR.) SULL. 4: *Polytrichum formosum* HEDW. 5: *Pogonatum spinulosum* MITT. 6: *Polytrichum commune* HEDW. 7: *Pogonatum nipponicum* NOG. et OSADA 8: *Polytrichum juniperinum* HEDW. 9: *Atrichum undulatum* v. *minus* (L. et D. C.) WEB. et MOHR.

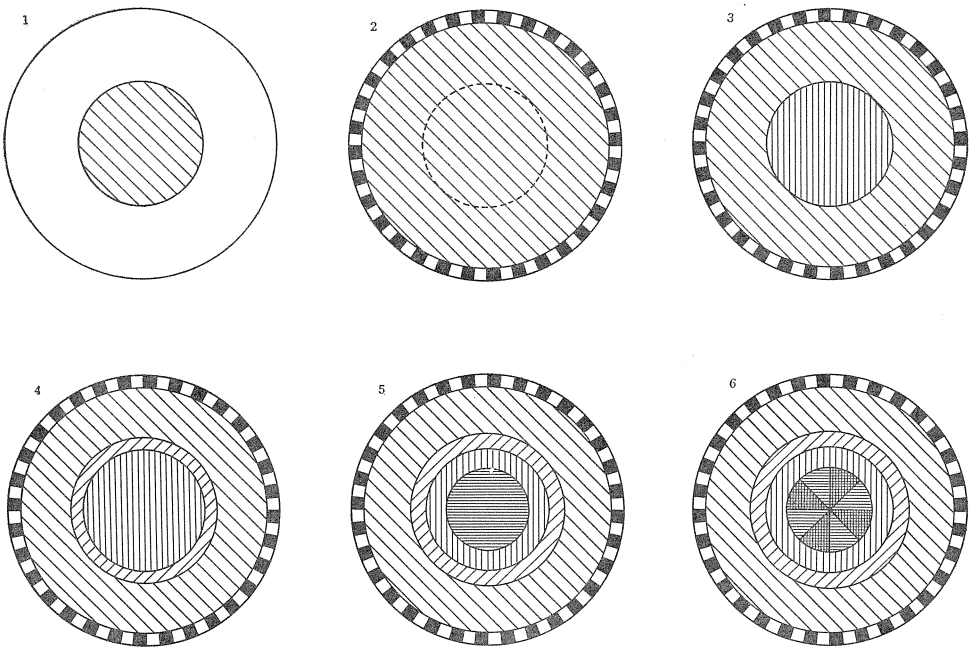

Fig. V Six types of the inner structures of the stem in Musci
1: I-type (cortex-axial cylinder)
2: II-type (epidermis-axial cylinder)
3: III-type (epidermis-cortex-central tissue)
4: IV-type (epidermis-cortex-endodermis-central strand)
5: V-type (epidermis-cortex-endodermis-leptom-hadrom)
6: VI-type (epidermis-cortex-endodermis-leptom-hydrom-stereom)

epidermis is one or two layers of the smaller fulvescent cells with thick walls. The epidermal cells are stained orange with fuchsin. Inside the epidermal layer is a band of brown sclerenchymatous cells, called external cortex, which, containing a few chloroplasts, merges internally into sparsely spaced, thin-walled parenchymatous, green cells, internal cortex, containing a great number of chloroplasts. This layer of chloroplast-containing parenchymatous cells may be a part of the assimilation tissue. At the inner limit of these cortical layers is a layer, one cell thick. This layer resembles the endodermis. The cells of the endodermal layer and the thin-walled green parenchymatous cells are much alike in characters such as shape, size and cell wall. The central part, in which two tissues, hadrom and leptom, are distinct one from the other, consists in an inner compact mass. The central portion of the mass, is called hadrom, of which the cell walls are thicker than those of the outer layers (leptom). The hadrom consists of very thick-walled elongated living cells often with oblique ends and containing here and there a little starch. These are the stereids, as a whole being called stereom. Scattered among these stereids are elements of about the same diameter, but quite destitute of contents. These are often united in bands of 2 or 3, the cells of each band being separated by extremely delicate cellulose walls, which are really the acutely oblique walls of the cells. These elements, which are similar to and

continuous with those of the central strand of the aerial stem, are given the name hydroids, that is, water conducting tissue, as a whole being called hydrom. Outside the hadrom, the sieve tube-like cells are known as leptoids, and as a whole are called leptom (in the seta of *Polytrichum*, *Pogonatum* and *Atrichum* outside leptom, there is the hadrom). The cells of the leptom and the pericycle are much alike in characters such as shape, size and cell wall. It is so difficult to distinguish between the leptoids and the pericycle that we would call these layers as leptom band (cf. Pl.I-VI *Atrichum undulatum*, *Pogonatum alpinum*, *Pogonatum contortum*, *Pogonatum grandifolium*, *Pogonatum inflexum*, *Pogonatum nipponicum*, *Pogonatum urnigerum*, *Polytrichum commune*, *Polytrichum formosum*, *Polytrichum gracile*, *Polytrichum juniperinum*, *Polytrichum ohioense*, *Polytruchum piliferum* and Fig. V-6, VI-type: epidermis-cortex-endodermis-leptom-hydrom-stereom).

The stem-structure which belongs to VI-type, is found in the species of *Polytrichum*, *Pogonatum* and *Atrichum*, genera of Polytrichaceae. In *Pogonatum*, numbers of cell layers of the hadrom are always 3-6 layers (B-type). In *Polytrichum* diameters of the central strand are in all cases 150-370μ (A-type). In view of these facts, we conclude that the characteristics of the conducting tissue are fairly peculiar to the genus, so that the characteristics of the stem-structure are vitally important in the classification system of the genus.

Next, we consider the origin of each tissue of the stem as shown in Tab. 13.

Tab. 13 The origin of each tissue of the stem

<table>
<tr><th colspan="2">Type of the stem</th><th>I-type</th><th>II-type</th><th>III-type</th><th>IV-type</th><th>V-type</th><th>VI-type</th></tr>
<tr><td rowspan="7">Segment cutting off from the apical cell</td><td rowspan="4">Outer cell</td><td>Leaf</td><td>Leaf</td><td>Leaf</td><td>Leaf</td><td>Leaf</td><td>Leaf</td></tr>
<tr><td rowspan="3">Cortex</td><td rowspan="3">Superficial layer</td><td>Epidermis</td><td>Epidermis</td><td>Epidermis</td><td>Epidermis</td></tr>
<tr><td rowspan="2">Cortex</td><td>Cortex</td><td>Cortex</td><td>Cortex</td></tr>
<tr><td>Endodermis</td><td>Endodermis</td><td>Endodermis</td></tr>
<tr><td rowspan="3">Inner cell</td><td rowspan="3">Axial cylinder</td><td rowspan="3">Axial cylinder</td><td rowspan="3">Central tissue</td><td rowspan="3">Central strand</td><td>Leptom</td><td>Leptom</td></tr>
<tr><td rowspan="2">Hydrom</td><td>Hadrom</td></tr>
<tr><td>Stereom</td></tr>
</table>

Those anatomical characters of the stem are morphologically distinguished, but it is not to clear from which particular cell each tissue is derived. We have to consider the origin of each tissue of the stem in our future studies.

Tab. 14 The similarity index shown by the number of the characters which are similar in two given species

	Bartramiopsis lescurii	*Oligotrichum parallelum*	*Pogonatum spinulosum*	*Pogonatum grandifolium*	*Pogonatum urnigerum*	*Pogonatum alpinum*	*Pogonatum contortum* (1)	*Pogonatum contortum* (2)	*Pogonatum inflexum* (1)	*Pogonatum inflexum* (2)	*Pogonatum inflexum* (3)	*Pogonatum nipponicum*	*Atrichum undulatum*	*Polytrichum ohioense* (1)	*Polytrichum ohioense* (2)	*Polytrichum gracile*	*Polytrichum formosum* (1)	*Polytrichum formosum* (2)	*Polytrichum juniperinum*	*Polytrichum piliferum*	*Polytrichum commune* (1)	*Polytrichum commune* (2)	*Polytrichum commune* (3)
Bartramiopsis lescurii		11	4	1	8	7	8	4	3	4	4	4	3	7	7	3	3	4	5	3	2	1	1
Oligotrichum parallelum	11		4	1	8	7	8	4	3	4	4	4	3	7	7	3	3	4	5	3	2	1	1
Pogonatum spinulosum	4	4		2	3	3	5	5	4	5	5	5	4	6	6	3	2	2	3	3	4	3	3
Pogonatum grandifolium	1	1	2		3	3	4	6	6	5	6	6	6	4	4	6	6	5	4	7	5	6	6
Pogonatum urnigerum	8	8	3	3		10	6	5	4	5	5	5	4	6	6	6	6	7	8	5	3	4	4
Pogonatum alpinum	7	7	3	3	10		6	6	5	6	6	6	5	7	7	7	7	8	9	6	3	4	4
Pogonatum contortum (1)	8	8	5	4	6	6		7	6	6	7	7	6	8	8	8	4	3	4	4	4	3	3
Pogonatum contortum (2)	4	4	5	6	5	6	7		10	10	11	11	10	8	8	8	6	5	6	7	7	6	6
Pogonatum inflexum (1)	3	3	4	6	4	5	6	10		9	10	10	11	7	7	9	7	6	7	8	8	7	7
Pogonatumi nflexum (2)	4	4	5	5	5	6	6	10	9		10	10	9	8	8	8	5	5	6	7	8	7	7
Pogonatum inflexum (3)	4	4	5	6	5	6	7	11	10	10		11	10	8	8	8	6	5	6	7	7	6	6
Pogonatum nipponicum	4	4	5	6	5	6	7	11	10	10	11		10	8	8	8	6	5	6	7	7	6	6
Atrichum undulatum	3	3	4	6	4	5	6	10	11	9	10	10		7	7	9	7	6	7	8	8	8	8
Polytrichum ohioense (1)	7	7	6	4	6	7	8	8	7	8	8	8	7		11	7	5	6	7	7	5	4	4
Polytrichum ohioense (2)	7	7	6	4	6	7	8	8	7	8	8	8	7	11		7	5	6	7	7	5	4	4
Polytrichum gracile	3	3	3	6	6	7	8	8	9	8	8	8	9	7	7		7	8	9	10	7	8	8
Polytrichum formosum (1)	3	3	2	6	6	7	4	6	7	5	6	6	7	5	5	7		10	9	6	4	5	5
Polytrichum formosum (2)	4	4	2	5	7	8	3	5	6	5	5	5	6	6	6	8	10		10	7	4	5	5
Polytrichum juniperinum	5	5	3	4	8	9	4	6	7	6	6	6	7	7	7	9	9	10		8	5	6	6
Polytrichum piliferum	3	3	3	7	5	6	4	7	8	7	7	7	8	7	7	10	6	7	8		6	7	7
Polytrichum commune (1)	2	2	4	5	3	3	4	7	8	8	7	7	8	5	5	7	4	4	5	5		10	10
Polytrichum commune (2)	1	1	3	6	4	4	3	6	7	7	6	6	8	4	4	8	5	5	6	7	10		11
Polytrichum commune (3)	1	1	3	6	4	4	3	6	7	7	6	6	8	4	4	8	5	5	6	7	10	11	

II. Affinity with the stem of the Polytrichaceae

The similarity index is shown by the number of the characters which are similar in two given species (Tab. 14). The similar indices of Bartramiopsis lescurii and Oligotrichum parallelum are both 11. This shows that both species can not be distinguished by the anatomical characteristics of the stem. The group with a great number in the similar index consists of *Pogonatum contortum*, *Pogonatum inflexum*, *Pogonatum nipponicum*, *Atrichum undulatum*, *Polytrichum ohioense*, and *Polytrichum gracile*. And *Polytrichum gracile*, *Polytrichum formosum*, *Polytrichum juniperinum* and *Polytrichum piliferum* have 6-10 similar indices each other, and *Pogonatum urnigerum*

Tab. 15 Relationship among the characteristics of the stem in 16 species of Polytrichaceae

Group	Species	Genera
A	*Bartramiopsis lescurii*	*Bartramiopsis*
	Oligotrichum parallelum	*Oligotrichum*
B	*Pogonatum spinulosum*	*Pogonatum*
C	*Pogonatum grandifolium*	
D	*Pogonatum urnigerum*	
	Pogonatum alpinum	
E	*Pogonatum contortum*	
	Pogonatum inflexum	
	Pogonatum nipponicum	
F	*Atrichum undulatum*	*Atrichum*
G	*Polytrichum ohioense*	*Polytrichum*
H	*Polytrichum gracile*	
I	*Polytrichum formosum*	
	Polytrichum juniperinum	
	Polytrichum piliferum	
J	*Polytrichum commune*	

and *Pogonatum alpinum* are much alike (10 similar indices) On the contrary, *Pogonatum grandifolium* as well as *Pogonatum spinulosum*, *Pogonatum urnigerum* and *Pogonatum alpinum*, bears very little resemblance to the other species of *Pogonatum*.

Tab. 15 shows the relationship among the characteristics of the stem in 16 species of Polytrichaceae. A-group, which consists of *Bartramiopsis lescurii* and *Oligotrichum parallelum*, is divided into genera *Bartramiopsis* and *Oligotrichum*. B-group consists of *Pogonatum spinulosum*. C-group consists of *Pogonatum grandifolium*. D-group consists of *Pogonatum urnigerum* and *Pogonatum alpinum*. B-, C-, and D-groups belong to the genus *Pogonatum*. E-group consists of *Pogonatum contortum*, *Pogonatum inflexum* and *Pogonatum nipponicum*. F-group consists of *Atrichum undulatum*. G-group consists of *Polytrichum ohioense*. H-group consists of *Polytrichum gracile*. E-, F-, G-, and H-groups are much alike. I-group consists of *Polytrichum formosum*, *Polytrichum juniperinum* and *Polytrichum piliferum*. There is much affinity between H-group and I-, J-groups.

The leptom might be a sieve tube-like tissue and the hydrom might be a element of the xylem. They seem to have very different developed into tissues specialized for conduction. Before examining this point, however, we must enquire into the physiology of conduction in bryophytes.

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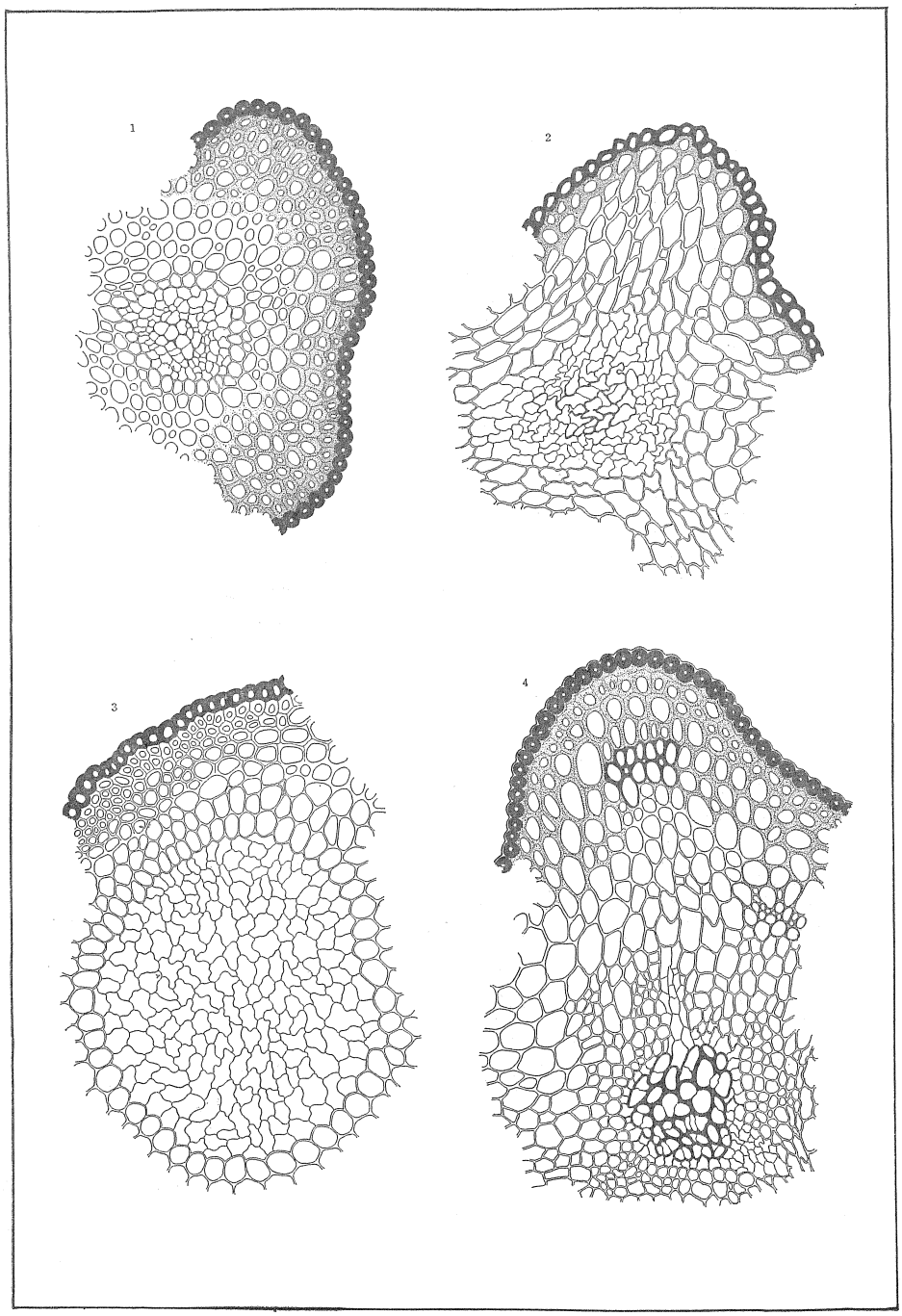

Plate I Cross sections of the stem

1: *Bartramiopsis lescurii* (JAM.) CARD. et THER. ×240

2: *Oligotrichum parallelum* (MITT.) KINDB. ×240

3: *Pogonatum spinulosum* MITT. ×160

4: *Pogonatum urnigerum* PAR. ×240

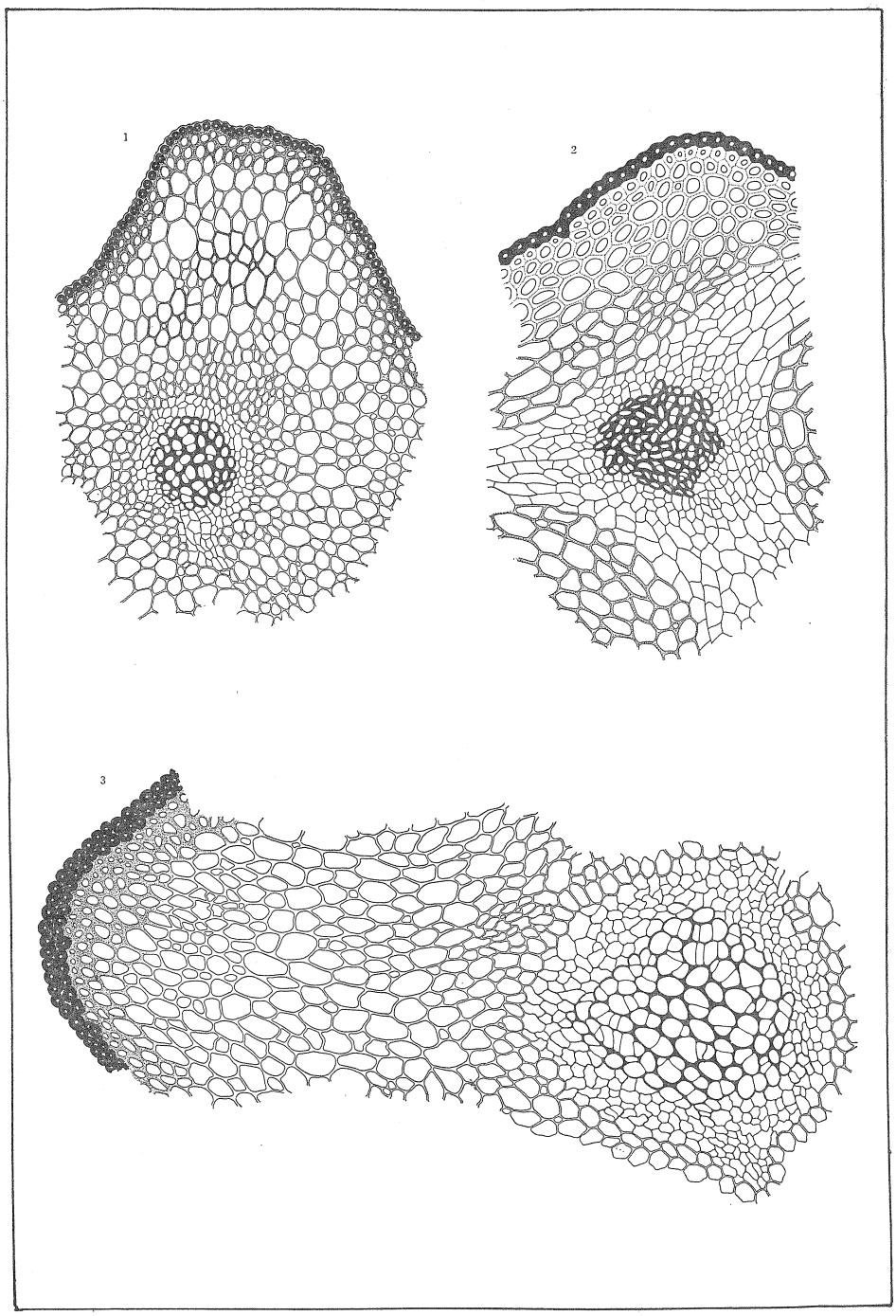

Plate II Cross sections of the stem

1: *Pogonatum alpinum* (HEDW.) ROEHL. ×160

2: *Pogonatum nipponicum* NOG. et OSADA ×240

3: *Pogonatum grandifolium* (LINDB.) JAEG. ×160

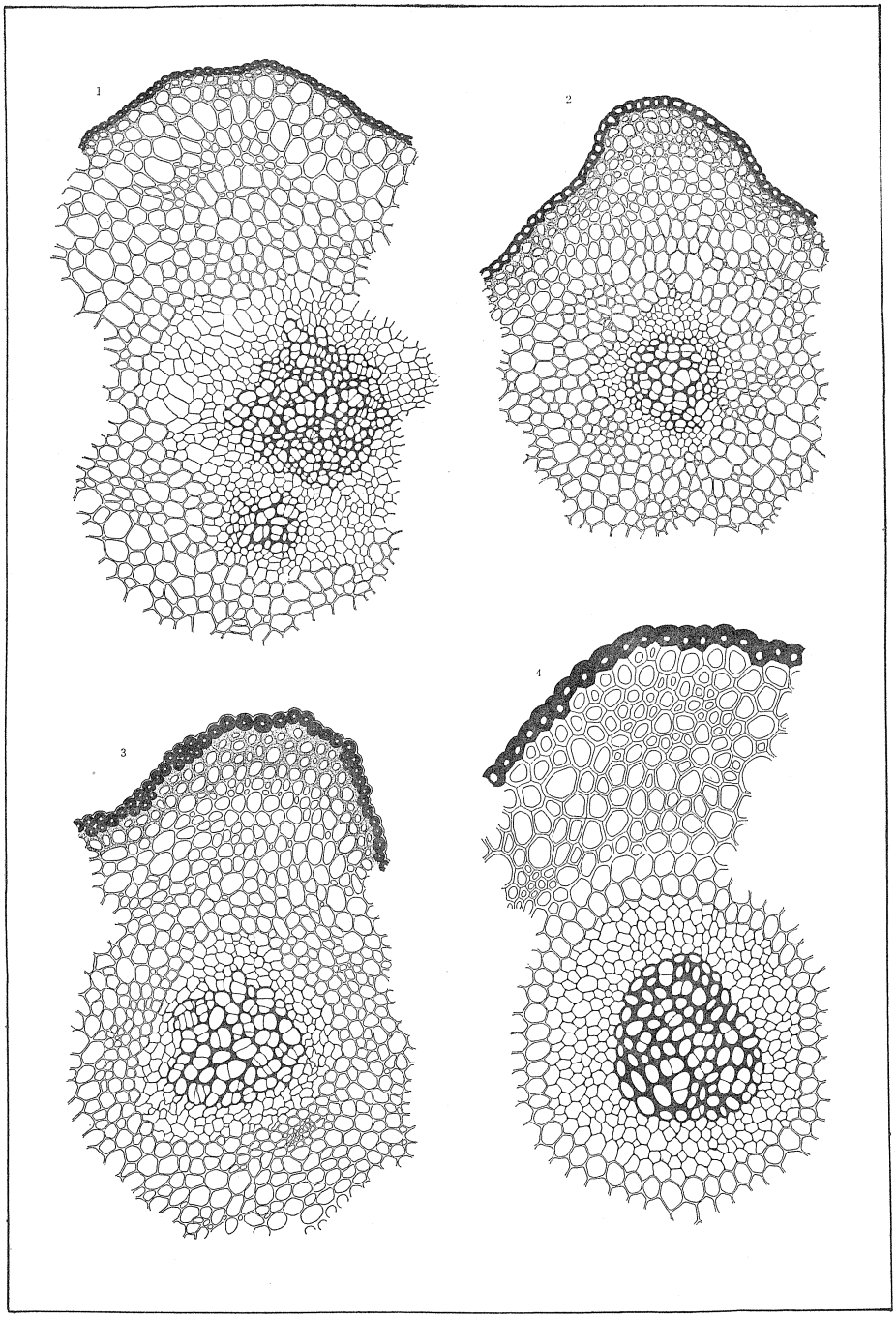

Plate III Cross sections of the stem

1: *Pogonatum inflexum* (LINDB.) PAR. ×160

2: *Pogonatum inflexum* (LINDB.) PAR. ×160

3: *Pogonatum inflexum* (LINDB.) PAR. ×160

4: *Atrichum undulatum* (HEDW.) P. BEAUV. ×160

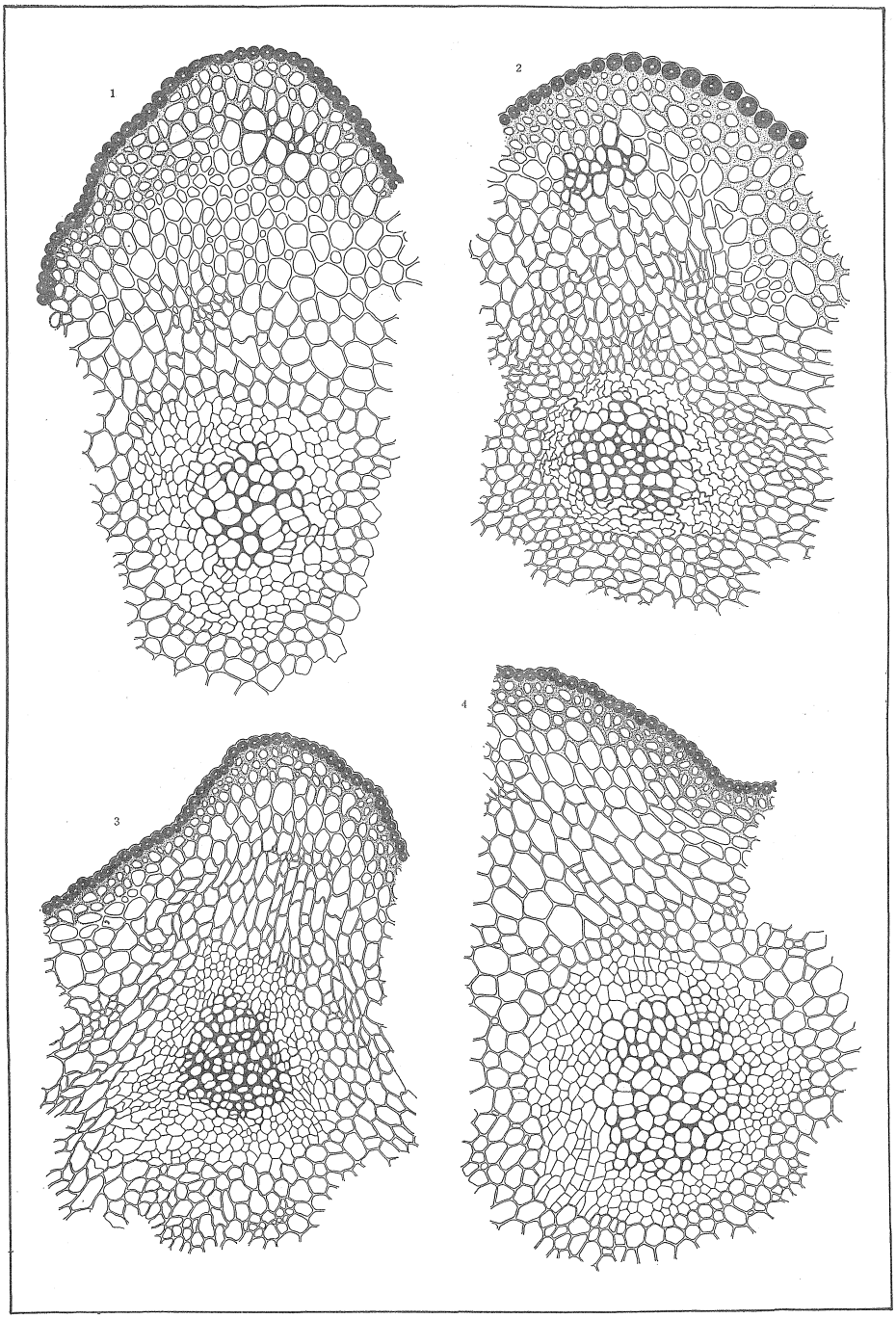

Plate IV Cross sections of the stem

1: *Polytrichum gracile* SM. ×160

2: *Polytrichum juniperinum* HEDW. ×160

3: *Pogonatum contortum* MENZ. ×160

4: *Pogonatum contortum* MENZ. ×160

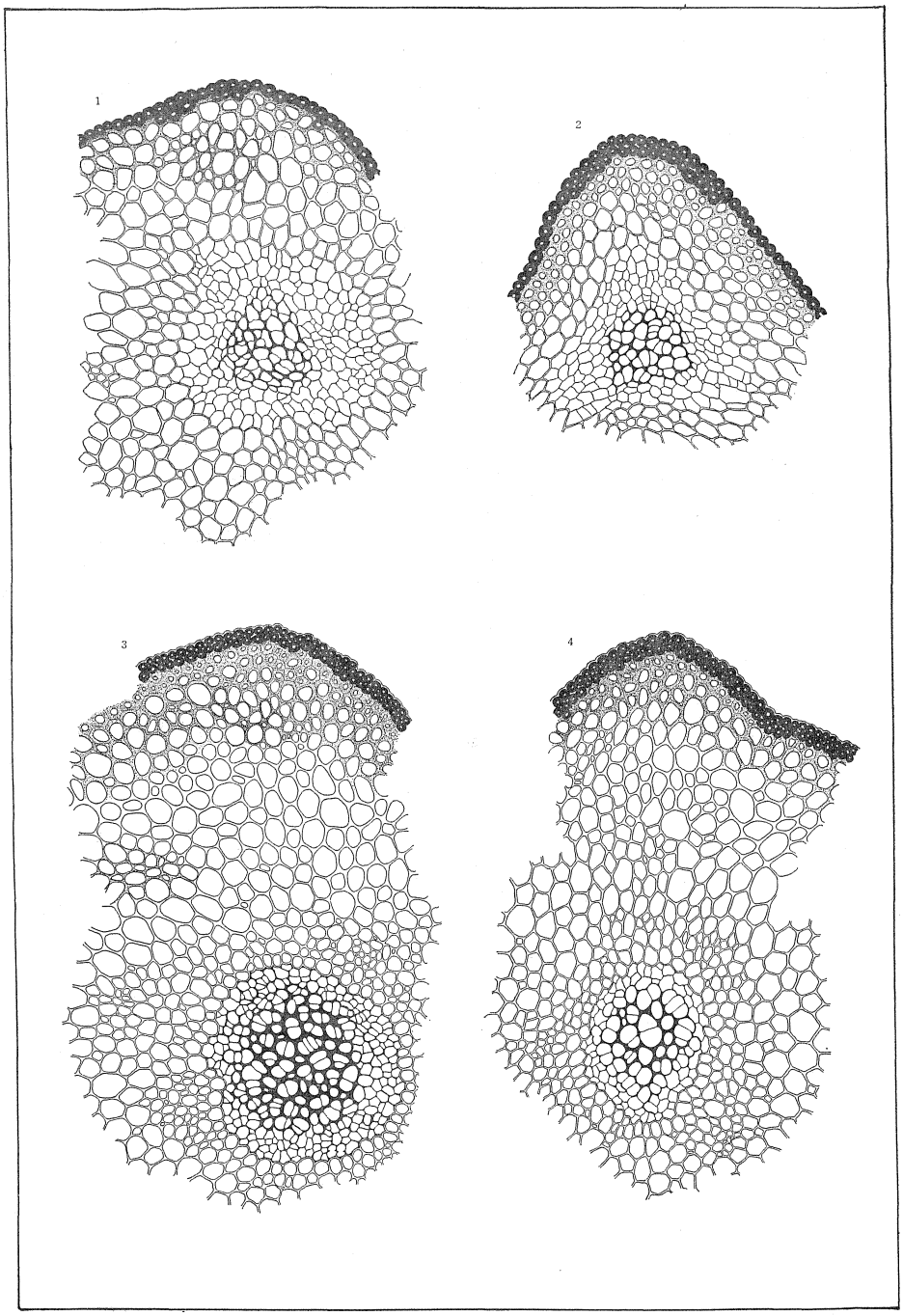

Plate V Cross sections of the stem

1: *Polytrichum ohioense* REN et CARD. ×160

2: *Polytrichum ohioense* REN. et CARD. ×160

3: *Polytrichum formosum* HEDW. ×160

4: *Polytrichum formosum* HEDW. ×160

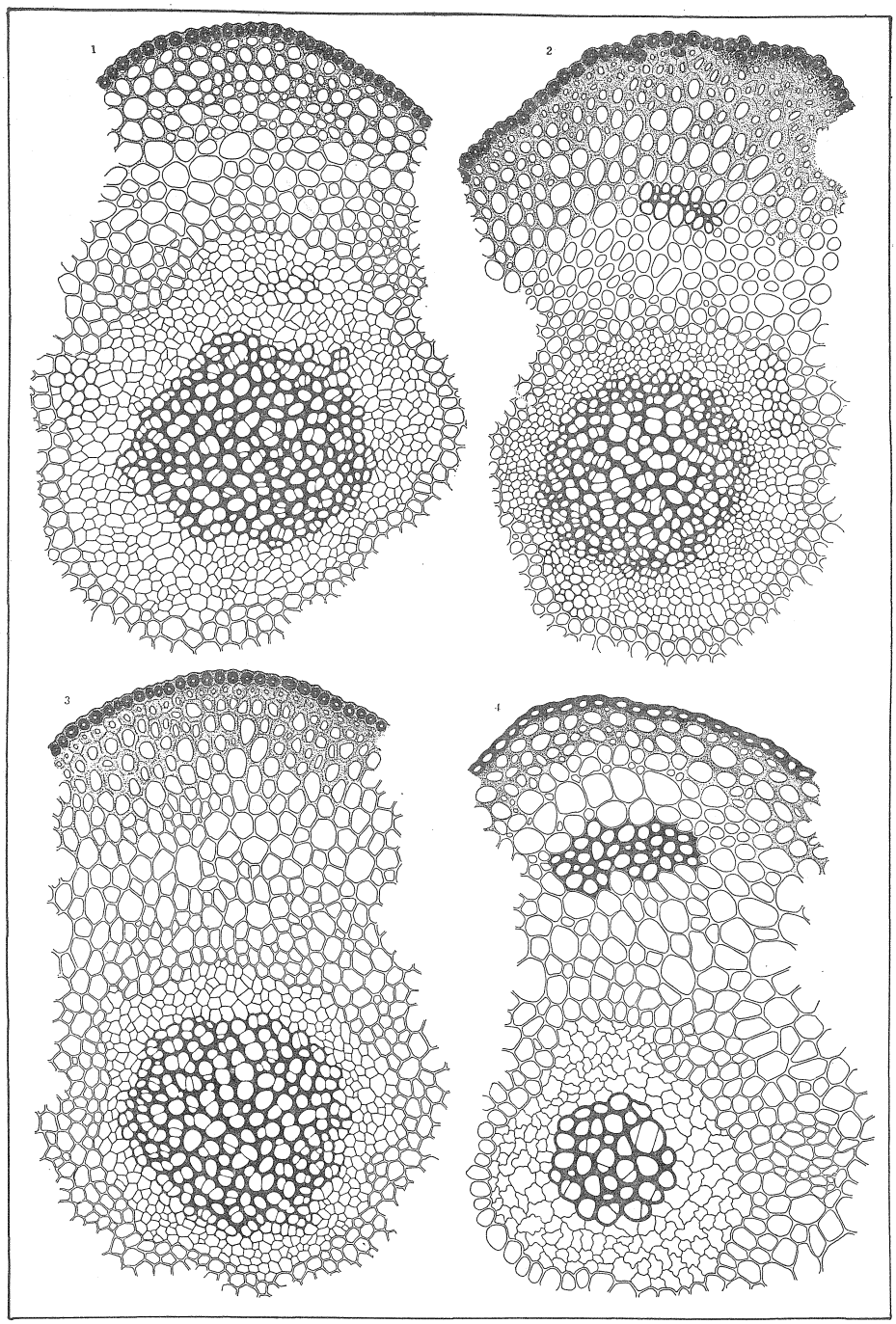

Plate VI Cross sections of the stem

1: *Polytrichum commune* HEDW. ×160

2: *Polytrichum commune* HEDW. ×160

3: *Polytrichum commune* HEDW. ×160

4: *Polytrichum piliferum* HEDW. ×160