Yellow 5³/₄ - 8½
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OF THE

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VOL. 39

FOUNDED BY WILLIAM HENRY LEGGETT, 1870

EDITOR
PHILIP DOWELL

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Errata

Page 96, line 8, for **Viloa** read **Viola.**
Page 152, line 4, for *Cubomia* read *Cubonia.*
Page 152, line 16, for *violaceus* read *violascens.*
Page 235, line 12 from below, for 1831 read 1827.
Page 244, line 2, for 1841 read 1832.
Page 244, line 7, for 1841 read 1844.
Page 246, line 5, for 1827 read 1829.
Page 246, line 4 from below, for 1827 read 1826.
Page 247, line 4 from below, for 1832 read 1829.
Page 248, line 20, for 1832 read 1827.
Page 313, line 22, for *calceoliformis* read *calceoliforme.*
Page 377, line 14, for *tubulare* read *tabulare.*

VOL. 39 JANUARY 1912 NO. I

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LANCASTER, PA.

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BULLETIN

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TORREY BOTANICAL CLUB

JANUARY 1912

Studies of West Indian plants—IV

NATHANIEL LORD BRITTON

16. DENDROPANAX IN THE WEST INDIES

1. DENDROPANAX ARBOREUM (L.) Dcne. & Planch.

A tree, up to 20 m. high, but usually much smaller and often flowering as a shrub. Leaves chartaceous, from ovate to obovate, mostly acuminate at the apex, narrowed or rounded at the base, often 2 dm. long; inflorescence from shorter than the leaves to equaling them, or longer, the 20 umbels or fewer racemosely arranged and umbellate at the summit, sometimes leafy-bracted, but the bracts usually small, ovate to lanceolate; peduncles of the umbels slender, ascending, up to 3 cm. long in fruit; pedicels 1½ to 3 times as long as the flowers, somewhat elongating in fruit; petals white or greenish; calyx rather sharply toothed, about 2 mm. wide at flowering time; fruit black, strongly lobed, 6–8 mm. thick.

Widely distributed at lower and middle altitudes in moist or wet districts in Jamaica, Cuba, Hispaniola, Porto Rico, and on Signal Hill, St. Thomas. Ascends to 1,600 meters in Jamaica.

2. DENDROPANAX SAMYDIFOLIUM (C. Wright) Seem.

This species is known to me only from the original specimens collected by Wright at S. Felepina near La Grifa, western Cuba; Wright's description calls for a tree up to 13 meters high. The leaf base is decurrent on the petiole. The species seems very closely related to *D. arboreum*, which is abundant in the mountains and hills of western Cuba.

[The BULLETIN for December 1911 (38: i–v, 531–570. *pl. 35*) was issued 6 Ja 1912.]

3. **Dendropanax brachypodum** (Urban) Britton nom. nov.

Gilibertia brachypoda Urban, Symb. Ant. 5: 452. 1908.

A short-petioled and long-pediceled Haitian mountain species, related to *D. arboreum*, known to me only from Professor Urban's description.

4. DENDROPANAX LAURIFOLIUM (E. March.) R. C. Schneider

A detailed description of this endemic Porto Rico mountain tree is published by Professor Urban in Symbolae Antillanae 1: 203.

5. DENDROPANAX CUNEIFOLIUM (C. Wright) Seem.

A shrub or tree up to 6 m. high, the branches slender, often drooping. Leaves spatulate to oblong-oblanceolate, 2 dm. long or less, 1.5–6 cm. wide, obtuse, or bluntly acute at the apex, cuneate at the base, the petiole 1/6 to 1/4 the length of the blade; peduncle slender, straight, as long as the leaves or longer; umbel 7–20-flowered; pedicels 1.5–2 cm. long; petals green, acute; flowering calyx about 4 mm. broad; fruit globose to globose-oblong, black, 6–8 mm. thick, the persistent style about half its length.

Banks of streams and wooded bogs at lower and middle elevations, Pinar del Rio and Isle of Pines, Cuba.

6. DENDROPANAX NUTANS (Sw.) Dcne. & Planch.

A shrub with stout gray branches. Leaves ovate to ovate-elliptic, coriaceous, 10 cm. long or less, acute or short-acuminate at the apex, narrowed or rounded at the base, the veins rather prominent on the under side, the stout petioles very unequal in length, sometimes two thirds as long as the blade; peduncle stout, 5–7 cm. long, bracted at or near the base; umbels many-flowered, inclined or nodding; pedicels 2–3 cm. long; flowering calyx 5 mm. broad.

Known only from Blue Mountain Peak, Jamaica, where it is reported as abundant. Professor Urban (Symb. Ant. 1: 200) characterizes the umbel as strictly erect, but it is inclined or nodding in all specimens seen by me.

7. DENDROPANAX PENDULUM (Sw.) Dcne. & Planch.

A shrub about 4 m. high. Leaves chartaceous in texture, ovate, acute or bluntish at the apex, rounded or subcordate at the base, triplinerved and rather prominently pinnately veined, the blades 12 cm. long or less, nearly twice as long as wide; petioles rather stout, one half to two thirds as long as the blades; peduncle much longer than the leaves, pendulous, 2 dm. long or less, bracted and jointed a little below the middle; umbel many-flowered; pedicels slender, 15–18 mm. long; flowering calyx broadly turbinate, 3.5 mm. broad; petals oblong-lanceolate, about as long as the calyx.

Cockpit Country, Jamaica, *Harris 9188*, from Lapland, near Catadupa; this specimen agrees with the type specimen of *Hedera nutans* Sw., in the herbarium of the British Museum of Natural History. The species is also recorded by Marchand from Catharine's Peak, collected by *Eggers, 3651*, which I have not seen.

8. **Dendropanax grandiflorum** sp. nov.

A tree, about 8 m. high. Leaves chartaceous, obovate, 5–10 cm. long, 5 cm. wide or less, bluntly pointed at the apex, cuneate-narrowed at the base, rather strongly pinnately veined, the margins slightly revolute, the stout petioles about 1 cm. long or less; inflorescence of simple, terminal, few-flowered umbels, or rarely a secondary umbel borne halfway up on the peduncle; peduncle rather stout, 3–5 cm. long, bracted and jointed just above the base; flowers 8 or fewer in the umbels; pedicels rather stout, nearly erect, 1.5–2 cm. long; flowering calyx 8 mm. high, narrowly campanulate, its mouth 6–7 mm. broad; corolla 5 mm. long just before expanding, the bud rounded; anthers in the unopen bud about as long as the filaments; fruit oblong, 1 cm. long, 7 mm. thick, the persistent style 6–7 mm. long.

Peckham woods, Upper Clarendon, Jamaica, July 7, 1911, *Harris 10994*.

9. **Dendropanax elongatum** sp. nov.

A slender tree about 8 m. high. Leaves clustered at the ends of the branches, oblong to oblong-lanceolate, coriaceous, faintly pinnately veined, acute at the apex, narrowed or somewhat rounded at the base, the blade 15 cm. long or less; the petiole one sixth to one third as long as the blade; peduncle shorter than the larger leaves, 8–12 cm. long, bracted somewhat below the middle, the bracts triangular-ovate, apparently nearly erect; very young inflorescence depressed-hemispheric, 8 mm. broad; the flower buds sessile or nearly so.

Peckham woods, Upper Clarendon, Jamaica, at 800 to 900 meters elevation, January 3, 1910, *Harris 10874*.

The very young state of the inflorescence does not enable me to give a description of the flowers of this interesting tree, and its generic position is therefore uncertain. Its jointed and bracted peduncle is similar to that of *Dendropanax pendulum*, but its foliage is altogether different from that species.

10. **Dendropanax grande** sp. nov.

A tree up to 16 m. high. Leaves clustered at the ends of the branches, ovate to ovate-elliptic, coriaceous in texture, rather prominently pinnately veined, obtuse at both ends, the blade 15 cm. long or less, the stout petioles as long as the blades, or shorter; peduncle much shorter than the leaves, erect, stout, about 4 cm. long, bracted at the base; pedicels numerous, about 50, rather stout, 2 cm. long; flowering calyx subhemispheric, 5 mm. broad; petals lanceolate, about as long as the calyx; filaments rather stout, somewhat longer than the petals.

Moneague, Jamaica, *Alexander Prior*, May 1850.

11. **Dendropanax blakeanum** sp. nov.

A slender tree about 8 m. high. Leaves clustered near the ends of the branches, elliptic, or somewhat obovate-elliptic, rather coriaceous in texture, faintly pinnately veined, sharply acute at the apex, cuneate at the base, 10 cm. long or less; the petiole one fifth to one third as long as the blade; peduncle erect, as long as the leaves or twice as long, bracted at the base; umbels 8–16-flowered; pedicels slender, 2 cm. long in fruit; flower buds ovoid-hemispheric, obtuse, 3 mm. long just before the petals unfold; calyx in young fruit turbinate, 4 mm. broad; fruit subglobose, 5 mm. in diameter; the conic persistent style 2.5 mm. long.

John Crow or Blake Mountains, Jamaica, at 550 meters elevation, *Harris & Britton 10761*, collected March 10, 1909.

Differs from *Dendropanax nutans* in the longer, strictly erect, few-flowered peduncles, and in the venation, texture, and shape of the leaves.

12. **Dendropanax cordifolium** sp. nov.

A tree about 6 m. high. Leaves clustered at the ends of the branches, chartaceous in texture, broadly ovate, prominently pinnately veined, obtuse, or short-acuminate at the apex, cordate, or subcordate at the base, the blades 2 dm. long or less, about two thirds as wide as long, the stout petioles about one half as long as the blades, or shorter; peduncle stout, bracted at and very near the base, inclined, longer than the petioles, 12–15 cm. long; umbels many-flowered; pedicels rather slender, 2.5 cm. long; flowering calyx broadly turbinate, 4–5 mm. broad; petals white, about as long as the calyx; filaments somewhat longer than the petals; persistent style of the young fruit very broadly conic, 2 mm. long or less.

Woodlands, summit of Dolphin Head, Jamaica, March 17, 1908, *Britton & Hollick 2856*.

17. THE GENUS CAMERARIA (PLUMIER) L.

The genus was accepted by Linnaeus from Plumier, *C. latifolia* being the type species, and *C. angustifolia* L. also appearing in the original publication of the genus, which is wholly West Indian in distribution, so far as I am aware.

1. CAMERARIA LATIFOLIA L. Sp. Pl. 210. 1753

This is a shrub or tree up to 15 m. high, as observed by me at the United States Naval Station, Guantanamo Bay, Cuba. It has characteristic ovate-elliptic acuminate leaves. Its fruit is about 6 cm. long. The species seems to be widely distributed in Cuba; occurring in the provinces of Oriente, Matanzas, and Havana. In Jamaica it is apparently rare, the only specimen seen by me being one collected by Dr. A. Hollick and myself (*2045*) in rocky woods at Negril, the extreme western end of that island. It is recorded from Haiti but I have seen no specimens from Hispaniola, which is presumably the type locality.

2. CAMERARIA ANGUSTIFOLIA L. Sp. Pl. 210. 1753

My knowledge of this species rests wholly on Plumier's description and *plate 72, figure 2*, where it is illustrated as having linear-acuminate leaves and fruit 2.5 cm. long. According to Miller, cited by Grisebach, Fl. Br. W. I. 410, it was found in Jamaica, but it is unknown to us from that island.

3. CAMERARIA RETUSA Griseb. Fl. Br. W. I. 410. 1861

(C. *angustifolia* Griseb. loc. cit. not L.)

This is wholly a Cuban species, so far as it is represented in our collections, occurring in the provinces of Santa Clara, Havana, Pinar del Rio, and on the Isle of Pines. It has lanceolate to oblong leaves, which are obtuse and emarginate at the apex. Its fruit is about 2 cm. long, the narrowly linear terminal wing about as long as the ovoid body. Its flowers are only about 1 cm. long, the corolla limb about 1.5 cm. wide.

I take as the type of this species the specimen from "West Indies," collected by *Lane*, and preserved in the Kew Herbarium.

4. **Cameraria oblongifolia** sp. nov.

A tree 4–6 m. high with slender twigs. Leaves oblong to oblong-lanceolate, acutish to obtuse or minutely emarginate at the apex, narrowed at the base, 2–3.5 cm. long, 14 mm. wide or less, the slender petiole about 2 mm. long; corolla about 17 mm. broad; fruit compressed, lanceolate, 2–3 cm. long, about 1 cm. wide, grooved at the base on one side, the terminal wing oblong-triangular, obtuse, about as long as the body.

In wet woods near Tiffin, Camagüey, November 1–5, 1909, *Shafer 2877*; also represented by part of Wright's Cuban *no. 2950*, collected at Hanabana.

The other part of Wright's *2950*, which has ovate-lanceolate acuminate leaves, may represent another species. It has much more slender and longer petioles than *C. oblongifolia*, but the specimens examined by me are too imperfect to afford a complete description. Combs' *no. 19*, collected in Cieneguita in the province of Santa Clara, appears to be the same as this, but our specimen of that number also is incomplete.

5. **Cameraria microphylla** sp. nov.

A tree up to 5 m. high, intricately branched, the twigs very slender. Leaves oblong to oblong-obovate, 1 cm. long or less, 2–4 mm. wide, emarginate at the apex, narrowed at the base, the margins strongly revolute; fruit 2 cm. long, 4–6 mm. wide, compressed, the wing oblique, sinuate, terminal and lateral, similar to that of *C. latifolia* but very much smaller.

Near the northwestern end of Cayo Coco, Camagüey, October 23–24, 1909, *Shafer 2709*.

18. UNDESCRIBED SPECIES FROM JAMAICA

Acalypha jamaicensis sp. nov.

A shrub, 2–2.7 m. high, the branches slender, the young ones densely pubescent. Leaves oblong-lanceolate to oblong-oblanceolate, thin in texture, rather strongly pinnately veined, 9–15 cm. long, 3–5 cm. wide, sharply serrate all around, long-acuminate at the apex, subcordate at the base, sparingly pubescent above, rather densely pubescent on the veins beneath, the slender pubescent petioles 4 cm. long or less; flowers apparently monoecious; staminate spikes dense, pubescent, slender-stalked, about 3 cm. long, the short narrow bracts ciliate; pistillate spikes 3–6 cm. long, their bracts ciliate and pubescent, especially on the veins, 5–7-cleft to about the middle, the lobes obtuse or acutish; style dissected into filiform segments; fruit compressed, pubescent, 2 mm. broad.

Woodlands, Upper Clarendon, Jamaica. Type, *Harris 10842*, collected at Leicesterfield, January 28, 1910.

Related to *A. pruinosa* Urban, a nearly glabrous species with more deeply cleft pistillate bracts.

Actinostemon jamaicensis sp. nov.

A tree, up to 10 m. high, with slender, somewhat drooping branches, glabrous throughout. Leaves ovate to oblong-lanceolate, thin, 5–7 cm. long, 2–3.5 cm. wide, acuminate at the apex, rounded or narrowed at the base, shining above, pale beneath, pinnately veined, the very slender petioles 1 cm. long or less; staminate inflorescence interruptedly spicate, slender, 4–5 cm. long, flowers opposite the upper leaves; stamens 12, in clusters of 3, the united part and the free part of the filaments about equal in length; fruit depressed-globose, 9–12 mm. broad, 8–9 mm. high, both apex and base slightly sunken; seed globose, 3–3.5 mm. in diameter.

Thickets, Grant's Pen, near Yallah's Bay, Jamaica, May 26, 1911, *Harris 10936*, type; also at the same station, *Harris 10643*, *10818*, and *10826*, *Britton 3470* and *3913;* coastal thickets, Morant Point, *Britton 4103*.

Clusia clarendonensis sp. nov.

A small tree, up to 5 meters high. Leaves thick, rigid, obovate, 10 cm. long or less, 5–7 cm. wide, rounded at the apex, narrowed at the base, finely but rather strongly pinnately veined, the stout petioles 4–6 mm. long; fruiting peduncles stout, 3 cm. long; inflorescence about 3-flowered; fruiting pedicels about 1 cm. long; bracts triangular-ovate, acute, rigid, 5 mm. long; fruit oblong, obtuse, 2.5 cm. long, 1.5 cm. thick, the persistent sepals broadly triangular-ovate, scarious-margined; stigmas 5.

Peckham woods, Upper Clarendon, Jamaica, in fruit July 7, 1911, *Harris 10992.* Related to *C. venosa* Jacq.

Maytenus clarendonensis sp. nov.

A tree, up to 18 meters high. Leaves broadly elliptic, coriaceous, obtuse at both ends, 8–10 cm. long, 5–7 cm. wide, strongly revolute-margined, shining above, dull, and the veins rather prominent beneath, the stout petioles 1 cm. long or less; fruiting pedicels about 6 mm. long; capsules oblong, pointed at both ends, 15–18 mm. long, 8 mm. thick, roughened with depressed tubercles.

Peckham woods, Upper Clarendon, Jamaica, in fruit July 5, 1911, *Harris 10947.* Related to *M. jamaicensis* Krug & Urban.

Portlandia Harrisii sp. nov.

A small tree up to 6 meters high. Leaves orbicular, coriaceous, sessile, 8–10 cm. long and broad, rounded at the apex, cordate at the base, shining and reticulate-veined on both surfaces; stipules broad, obtuse; flowers 2–5 together in the upper axils, about 5 cm. long; corolla campanulate, the tube apparently about as long as the limb; fruiting pedicels stout, 6–8 mm. long; immature capsules obovoid, obtusely 5-angled, 2 cm. long, 1.5 cm. thick, crowned by the short calyx teeth.

On limestone rocks, Peckham woods, Upper Clarendon, July 6, 1911, *Harris 10975.* Only old withered fallen corollas were obtained.

Rondeletia saxicola sp. nov.

A shrub about 4 meters high, the twigs pilose-pubescent. Leaves thin, oblanceolate to oblong, acute at the apex, narrowed at the base, rather dark green and loosely appressed-pubescent above, paler green and loosely pilose-pubescent at least on the veins beneath, pinnately veined, 7–10 cm. long, 3 cm. wide or less, the pilose petioles about 1 cm. long; flowers in short-stalked globose clusters about 1 cm. in diameter, the rather stout, densely pubescent peduncles 5–8 mm. long; bracts linear, acute, 5–8 mm. long; calyx 4 mm. long, pubescent, lobed to below the middle, the lobes narrowly lanceolate, acute; fruit pubescent, about 5 mm. thick.

Rocky Cliff, Somerset, Manchester, September 23, 1908, *Harris & Britton 10609.*

Bidens clarendonensis sp. nov.

Perennial, glabrous, the stem and branches terete, trailing, somewhat woody. Leaves firm in texture, 4–7 cm. long,r hombic-ovate, acute at the apex, rather coarsely serrate, except at the broadly cuneate base, with slightly incurved gland-tipped teeth with revolute margins, the venation rather prominent, the petioles one fourth to one third as long as the blades; heads several together, on stalks 1.5 cm. long or less; involucre nearly hemispheric, many-flowered, its bracts about 1 cm. long, linear, obtuse or with a triangular acutish tip, 1.5–2 mm. wide; ray flowers about 5, 1.5–2 cm. long, the rays oblong, orange yellow, 2-toothed, 6–7 mm. wide, the tube about 3 mm. long; disk flowers 6 mm. long, the cylindric limb acutely 5-toothed; achenes 1 cm. long, less than 0.5 mm. thick, pappus of 1 or 2 subulate awns about 0.5 mm. long at flowering time, becoming 2 mm. long and downwardly barbed at maturity.

Peckham woods, Upper Clarendon, July 7, 1911, *Harris 10987.*

19. UNDESCRIBED SPECIES FROM CUBA

Mettenia acutifolia Britton & Wilson sp. nov.

A slender tree, 3–8 m. high, with hirsutulous twigs and petioles. Leaves ovate, occasionally lanceolate, 2–6 cm. long, 1–3.4 cm. broad, bluntly acuminate at the apex, rounded and equilateral or nearly so at the base, obscurely reticulate-veined and more or less pubescent with blackish hairs along the midrib and lateral veins above, hirsutulous on the midrib and lateral veins beneath, the margin ciliate; flowers unknown; valves of the capsule with crowded conic or subpyramidal tubercles, each tubercle tipped with a hair; seeds (immature) brownish black, lustrous, 4 mm. long, 3 mm. broad.

Camp La Gloria, south of Sierra Moa, Oriente, Cuba, December 30, 1910, *Shafer 8250.* Distinguished from *M. globosa* (Sw.) Griseb. by its spreading pubescence and by its pointed leaves.

Clerodendron (?) **calcicola** sp. nov.

A tree, 8 m. high, the branches smooth, the bark flaky in narrow strips. Leaves opposite, coriaceous, ovate to ovate-elliptic, distantly low-serrate, 10 cm. long or less, 3–5 cm. wide, glabrous, shining and with the inconspicuous venation somewhat impressed above, pale, strongly reticulate-veined with elevated venation, and rather densely pubescent beneath, the stout nearly terete petioles puberulent, 8–12 mm. long; flowers and fruit unknown.

Apparently related to *C. spinosum* Urban, of Santo Domingo, which has similar leaves with bristle-tipped teeth and villous petioles.

Pseudocarpidium pungens sp. nov.

A tree 8 m. high, the twigs slender. Leaves oblong to oblong-lanceolate, 3–7 cm. long, 3 cm. wide or less, chartaceous, strongly pinnately veined, spinulose-dentate, the apex acuminate, spinulose-tipped, the base obtuse, the upper surface smooth and shining, the under surface dull and puberulent; fruit irregularly 4-lobed, puberulent, depressed, 8 mm. in diameter.

Hillside, near Guantanamo, Oriente, Cuba, March 1909, *Britton 1992*, type; Sevilla Estate, near Santiago, Oriente, Cuba, *Norman Taylor 19*.

Related to *P. avicennioides* (A. Rich.) Millsp., which has entire leaves and more deeply lobed fruit.

Pseudocarpidium rigens (Griseb.) Britton comb. nov., *Vitex rigens* Griseb., has glabrous oblong to oblanceolate shining leaves, spinulose-dentate, at least above the middle, or some of them entire.

Portlandia nitens sp. nov.

A slender shrub, about 3 meters high. Leaves sessile, coriaceous, broadly ovate-elliptic, rounded at the apex, cordate or subcordate at the base, inconspicuously pinnately veined, shining above, dull beneath, 9 cm. long or less, the upper much smaller than the lower; flowers corymbose; pedicels short, viscid; calyx viscid, its lobes linear, about 8 mm. long; corolla pink, campanulate, 2.5 cm. long; capsule obovoid-oblong, 13 mm. long.

Dry thicket, upper valley of the Rio Navas, Oriente, March 22, 1910, *Shafer 4450*.

Elaeagia cubensis sp. nov.

A shrub, up to 3.2 meters high, the branches rather stout, the young twigs, branches of the inflorescence, and pedicels minutely pubescent. Leaves chartaceous, oblong or oblong-obovate, 7 cm. long or less, 2.5–3 cm. wide, abruptly short-acuminate at the apex, narrowed at the base, strongly pinnately veined, the petioles 6–9 mm. long; stipules narrow, obtuse, deciduous, 1 cm. long; panicles rather loosely flowered, 7 cm. long or less, minutely bracteolate; pedicels 2–3 mm. long; calyx tube obconic, 2 mm. long, the limb with 5 short rounded lobes; corolla white, 4 mm. long, its narrowly oblong lobes twice as long as the tube; filaments about as long as the corolla, the scale near the base of each with a dense tuft of white hairs; stigmas one fourth as long as the style.

Monte Jiquarito, Sierra Maestra, Oriente, Cuba, at about 1,100 meters altitude, September 18, 1906, *Norman Taylor 515*.

The genus has been hitherto known only from the South American Andes.

20. NOTES ON SPECIES OF SOLANUM

SOLANUM BLODGETTII Chapm.

This species is cited by Mr. O. E. Schulz* as a synonym of *Solanum bahamense subarmatum* (Willd.) O. E. Schulz, but he has wholly misunderstood its type specimens, which show that it is more nearly related to *S. verbascifolium* than to *S. bahamense;* it grows plentifully on Key West, Florida (*Blodgett*, type; *Merrill; Pollard, Collins & Morris 3; Britton 520; Lansing 1969*), in the Florida Everglades (*Britton 237; Small & Wilson 1678, 1962; Small & Carter 2674, 2675, 2936, 3101*), and is to be added to the West Indian Flora, as it occurs on Cat Cay, Bahamas (*Millspaugh 2341; Brace 3749*).

The varietal name *Solanum bahamense subarmatum*, under which Mr. Schulz groups nearly or quite unarmed specimens of *S. bahamense*, is redundant, for there is every transition from very prickly plants to entirely unarmed ones throughout the range of the species, individual bushes often bearing prickles below and being quite devoid of them above. *Harris 8169*, from Plowden Hill, Jamaica, as represented by our specimen, is unarmed, though the duplicate of it, examined by Mr. Schulz, is referred by him to the typical prickly form.

SOLANUM BOLDOENSE A. DC.

This interesting Cuban vine is apparently of quite local distribution at widely separated stations; about Matanzas it

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* Urban, Symb. Ant. **6**: 223.

grows especially in the famous gorge of the Yumury or Yumuri River (*Rugel 145*). Mr. Schulz (loc. cit. 170) erroneously spells this "Tomory," while Mr. A. H. Moore* also has it wrong as "Sumuri." This gorge is one of the scenic attractions of the northern coast of Cuba; the handwriting of Rugel's labels is somewhat difficult to decipher. In Pinar del Rio it inhabits limestone rocks at San Diego de los Baños (*Britton, Earle & Gager 6674*); C. Wright's specimen *381* was collected in Oriente; the locality of the type specimen is doubtfully cited as Havana.

21. NOTES ON TWO JAMAICA PLANTS

AMPELOCISSUS ALEXANDRI Urban, Symb. Ant. **6**: 15. 1909

To the description may be added "berry depressed-globose, black, shining, 1.5 cm. in diameter, the pulp watery; seeds 2 or 3, depressed-obovoid, slightly rugose, rather deeply and broadly grooved, 5 mm. long, 4 mm. wide."

Wooded hillside, Union Hill near Moneague, St. Ann's, Jamaica, at 500 meters altitude, *Britton & Hollick 2767;* this station is within a few miles of the type locality at Mount Diablo.

TABERNAEMONTANA DISCOLOR Sw. Prodr. 52. 1788

Tabernaemontana ochroleuca Urban, Symb. Ant. **6**: 34. 1909.

An examination of the type specimen of Swartz' species in the herbarium of the British Museum of Natural History establishes the identity of these species.

22. THE GENUS GINORIA IN CUBA

GINORIA AMERICANA Jacq.

As intimated by Koehne (Bot. Jahrb. 3: 349) this species may sometimes bear spines, as observed by me on plants in the palm barren at Santa Clara, in March, 1910 (*Britton & Wilson 6093*). This shrub grows along brooks and streams, attaining a height of 2.5 meters, at lower elevations in all provinces of Cuba, ascending to 160 meters in Oriente.

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* Proc. Am. Acad. **42**: 530.

GINORIA SPINOSA Griseb. Cat. Pl. Cub. 106. 1866

I know this only from *Wright's 2545*, collected in eastern Cuba (not western Cuba, as cited by Koehne). Rugel's *727* from the Rio San Juan at Matanzas, as shown by our specimen, is certainly *G. americana* Jacq. and was so written up by Grisebach, though this number, as studied by Koehne, is by him referred to *G. spinosa*. The true *G. spinosa* Griseb. (*Wright 2545*) is quite a different plant, with much smaller leaves and acicular spines; it is possible, however, that the species are not distinct.

GINORIA GLABRA Griseb. Cat. Pl. Cub. 106. 1866

Known to me from Wright's *2544*, collected in eastern Cuba; and from Shafer's *8784*, collected at Farallon de la Perla, Oriente, where it grows on cliffs as a shrub 6 dm. high. It is evidently quite distinct from the other species.

Ginoria arborea sp. nov.

A tree, 8 meters high, the trunk up to 2.5 dm. thick, the bark gray, the branching irregular, the twigs of the season 4-angled with internodes 5–15 mm. apart; nodal spines 4, spreading, recurved, yellowish, 1–1.5 mm. long. Leaves sessile, linear-oblong, 1.5–3 cm. long, 2–5 mm. wide, coriaceous, bright green, shining, obtuse at the apex, narrowed at the base, strongly pinnately veined, the veins prominent on both surfaces; flowers solitary in the axils; pedicels filiform, a little shorter than the leaves; sepals triangular-lanceolate, acute, 4 mm. long.

Thicket, Leeward Point, United States Naval Station, Guantanamo Bay, Cuba, March 1909, *Britton 2217*.

GINORIA CURVISPINA Koehne, loc. cit. 349. 1882

In the palm barren near Santayana, Camagüey, this species is a shrub 1 meter high (*Britton 2368*); near Tiffin, Camagüey, it grows in wet woods and becomes nearly 3 meters high.

Ginoria ginorioides (Griseb.) Britton comb. nov.

Diplusodon ginorioides Griseb. Cat. Pl. Cub. 106. 1866.
Ginoria Diplusodon Koehne, Bot. Jahrb. 3: 350. 1882.

This beautiful shrub or tree inhabits cliffs and rocky hillsides; in the province of Santa Clara it ascends to 560 meters on the southern slope of the Trinidad Mountains, and at sea level on the southern coast becomes a tree up to 7 meters high; the flowers are rose pink to purple and densely cover leafless branches in March.

NEW YORK BOTANICAL GARDEN.

Observations on the degree of stomatal movement in certain plants*

BURTON E. LIVINGSTON AND ARTHUR H. ESTABROOK

The studies of Lloyd† and of Livingston‡ on the relation of stomatal changes to the rate of plant transpiration have rendered it very desirable that some quantitative information upon the opening and closing of stomata in a large number of plants be made available. Primarily, such knowledge should hasten the acquisition of some generalization upon the relation between stomatal changes and the daily march of water loss in plants, a generalization that seems to be utterly lacking at the present time.

We give, therefore, in the present paper, the results of a series of stomatal measurements on several different plant forms and at various hours of the day. Limitations in facilities and time prevented the testing of a larger number of forms as well as the undertaking of a study of the problem of stomatal influence upon transpiration as such; we have confined ourselves to an effort to determine approximately the degree of usual stomatal change which occurs between day and night under a somewhat widely representative complex of climatic conditions. The plants with which we have worked were all growing in the open soil in the recently established Botanical Garden of the Johns Hopkins University at Homewood, Baltimore, Maryland. The plants used were *Funkia ovata*, *Isatis tinctoria*, *Allium Cepa*, *Eichhornia speciosa*, and *Oenothera biennis*.

Following Lloyd's method,§ at various times of day and night samples of epidermis were stripped from the leaves without removal of the latter from the plants, and were quickly placed in absolute alcohol contained in suitable vials. Different but similar leaves of the same plant were used for any single series of observations. At a later time the samples were mounted in a solution of

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* Botanical contribution from The Johns Hopkins University No. 27.

† Lloyd, F. E. The physiology of stomata. Publ. 89 Carnegie Inst. 1908.

‡ Livingston, B. E. Stomata and transpiration in *Tradescantia zebrina*. Science II. 29: 269, 270. 1909.

§ Loc. cit. p. 26.

iodin in absolute alcohol and the determinations made microscopically. These consisted in finding the mean number of stomata occurring per unit area, on either side of the leaf, and measuring with ocular micrometer the length and breadth of the stomatal openings. Twenty stomata, taken at random, were measured in each case. It was found by repeated tests that the average result obtained from twenty stomata was not considerably altered by employing a larger number; a higher degree of accuracy than that here obtained would entail no great difficulty, but would be quite useless in the present state of our knowledge.

That the stomatal openings in the bits of epidermis fixed in alcohol by the method of Lloyd are generally unaltered by this treatment, is attested by Lloyd himself, by Miss S. Eckerson* and by Renner.† Since the method depends for its efficiency upon the rapidity with which the walls of the guard cells are dehydrated, it is clear that the reagent used must contain not more than a certain amount of water. We are not aware that this question of the requisite purity of the alcohol to be used in this sort of work has heretofore received attention in a quantitative way, and therefore present here the result of an extensive test in this regard, using the stomata of *Eichhornia* as subject. The bits of epidermis were placed in a series of "alcohols," ranging from absolute to 80 per cent (volume). We were surprised to discover that, for these stomata at least, 90 per cent alcohol was apparently as satisfactory for our purpose as was absolute. With over 10 per cent of water a slight closure of previously open stomata could be detected. With more than 20 per cent of water this induced closure was marked. In spite of these indications we persisted in the use of absolute alcohol for all the tests.

To bring out the method of handling the dimension data, TABLE 1 is presented. It includes the results of measurements of *Allium* stomata at 3:00 p. m. and at 12:30 a. m. Under each hour are first shown the actual dimensions, *a* and *b* (the long and short dimensions of the more or less elliptical cross sectional area

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* Eckerson, Sophia H. The number and size of stomata. Bot. Gaz. 46: 221–224. 22 S 1908.

† Renner, O. Beiträge zur Physik der Transpiration. Flora 100: 451–547. 1910.

TABLE I

Allium Cepa

August 30, 3:00 p. m.		August 31, 12:30 a. m.	
Dimensions of openings, *micra* ($a \times b$)	$\sqrt{ab}$	Dimensions of openings, *micra* ($a \times b$)	$\sqrt{ab}$
15 ×4.2	7.94		
15 ×6	9.49	12.6×3	6.15
15 ×6	9.49	12 ×4.5	7.35
15 ×6	9.49	Remainder closed	
15 ×6	9.49		
15 ×5.7	9.25		
14.1×4.2	7.70		
15 ×4.2	7.94		
15 ×3.6	7.35		
13.5×3.9	7.26		
12.9×4.2	7.36		
12.9×4.5	7.62		
13.2×6	8.90		
14.1×4.5	7.97		
18 ×3.9	8.38		
12.6×4.8	7.78		
15 ×6	9.49		
12.9×4.5	7.62		
15 ×6	9.49		
12.9×5.1	8.11		
Mean $\sqrt{ab}$ (the index of relative diffusive capacity) is 8.40.		Mean $\sqrt{ab}$ (the index of relative diffusive capacity) is 0.685.	

of the stomatal pore). These are expressed in the form of an indicated product. In the second column of each series is shown the square root obtained, in each case, from the product of a and b. If we assume that the stomatal pore is elliptical in cross section, then the derived square root must represent the diameter of a circle with area equivalent to that of the ellipse in question. If minute elliptical openings allow the passage of diffusing gases at approximately the same rate as do circular openings of the same cross sectional area,* and also if such rates of gas diffusion through minute circular openings are proportional, not to cross sectional areas but to similar linear dimensions (as the diameters) of the openings;† then it follows that the square roots given in the

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* Brown, H. T., and Escomb, I. Static diffusion of gases and liquids in relation to the assimilation of carbon and translocation in plants. Phil. Trans. Roy. Soc. London **193**: 283–291. 1900.

† Stefan, J. Versuche über die Verdunstung. Sitzber. K. Akad. Wiss. Wien, math. nat. Kl. **68**: 385–428. 1873. This contribution formed the point of departure for the work of Brown and Escomb (loc. cit.). See also, on this subject, Renner (loc. cit.).

table should be proportional, under otherwise identical conditions, to the rate of diffusion of water vapor through the corresponding stomatal pores. The studies of Brown and Escomb have left no doubt in regard to the validity of the principle of linear dimensions, as regards minute circular openings. The two assumptions, (1) that the configuration of the cross section of the stomatal pore nearly enough approaches that of an ellipse to permit the use of such calculations as ours, and (2) that diffusion through minute elliptical openings occurs at the same rate as through circular ones of the same cross sectional area, need further substantiation, but they are highly probable and at least carry us much further toward the inception of a quantitative knowledge of stomatal diffusive capacity than can any other method of treatment thus far available. While it is undoubtedly true that a stoma may close very considerably without at the same time producing alteration in the long axis of the ellipse, yet by the time closure is nearly completed that axis has shortened markedly in many plants. We are thus convinced that to assume the long axis as constant and compute diffusive capacities on the basis of the length of the short axis alone is a method not generally applicable.

If the square root of the product of the two elliptical axes may be taken as proportional to the diffusive capacities of the stomata involved, that is, to their power of transmitting water vapor, then the mean of the square roots derived from all measurements should be a relative measure of the average stomatal diffusive capacity at the hour of sampling. At the base of each part of TABLE I is given this mean.

It is seen at once from TABLE I that all stomata were open at the hour of daylight observation while the majority were closed at the night hour. The two open pores, out of twenty observed for the night hour, are seen to be less widely open than were any at the other time. All conditions being equal excepting that of the size of opening, the diffusive capacity of the stomata appears to be approximately 69/840, or 8.2 per cent as great at about midnight as at 3 in the afternoon.

In TABLE II are given the final results of the calculation for each case tested. Two series are presented, one carried out on August 30 and 31, the other on September 7 and 8, 1910. Besides the calculated diffusive capacities, are given the minima, means, and maxima of the actual dimensions. These latter are expressed as a series of three quantities, the middle one, in full face type, being the mean. The two series thus given for each hour represent, of course, the two axes of the stomatal ellipse. The number of stomata per square millimeter of leaf surface is given above the data in each case, excepting that of *Allium*, where it was not determined. *Funkia* has stomata only below and *Allium* has but one leaf surface to be considered.

It appears from our results that the diffusive capacity of the stomatal openings reached the zero point at night in all cases excepting *Allium*, *Eichhornia*, and the lower leaf surface of *Oenothera*. This is not to be taken as meaning even that stomatal transpiration actually ceased when the index of diffusive capacity, as here determined, vanished. There must always be some stomata that are SLIGHTLY open, and SOME diffusion undoubtedly may occur when closure is apparently complete. Of course, cuticular transpiration must continue whether the stomata are open or closed.

The greatest diffusive capacities are exhibited by the aquatic *Eichhornia*, and the stomata of this plant are clearly seen to alter

TABLE II

Funkia

Time of observation	Lower leaf surface (54 stomata per sq. mm.)	
	Dimensions of openings, *micra*	Index of relative diffusive capacity
Aug. 30 3:00 p. m.	0.6–**0.5**–3.0 × 10.0–**11.0**–15.0	3.93
6:30 p. m.	0 × 0	0.00
Aug. 31 12:30 a. m.	0.0–**0.27**–3.0 × 0.0–**1.0**–11.4	0.54
5:30 a. m.	0.0–**1.08**–4.5 × 0.0–**3.6**–15.0	1.95
10:00 a. m.	0.0–**1.3**–3.0 × 0.0–**6.5**–15.0	2.88

TABLE II—*Continued*

Isatis

Time of observation	Upper leaf surface (173 stomata per sq. mm.)		Lower leaf surface (182 stomata per sq. mm.)	
	Dimension of openings, *micra*	Index of relative diffusive capacity	Dimension of openings, *micra*	Index of relative diffusive capacity
Aug. 30 3:00 p. m.	0.0–**2.4**–4.5 × 0.0–**8.9**–13.5	4.56	0.0–**2.5**–4.8 × 0.0–**9.5**–15.0	4.77
6:30 p. m.	0×0	0.00	0.0–**0.15**–3.0 × 0.0–**0.45**–9.0	0.27
Aug. 31 12:30 a. m.	0×0	0.00	0×0	0.00
5.30 a. m.	0×0	0.00	0.0–**0.08**–1.5 × 0.0–**0.53**–10.5	0.21
10:00 a. m.	0.0–**0.66**–3.0 × 0.0–**2.1**–13.5	1.17	0.0–**2.2**–4.2 × 0.0–**9.9**–1.50	4.65

TABLE II—*Continued*

Allium Cepa

Time of observation	Dimensions of openings, *micra*	Index of relative diffusive capacity
Aug. 30 3:00 p. m.	3.6–**5.0**–6.0 × 12.6–**14.4**–18.0	8.40
6:30 p. m.	3.0–**4.2**–6.0 × 12.0–**13.0**–15.0	7.32
Aug. 31 12:30 a. m.	0.0–**0.38**–4.5 × 0.0–**1.23**–12.6	0.68
5:30 a. m.	3.0–**5.4**–7.5 × 9.0–**13.2**–15.6	8.37
10:00 a. m.	5.4–**7.5**–9.0 × 15.0–**19.3**–24.6	12.03

TABLE II—*Continued*

Eichhornia

Time of observation	Upper leaf surface (182 stomata per sq. mm.)		Lower leaf surface (91 stomata per sq. mm.)	
	Dimensions of openings, *micra*	Index of relative diffusive capacity	Dimensions of openings, *micra*	Index of relative diffusive capacity
Aug. 30				
3:00 p. m.	————	———	————	———
6:30 p. m.	9.0–**11.7**–12.0 × 18.0–**21.2**–24.0	15.75	4.8–**7.3**–9.0 × 22.5–**25.2**–27.6	13.53
Aug. 31				
12:30 a. m.	4.5–**7.5**–12.0 × 15.0–**19.8**–24.0	12.09	1.8–**5.6**–9.0 × 18.0–**23.1**–27.0	11.31
5:30 a. m.	4.5–**9.2**–11.4 × 18.6–**21.0**–24.0	13.89	3.9–**6.7**–12.0 × 20.1–**22.7**–27.0	12.27
10:00 a. m.	6.0–**11.1**–15.9 × 16.5–**22.8**–27.0	15.81	6.9–**10.1**–12.0 × 19.5–**22.6**–26.4	15.06

TABLE II—*Continued*

Oenothera biennis

Time of observation	Upper leaf surface (71 stomata per sq. mm.)		Lower leaf surface (364 stomata per sq. mm.)	
	Dimensions of openings, *micra*	Index of relative diffusive capacity	Dimensions of openings, *micra*	Index of relative diffusive capacity
Sept. 7				
1:00 p. m.	3.6–**5.1**–6.3 × 7.5–**10.0**–13.2	7.11	4.2–**5.55**–6.3 × 8.7–**10.9**–18.0	7.74
3:45 p. m.	3.0–**4.3**–6.0 × 6.3–**9.8**–15.0	6.42	0.0–**2.2**–5.1 × 0.0–**7.2**–12.9	4.23
6:20 p. m.	2.4–**3.3**–4.8 × 7.8–**10.4**–12.0	5.82	0.0–**1.6**–3.6 × 0.0–**6.5**–12.9	3.18
11:40 p. m.	0 × 0	0.00	0.0–**1.6**–3.0 × 0.0–**5.5**–12.0	2.91
Sept. 8				
5:40 a. m.	1.8–**3.8**–5.1 × 6.0–**9.2**–13.5	5.85	0.0–**2.3**–4.2 × 0.0–**6.7**–15.0	3.87
11:00 a. m.	3.0–**4.4**–6.0 × 6.0–**10.1**–15.0	6.63	1.8–**2.9**–4.5 × 6.3–**10.1**–12.6	5.34

their openings from day to night, though to a relatively slight degree. The diffusive capacity at night is about 12/16 (75 per cent) of its day magnitude for the upper leaf surface, and 11/15 (73.3 per cent) for the lower. Furthermore, *Eichhornia* possesses by far the largest daylight openings with which we have dealt. Next in order are *Allium* with an open capacity about half as great as in *Eichhornia*, and *Oenothera* with an open capacity somewhat less than that of *Allium*. *Funkia* and *Isatis* are not widely different from each other in the diffusive capacity of their open stomata, which is approximately half as great as that of *Allium*. A comparison of the amount and rate of stomatal closure, as exhibited by the two sides of the leaf, indicates that the upper stomata close and open more rapidly, or close more completely, than do the lower, though this difference is not pronounced in *Eichhornia*.

Many other points of interest are suggested by the data of TABLE II, but the time is not ripe for more detailed discussion; our aim in presenting these results has been merely to make a beginning in the acquisition of information upon which somewhat critical and quantitative studies may be based. It is hoped that others will attack this problem, so that the theory of stomatal effects may, as soon as may be, be brought to rest upon a more adequate foundation of actual measurements than is at present the case.

LABORATORY OF EXPERIMENTAL EVOLUTION,
JOHNS HOPKINS UNIVERSITY.

Notes on the North American species of Phanerophlebia*

WILLIAM R. MAXON

In determining recently two species of *Phanerophlebia* collected by the writer in the mountains of Chiriqui, in western Panama, it became necessary to go somewhat critically over most of the material of this genus in the U. S. National Herbarium. Specimens have been received from various sources during the past twelve years, so that it is now possible to separate the species somewhat more exactly than at the time of Dr. Underwood's revision of the genus,† and partly by the use of characters not previously emphasized. The following key and notes are offered merely as supplementing that treatment. One species, *P. guatemalensis*, appears not to have been well founded.

Key to the North American species of Phanerophlebia

- Venation copiously areolate.
  - Plants of lax spreading habit; pinnae few (5–11), normally 3.5–5 cm. broad; veins distant (mostly 3–3.5 mm. apart), spreading at a very wide angle; sori distinctly inframedial upon the veinlets, the first row distant usually about 2 mm. from the midvein, the other sori similarly situated or often nearly basal upon the branches. 1. *P. juglandifolia.*
  - Plants apparently of more upright habit; pinnae numerous (16–20), mostly 2–3 cm. broad; veins closer, usually 2–2.5 (rarely 3) mm. apart, much more oblique; sori medial or supramedial (rarely subterminal), the first row usually 3–5 mm. distant from the midvein. 3. *P. remotispora.*
- Venation wholly free, or the veins casually anastomosing near the margin.
  - Pinnae 3–5, cordate or at least subcordate at the base. 2. *P. pumila.*
  - Pinnae 10–30, variously cuneate, or unequally rounded or auriculate at the base, never cordate.
    - Sori borne in a definite zone much nearer the margin than the midvein. 5. *P. umbonata.*
    - Sori occupying a medial zone or generally distributed over the pinna.

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† Bull. Torrey Club **26**: 205–216. 15 My 1899.

Lamina 15–30 cm. long; pinnae auriculate at the upper base, the auricles usually overlapping the rachis, the margins elsewhere serrate or often deeply incised. 6. *P. auriculata.*

Lamina 40–90 cm. long; pinnae not auriculate.

  Pinnae 12–15 cm. long, mostly falcate; veins 1.5–3 mm. apart at the base, the veinlets very close; sori small; margins slightly cartilaginous, nearly all the outer veinlets prolonged into slender awnlike antrorse teeth. 4. *P. nobilis.*

  Pinnae 18–25 cm. long, usually very much broader (3–4 cm.); veins 4–6 mm. apart at the base, branched at a much wider angle; sori very large; margins heavily cartilaginous, the marginal teeth stout and short, one to each group of veinlets. 7. *P. macrosora.*

1. PHANEROPHLEBIA JUGLANDIFOLIA (H. & B.) J. Sm.

In addition to Dr. Underwood's description it may be noted that the rhizome is woody, relatively slender (about 1 cm. in diameter), 10 cm. long, or less, decumbent and without exception strongly curved. The small crown is densely clothed within with thin dark brown deltoid-oblong laxly ciliate scales, mostly with lighter brown margins. A few similar scales are borne at intervals along the strongly sulcate greenish or stramineous stipe. Both this and the next species are remarkable for the length of the stipe, which is usually much greater than that of the lamina. The characters of venation and position of sori mentioned above in the key appear to be constant, in the case of normally well-developed plants.

As observed by the writer in Alta Verapaz, Guatemala (*Maxon & Hay* 3289), and in the mountains of Chiriqui (*Maxon* 4935, 5192, 5544), at from 900 to 1,500 meters elevation, *P. juglandifolia* grows in deep shade, on very humid heavily forested slopes. Additional specimens, not cited by Dr. Underwood, are as follows:

COSTA RICA: Alajuelita, altitude 900 meters, *John Donnell Smith* 8074; collected by A. Alfaro, original number 103.

GUATEMALA: San Miguel Uspantan, altitude 6,000 ft., *John Donnell Smith* 3259;* collected by Heyde and Lux. Coban, Alta Verapaz, altitude 1,350 meters, *H. von Türckheim* II. 1856.

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* The balance of this number in the National Herbarium (3 sheets) is *P. remotispora.*

The Coban plants, which are only partially fertile and are aberrant in the position of the sori, were listed* incorrectly by the writer as *P. remotispora*.

2. PHANEROPHLEBIA PUMILA (Mart. & Gal.) Fée.

Of this species only the following material has been seen by the writer:

MEXICO: Top of the Sierra Madre, near Chilpancingo, Guerrero, *E. W. Nelson* 2222 (2 sheets).

3. PHANEROPHLEBIA REMOTISPORA Fourn.

There are in the National Herbarium three sheets of specimens of this species from the vicinity of Cordoba, Vera Cruz, collected by Hugo Fink, 1889–1891, no. 60, and not listed by Dr. Underwood. Two of these respresent fertile fronds which appear quite typical; the third is of a plant with four fronds (30 to 50 cm. high), three of which are sterile, the fourth partially fertile and showing the true characters of the species in the position of its sori. The rhizome, which is not very complete, appears to have been short and nearly erect; it is clothed with thin delicate pale brown laxly ciliate-fibrillose scales of oblong-ovate form. A few scales of similar character occur sparingly upon the lower part of the stipe, and mixed with them are others that are nearly capillary and of a rusty color. These last extend along the stipe and rachis throughout, but are readily abraded. The pinnae of this young and nearly sterile plant are narrowly ovate or oblong-ovate, 10 to 12 cm. long, 2.5 to 3 cm. broad (3.5 in one pinna), strongly falcate, long-acuminate and caudate. The margins are conspicuously long-spinulose nearly or quite to the base of the pinna (the spines very oblique or appressed), in this respect differing widely from *P. juglandifolia*.

An additional specimen is:

MEXICO: Orizaba, altitude 4,000 ft., Aug. 26, 1891, *Henry E. Seaton* 49; distributed as *Hemitelia* sp.

4. PHANEROPHLEBIA NOBILIS (Schlecht.) Fée.

A species readily distinguished by the characters noted in the key. The margins are, naturally, more freely spinulose in the

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* Contr. U. S. Nat. Herb. 13: 20. 1909.

sterile fronds, the numerous teeth being almost wholly correlated with those outer veinlets that extend to the margin.

A single new specimen:

MEXICO: Ixtaccihuatl, *C. A. Purpus* in 1905, 1595.

5. PHANEROPHLEBIA UMBONATA Underw.

A unique species, not to be confused readily with any other of the genus. A single additional specimen has been received:

MEXICO: Sierra Madre, above Monterey, Nuevo Leon, altitude 3,000 ft., March 12, 1906, *Pringle* 13739.

6. PHANEROPHLEBIA AURICULATA Underw.

This species is noteworthy not only for its auriculate and often incised pinnae, but for its thin, almost membranous texture.

The following additional specimens have been received:

NEW MEXICO: Van Patten's Camp, Organ Mountains, Doña Ana County, altitude about 6,300 ft., *Wooton*, May 14, 1899, and March 5, 1902. Filmore Cañon, Organ Mountains, Doña Ana County, *Wooton*, Feb. 28, 1904.

7. PHANEROPHLEBIA MACROSORA (Baker) Underw. Bull. Torrey Club **26**: 213. 1899

Aspidium juglandifolium var. *macrosorum* Baker, Journ. Bot. **25**: 25. 1887.

Phanerophlebia guatemalensis Underw. Bull. Torrey Club **26**: 214. 1899.

Complete material now at hand indicates very clearly that *P. guatemalensis*, founded upon John Donnell Smith's no. 3241, collected by Heyde and Lux at San Miguel Uspantan, Department of Quiché, Guatemala, altitude 7,000 ft., is identical with *P. macrosora*, which was described first as a variety by Baker based upon imperfect Costa Rican specimens collected by J. J. Cooper. Specimens of both type collections are in the National Herbarium, and in addition further very complete specimens from Guatemala, Costa Rica, and western Panama. These prove beyond all question the distinctness of the species as emended and indicate for it a probable continuous distribution along the higher mountains of Central America. From this material the following description is drawn:

Rhizome very stout, decumbent, chaffy at the summit, bearing a semierect crown of 4 to 6 fronds, these 85 to 135 cm. long; stipes stout, 35 to 45 cm. long, 5 to 9 mm. thick at the base, at first very densely clothed on all sides with spreading light brown to dirty yellowish brown oblong to oblong-ovate scales, these 1 to 2 cm. long, of thin texture, or those toward the base thicker, glossy, and with darker brown centers, all delicately erose or lightly fimbriate-lacerate; lamina oblong to very broadly oblong in outline, 40 to 90 cm. long, 25 to 45 cm. broad, comprising 6 to 17 pairs of equal pinnae below the conform terminal segment of the same size; rachis very stout, strongly angled, copiously but deciduously chaffy, the scales narrow to nearly capillary, forming a loosely crispate covering; pinnae spreading or somewhat ascending, 4.5 to 7 cm. apart on each side, straight or nearly so (rarely falcate), 18 to 25 cm. long, 3 to 4 cm. broad,* sharply long-acuminate, narrowly oblong to oblong-lanceolate from a strongly inequilateral base, the upper side broadly cuneate and parallel to the rachis, the lower widely and abruptly excavate, all petiolate (the basal ones 5 to 10 mm.); leaf tissue coriaceous, the under surface bearing numerous minute setiform reddish scales, especially along the veins; veins 4 to 6 mm. apart at the base, evident, or below conspicuously elevated, 3- to 5-forked, the lowest proximal branch usually extending nearly to the margin; margins strongly cartilaginous, the marginal teeth stout and short, almost invariably only one to each group of veinlets; sori (except with age) very large, 2 to 3 mm. in diameter, hemispheric, distinctly inframedial as to the veinlets, 1 to 4 to each group, forming 1 to 4 lines (the outer ones often incomplete) upon each side of the midvein, the first row usually about 1 to 2 mm. distant, the others close or apart, never extending to the vicinity of the margin; indusia ample, but delicate and usually early withering.

Specimens examined in the National Herbarium:

COSTA RICA: Without definite locality, *J. J. Cooper* (type collection). Forêts du Tittoral, southeastern slope of Volcano Irazu, altitude 2,400 meters, *Pittier* 848. Forêts du Copey, altitude 1,800 meters, *Tonduz* 11930.

GUATEMALA: San Miguel Uspantan, Depart. Quiché, altitude 7,000 ft., *J. D. Smith* (Heyde & Lux) 3241 (type collection of *P.*

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* In one exceedingly fertile frond only 2 cm. broad.

guatemalensis). Volcano Atitlan, Depart. Sololá, *W. A. Kellerman* 5774.

PANAMA: Vicinity of Camp Aguacatal, eastern slope of Chiriqui Volcano, altitude 2,100 to 2,300 meters, March 10–13, 1911, *Maxon* 5273, 5290.

WASHINGTON, D. C.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1910-1911)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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FEBRUARY 1912

Variation in the floral structures of Vitis*

M. J. Dorsey

(WITH PLATES 1–3)

The genus *Vitis* has invited special attention botanically and horticulturally on account of its economic importance. The normal morphology of the flower is, of course, well known, and some observations have been made respecting variation in the different floral members. It would seem, however, that there is accessible no sufficient account of variation in the floral types. In the present paper the writer proposes to bring together some general facts and observations and especially to record some studies on the structural and numerical variation in the floral parts of certain species and varieties.

GENERAL FLORAL HABITS OF VITIS

The flower of *Vitis* presents a number of interesting variations, occurring both in the number and in the development of floral parts. In the flowers of many other genera where there is a multiplication of floral envelopes, there is often a complete or partial metamorphosis of some of the members into others, as in doubling, where stamens may be found showing a more or less complete transformation into petals. In *Vitis*, however, there occur either only completely developed floral members, or if there are modifications, they are in the direction of the suppression of certain members. There is, moreover, a close numerical relation

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between members of the floral organs in the several whorls; and this relation obtains when there occurs either an increase or decrease in the number of parts of the flower.

FLOWER TYPES: *Vitis* may be regarded as dioecious, polygamo-dioecious, or perfect. Individual vines of *V. vulpina* and *V. bicolor* occur in the wild in either the staminate or the perfect form. By staminate is meant forms in which no well-developed pistils are produced.

In the open the staminate plants occur in the greater number; of the 347 vines observed by the writer, 218 were staminate and 129 perfect. In these species the reflexed or recurved type of stamen was an invariable accompaniment of the perfect flower; that is, in no case were upright stamens found along with well-developed stigmas. Two wild vines, however, of *V. vulpina* were found in which the stigmas were partially developed. Yet the upright stamen form is to be regarded as signalizing the typical perfect flower, since, as is shown later, pollen development in the reflexed stamen may be poor.

As has been observed by Engelmann ('94) and others, the cultivated varieties, on the other hand, have two distinct floral types which are quite constant for all of the individual vines of a variety. These types are both perfect forms, the one possessing upright and the other reflexed or recurved stamens. As might be expected, the staminate form is not found under cultivation, except in rare instances where it may be grown in order to pollinate some of the self-sterile varieties.

It may be of interest to consider briefly the significance of the perfect form of flower, in general. From the standpoint of the evolution of the floral forms, either we may regard the perfect flower as the original form, and the pistillate and staminate forms as being derived from this; or we may consider the original form to have had diclinous flowers, and the perfect form to have been a later development.

There occur in the known species of *Vitis*, flowers (1) with stamens upright and pistils abortive (functionally staminate), (2) stamens upright and pistil fully developed and functional (perfect), and (3) stamens reflexed, pollen more or less abortive, and fully developed pistils (sometimes functionally pistillate).

Flowers possessing no stamens do not occur, or at least have not been recorded. Among these existent floral types which way is the evolution taking place? Goebel ('98) states "as a further peculiarity of the angiospermous flower that it is predominantly hermaphrodite, and unisexual flowers can be proved to be frequently the result of arrest of either the microsporophylls or the megasporophylls."

The perfect form of flower occurs in the cultivated varieties of many species of grape. In fact, this form of flower, according to Engelmann, has, by some, been considered of taxonomic value in *V. vinifera*. As has been noted, however, in wild vines of *V. bicolor* and *V. vulpina* the perfect flower with upright stamens was not observed in 347 individuals. Nevertheless, Beach ('98 and '99) and Booth ('02) have shown that in many cultivated forms with perfect flowers, having reflexed stamens, the pollen is abortive to a variable extent, this often rendering the flower pistillate,—at least functionally. Under similar conditions, also, vines are found bearing flowers with partially developed stigmas; and functionally these may be considered on the border line between the perfect and staminate forms. (PLATE 1, FIG. 9.)

Even taking into consideration these variations, there were observed to occur among the wild vines native to the region about Ithaca and Geneva, N. Y., only the staminate form and the perfect form with reflexed stamens. This would seem to indicate that the evolution is toward the dioecious habit.

In the genera closely related to *Vitis* there is a similar condition with respect to differentiation. According to Small, *Cissus* L. is perfect or sometimes polygamous, *Ampelopsis* Michx. mostly perfect, and *Parthenocissus* Planch. perfect or polygamo-monoecious. In this regard the degree of differentiation in *Vitis* and in the genera related to it is therefore considerable. These variations are both structural and functional. It is not clear which is the most primitive form, so that attempts to determine precisely the direction toward which evolutionary changes are now taking place would be largely speculation.

THE FLOWER CLUSTER: The branching habit of the grape is sympodial. The tendrils, or early in the growth of the shoot, the clusters, are the terminal growths of the stem. Upon further elongation of the shoot new tendrils become terminal, while the older tendrils and clusters assume a lateral position upon the stem, opposite and alternating with the leaves. Intermediate forms between tendrils and flower clusters are common. Durand ('01) shows that in their origin and anatomical structure the grape tendrils and clusters are identical, and that they may change naturally one to the other. Tendrils frequently occur that bear a number of buds, the tendril retaining in such cases its irritability in the region of the buds and twining much in the same way as the normal tendril.

The flower clusters vary considerably, both in size and in number of clusters upon the cane, in the different varieties and species. Instances are common in the varieties of *V. Labrusca* in which five or more clusters are borne in succession on a single cane. This may be accounted for largely by the fact that in this species a tendril or cluster is usually borne opposite each leaf ("continuous tendrils"). In the other native species, which have no tendril or cluster for each third leaf ("intermittent tendrils"), the number of clusters per cane is reduced somewhat, the usual number being two or three.

The staminate cluster usually bears more flowers, has greater fragrance, and blooms earlier in the open than the perfect form. The flowers on the main axis of the cluster open commonly from one to four days or more earlier than those on the "shoulder." The blooming period of the different varieties and species varies much, and in the case of *V. vulpina* and *V. bicolor* the blooming periods rarely overlap, *V. bicolor* flowering last.

THE FLOWER: The grape flower is hypogynous. The calyx is represented by a narrow rim at the base of the flower. The normal perfect form has five green petals with five stamens opposite. Yellowish nectariferous glands occur between the stamens and are equal in number to them. There is a large sessile stigma. The carpels are from two to four in number, each usually with two ovules. The perfect form differs from the staminate merely in possessing a fully developed and functional pistil, this usually being abortive to the extent that no stigma is developed in the staminate flower.

Engelmann ('94) divides the pistil-bearing form into two types, the "perfect" and the "imperfect hermaphrodites." This distinction was made as a result of the difference in the filaments; the "perfect hermaphrodite" having upright stamens (PLATE 1, FIG. 1); and the imperfect the reflexed stamens, in which the filaments curl back and down, bringing the anthers below the plane of the stigma (PLATE 1, FIG. 2). From the standpoint of self pollination this last mentioned position is an important consideration.

THE COROLLA: The corolla is gamopetalous; the united petals in the bud forming the "cap" (PLATE 1, FIG. 3 and 5). In the opening of the flower the petals break away at the base and remain united at the tips. This is one of the characters distinguishing *Vitis* from *Cissus*, the latter opening by breaking at the apex instead of at the base.

OPENING OF THE FLOWER: In the bud the cohering petals completely enclose the stamens and pistil. The first evidence that the flower is opening is the breaking away of the petals at the base. In most cases the break occurs at the base of one petal, the small fracture in the epidermis thus formed permitting further drying out of the surrounding tissue. Other petals break away at the base, curling as they break, thus separating one from another along the shallow sutures between. When the petals are released at one side, those on the opposite side hold fast. With further drying out, the tension brings the cap off sidewise, until it finally hangs by one petal, which soon breaks away, allowing the cap to fall (PLATE 1, FIG. 4 and 5). In other cases all the petals break away at about the same time, the individual petals gradually separating and curling up at the base, until they finally open wide and fall off. The cap may be only a few minutes in coming off, or it may remain partly open for several hours, depending upon the environmental conditions. Sometimes the cap breaks at the base and comes off almost instantly, the filaments gradually straightening out in the cases where the stamens are upright, or curling backward if the stamens are normally reflexed.

It is quite probable that the movements of the cap are primarily due to a drying out process rather than to pressure from the stamens. If the cap is removed, the separate petals soon curl up, as in the normal opening. In a very few cases the cap breaks away at the top and the stamens extend through the slit. In some varieties this occurs more commonly at the beginning of the blooming season. The filaments are curled up under the cap before the flower opens and soon become straight and upright or reflexed (according to the flower type) when the cap is released or removed. In the wild staminate forms the filaments soon curl back, bringing the anthers near the base of the ovary (PLATE 1, FIG. 6). In some cases the cap will hold a part of the stamens together while one or more may be released, the latter soon curling backward if the stamens are reflexed. The flower opens in much the same way in all of the flower types. Beach ('92) observed that in a number of varieties the anthers opened before the cap was thrown off.

SPECIAL VARIATION IN FLOWER PARTS

VARIATION IN THE STAMEN NUMBER: There are usually five stamens in the grape flower. In order to determine how constant the number of stamens per flower is, the flowers on a number of clusters were classified with respect to stamen number. This classification shows considerable variation in the number of stamens per flower, both above and below the normal number five, and also that the proportion of flowers having either more or less than five stamens was nearly constant for the clusters of each vine. This proportion was found to be quite characteristic for each vine without regard to the type of flower, variety, or species. In a total of 115 clusters counted, not a single vine was found in which the proportion of flowers for each stamen number was not quite constant. The proportion may differ materially in the different vines of a variety, as in Petite Sirah, a variety of *V. vinifera;* on one vine (TABLE I) there are more flowers having five stamens than six, while on an adjacent vine there are more having six stamens than five.

TABLE I gives in a summarized form the data for all of the counts made; it includes for various species and certain cultivated varieties the total number of flowers per cluster, the number of flowers in each cluster for each stamen number, and the necessary indications respecting the type of flowers. The number of stamens varies from 3 to 9, or in other words, two below the usual number

TABLE I

Variety or species	Wild or cultivated	Sex	Clusters counted per vine	Class frequency for no. of stamens per flower							Total no. of flowers per cluster
				3	4	5	6	7	8	9	
V. aestivalis............	C	♂	1		16	208	88	11			323
“	“	“	1		21	426	125	4			576
“	“	“	2		14	391	147	8			560
V. bicolor..............	W	♂	1	1	63	450	37				551
“	“	“	2		34	487	38				559
“	“	“	3	2	45	355	20				422
“	“	“	4		35	261	25				321
“	“	“	5		28	279	8				315
“	“	“	1		106	472	17				595
“	“	“	2		38	205	9				252
“	“	“	3		108	437	13				558
“	“	“	4		61	408	8				477
“	“	“	5		94	394	12				500
V. vulpina.............	W	♀	1		5	66	13				84
“	“	“	2		3	89	9				101
“	“	“	3		2	105	11				118
“	“	“	4			112	16				128
“	“	“	5		4	121	10				135
“	“	“	1		3	77	13				93
“	“	“	2		3	64	25				92
“	“	“	3		4	144	18				166
“	“	“	4		1	74	10				85
“	“	“	5		1	86	13				100
“	“	“	1		9	101	9				119
“	“	“	2		6	86	7				99
“	“	“	3		3	84	3				90
“	W	♂	1		78	298	5				381
“	“	“	2		86	279	6				371
“	“	“	3		94	308	7				409
“	“	“	1		49	362	20				431
“	“	“	2		44	237	9				290
“	“	“	3		60	203	13				276
“	“	“	4		50	176	7				233
“	“	“	5		121	294	9				424
“	“	“	6		81	303	9				393
“	“	“	7		69	240	6				315
“	“	“	1		43	82	7				132
“	“	“	2	1	28	140	8				177
“	“	“	3		34	109	6				149
“	“	“	4		15	113	23				151
“	“	“	5		33	191	23				247
“	“	“	6		35	92	8				135
“	“	“	7		32	128	12				172
“	“	“	8		33	190	21				244

Variety or species	Wild or cultivated	Sex	Clusters counted per vine	Class frequency for no. of stamens per flower							Total no. of flowers per cluster.
				3	4	5	6	7	8	9	
V. vulpina	W	♂	9		21	211	12				244
"	"	"	10		28	118	4				150
"	"	"	11		31	177	9				217
"	"	"	12		26	194	8				228
"	"	"	13		21	238	13				272
"	"	"	14		18	259	15				292
"	W	♂ ♀	1		23	427	127	2			579
"	"	"	2		11	159	38	1			209
"	"	"	3		32	372	65	1			470
"	"	"	4		24	481	156				661
"	W	♂	1		60	347	63				470
"	"	"	2		29	325	72				426
"	"	"	3		10	362	65				437
"	"	"	4		18	348	91				457
"	"	"	5		24	416	70				510
"	"	"	1		9	328	190	9	2		538
"	"	"	2		15	383	302	38			738
"	"	"	3		23	209	81	2			315
"	"	"	4		26	424	161	7			618
Concord (*V. Lab.*)	C	☿	1		4	67	30				101
"	"	"	2		2	32	22	2			58
"	"	"	3		1	61	26	2			90
"	"	"	4		3	75	9	1			88
Brighton (*Lab., vin.*)	C	♀	1		13	74	38	2			127
" "	"	"	2		11	83	22	1			117
" "	"	"	3		7	76	32	3			118
Hybrid Franc (*vin., rup.*)	C	☿	1		1	47	83	6			137
" "	"	"	2		1	34	106	6			147
" " "	"	"	3		1	27	74	11	1		114
Jaeger No. 43 (*vin.*)	C	♀	1			33	117	35	2		187
" "	"	"	2			22	123	47	1		193
Janesville (*Lab., vulp.*)	C	☿	1			4	47	46	6	1	104
" "	"	"	2		1	5	59	56	6		127
" "	"	"	3			2	56	66	11	1	136
" "	"	"	4			3	32	32	2		69
" "	"	"	5			3	41	41	8		93
" "	"	"	6			1	41	47	8	1	98
Massasoit (*Lab., vin.*)	C	♀	1		10	81	77	7			175
" "	"	"	2		7	56	50	6			119
" "	"	"	3		3	42	38	6			89
Norton (*aest., Lab.*)	C	☿	1			1	18	46	18	2	85
" "	"	"	2			6	52	64	14	1	137

Variety or species	Wild or cultivated	Sex	Clusters counted per vine	Class frequency for no. of stamens per flower							Total no. of flowers per cluster
				3	4	5	6	7	8	9	
Petite Sirah (*vin.*) *	C	☿	1		2	172	93	1			268
“ “ “	“	“	2		6	195	88	3			292
“ “ “	“	“	3		2	118	47				167
“ “ “ †	“	“	1		4	109	46	1			160
“ “ “	“	“	2		8	192	78	2			280
“ “ “ *	“	“	1		1	73	111	5			190
“ “ “	“	“	2		4	88	128	4			224
“ “ “	“	“	3		5	83	106	1			195
“ “ “ †	“	“	1		9	52	65	2			128
Seibel No. 2	“	“	1			34	121	15			170
“	“	“	2			27	104	24	1		156
“	“	“	3			49	122	8			179
“	“	“	4			19	115	30	1		165
V. Labrusca (small cluster)	W	♂	1		1	14	9				24
Cross (*Lab.* × *vin.*)	C	?	1		35	285	51	1			372
“ “	“	“	2		38	383	117	2			540
“ “	“	“	3		6	128	48	1			183
Cross (*Lab.* × *vulp.*)	C	♂ ♀	1		13	408	69	4			494
“ “	“	“	2		9	561	73	2			645
“ “	“	“	3		5	224	52	3			284
“ “	“	“	4		5	284	49	2			340
“ “	“	“	5	1	14	176	67	2			260
“ “	“	“	6		13	235	121	11			380
Cross (*Lab.* × *bic.* × *vin.*)	C	♂	1	1	41	105	8				155
“ “	“	“	2		18	60	6				84
Cross (*Lab.* × *vin.*)	“	“	1		4	139	77	8			228
“ “	“	“	2		3	159	181	35	1		379
Cross (*Lab.* × *vin.* × *bic.*)	“	“	1		63	260	15				338
“ “	“	“	2		115	413	24				552
Total			115	6	2,630	21,385	5,829	783	82	6	30,721

* Counted in 1909.

† Counted in 1910.

and four above it. The highest number of flowers found in any cluster was 738, which occurred in a wild vine of *V. vulpina*. The staminate cluster usually has more flowers than either form of the perfect.

It will be seen from an inspection of TABLE I that the variation in the stamen number has, in general, a definite direction in the flowers of each vine. In most cases the mode falls on five, but in some of the cultivated varieties, as in Jaeger No. 43 and Seibel No. 2, the mode is distinctly on six; while in Janesville there are only a few flowers having five stamens, with the number having six and seven practically equal, more having eight stamens than five, and three flowers having nine. This is a striking variation from the usual number five. Among those included in this table there were no flowers observed having double the number of stamens, the nearest approach to this being nine.

The summary of TABLE I, giving the total number of flowers for each stamen number, shows considerable variation in the number of stamens per flower in *Vitis*. The stamen number is variable in all the clusters included, whether of a species, variety, or cross. Out of a total of 30,721 grape flowers in which the stamens were counted, there are more (21,385) having five stamens than any other number; more (5,829) having six stamens than four, which is represented by 2,630 flowers; 783 have seven stamens and 82 have eight; while the two extremes are represented by much smaller numbers, 6 having nine stamens and 6 also three. The trend of the variation, therefore, is toward an increase in the number of stamens rather than a decrease.

VARIATION IN COROLLA NUMBER: The number of parts to the cap is usually the same as the number of stamens (PLATE 1, FIG. 3 and 5). Exceptions to this occur where two small stamens are found opposite one petal, or where two filaments are united more or less throughout their entire length; but this occurs so seldom, and the relation between the petal and the stamen number is so close, that TABLE I may be regarded as showing fairly accurately the variation in the number of petals in the cap as well as the stamen number.

VARIATIONS IN THE NECTARIFEROUS GLANDS: The nectariferous glands vary much in color and size; they also correspond very closely in number with the stamens and petals. On some vines they are pale yellow while in other cases they are a dark yellow or yellowish green. On some of the cultivated varieties, as Concord and Worden of the blue varieties, and Diamond, Leader, or Pocklington of the green, they still persist in the mature berry as yellowish or brownish dots around the base of the pedicel. In PLATE I, FIG. 7, 8, and 9, are shown some of the forms they assume in the staminate flower. In FIG. 7 (PLATE I) the nectariferous gland forms a distinct five-sided ridge around the abortive pistil; in FIG. 8 (PLATE I) the glands protrude distinctly between the stamens; and in FIG. I (PLATE I) they are shown in the perfect flower. Closely observed, this organ exhibits differences in almost every vine.

VARIATION IN THE PISTIL: Where the number of stamens varies either above or below the usual number five, changes result in both the external and internal structure of the ovary. Externally the number of lateral surfaces of the pistil vary and correspond in number to the stamens. Internally there is associated with an increase in the number of stamens a larger number of carpels, and likewise more ovules or seeds per berry. The number of carpels may be independent of the number of parts to the flower, but in general there seems to be a relation between them. In one cluster of Janesville, in which the seeds were counted, there were for each stamen number, 4 berries that had five stamens, and all had two carpels; of the 29 berries that had six stamens 22 had 2 carpels and 7 had three; 23 had seven stamens, and of these 15 had 2 carpels and 8 had 3; 5 berries had eight stamens, one of which had 2 carpels and 4 had three. In the staminate flowers this relation, of course, would not hold.

STRUCTURAL VARIATION IN THE STIGMA: A careful distinction does not seem to have been made by previous writers on this subject between the stigma and pistil. Engelmann ('94) observes that "the sterile plants do bear male flowers with abortive pistils, so that while they never produce fruit themselves they may assist in fertilizing the others." Booth ('02) states that "all of the staminate flowers, so called, which I have observed, have small abortive pistils; which also conforms with the observations of Engelmann. Others report staminate flowers with no trace of pistil remaining." In the same publication he states further that "there is a vine on this station which bears both staminate and hermaphrodite flowers. Mr. N. B. White, Norwood, Mass., reports that he has a male (?) *Rip.* × *Lab.* vine which has fruited twice in the last thirty years, the pistils evidently varying in strength but being generally too weak to produce fruit." Munson ('99) mentions that it is clear that the staminate vine can not bear since it has no pistil, "unless the vine changes its action from producing purely staminate flowers to bearing pistillate flowers, which in two or three instances only, in all my observation, I have known to occur."

In the instance mentioned by White, the stigma probably had a development similar to that shown in FIG. 10, PLATE 2, which is a photograph of two clusters from one cane of a Marian × Pocklington cross, which grew in the vineyard of the New York State Experiment Station. It will be seen from this photograph that the flowers of this vine are functionally so nearly midway between the pistillate and perfect forms that on the same cluster some pistils have sufficient stigmatic tissue to permit of pollen germination, while others do not. During the three seasons in which the writer had the opportunity to observe this vine some clusters bore fruit each season. In PLATE 2, FIG. 15–18, there are shown photomicrographs of median sections of four pistils from this vine. Flowers with a similar stigmatic development have been observed by the writer on two wild vines of *V. vulpina* and also in a number of crosses at the New York State Experiment Station, in which *V. Labrusca*, *V. bicolor*, *V. vulpina*, and *V. vinifera* occurred.

The series of median sections included (PLATES 2 and 3, FIG. 11–24) shows practically all gradations in stigmatic development between the truly perfect and the staminate forms. Even the purely staminate forms represented (PLATE 3, FIG. 19–24) in the sections show an abortive pistil with no stigmatic tissue, yet having carpels and rudimentary ovules. The statement of Booth ('02) that all staminate flowers observed have small abortive pistils is corroborated. By following the series, then, it will be seen that the seed coats in the ovules are not fully developed in staminate forms and only partially so in some of the intermediate forms with small stigmatic surfaces. This fact is significant in that it indicates, that there is not a complete segregation of the pistillate and staminate forms but a suppression of pistil development in the case of the staminate flowers.

Median sections through the pistils of some of the intermediate forms are shown in PLATE 2, FIG. 15–18; these show different stages of stigmatic development occurring on different vines. The seed coats in the ovules show considerable development in PLATE 2, FIG. 14–18. The material, with the exception of PLATE 3, FIG. 21–24, was all fixed just after the flower was completely open, so there is probably not more than one or two days' difference in their relative ages; the others were fixed before blooming, to show the relative position of the anthers, filaments, and pistils in the bud. The crouched position of the filaments will be noted in PLATE 3, FIG. 22. In many flowers, however, the filaments are even more crouched and bent than in this instance.

SOME ABNORMALITIES OF THE PISTIL: Cases are rarely observed in which one or more anthers of a flower may be found with the filament adhering to the side of the pistil, the tissue of both filament and pistil being united. In this way the stigmatic tissue and the anthers, sometimes partly abortive or deformed, are brought into very close contact. Some abnormalities of this nature have been observed where the stigmatic and anther tissues are intermingled, the pollen being to all appearances normal. This adherence is probably due to a lack of differentiation in the meristem and does not seem to be a case similar to that observed by Chamberlain ('97) in *Salix petiolaris*, in which microsporangia were found in the placenta of the ovary, as well as stigmas developing on stamens.

Some vines bear flowers with distinctly pinkish stigmas. The writer has observed this in a few wild vines of both *V. vulpina* and *V. bicolor*, and also in a number of cultivated varieties, as in the R. W. Munson. The stigma is distinctly lobed in some vines, both cultivated and wild, the lobes generally corresponding to the carpels. In varieties like the Goff, where many grapes on a cluster show distinct sutures, varying in number from one to three or four, this tendency can be seen soon after blooming; and in a few extreme cases the pistil may be nearly separated into two parts. In outline the stigmatic surface varies much, being oval, flaring or flat. Under favorable conditions the stigma may become receptive before the corolla opens. This condition was observed by the writer in both Concord and Hubbard Seedless.

The writer wishes to acknowledge his indebtedness to Dr.

B. M. Duggar, of Cornell University, under whom this work was done as a topical problem, for helpful suggestions and criticisms, to Professor U. P. Hedrick, of the New York State Experiment Station, for courtesy in the use of material, and to Mr. Ernest Dorsey for assistance in obtaining some of the data.

SUMMARY

Vitis is dioecious, polygamodioecious, or perfect. The flower forms which occur are the staminate, and the perfect (1) with upright and (2) with reflexed stamens. Individual vines either within the variety or species are quite distinct with respect to these flower forms. In *Vitis* the flower forms resemble those of the closely related genera, *Cissus* L., *Ampelopsis* Michx., and *Parthenocissus* Planch. The direction of the evolutionary changes in the flower forms is not entirely clear.

The typical staminate cluster is larger than either form of the pistil-bearing. The typical grape flower is 5-merous, although about 30 per cent show a variation from this plan. The petals, nectariferous glands, and stamens correspond closely in number. The dehiscence of the corolla seems to result largely from a drying-out process rather than from being pushed off by the straightening out of the filaments.

The number of stamens per flower was found to vary from three to nine, the variation being independent of the flower form, variety, or species. The flowers from different clusters of the same vine show in general the frequency of distribution that is characteristic of the vine. Clusters from different vines may have different arrays. When the stamens are increased or decreased, the petals and nectariferous glands, in general, correspond in number. An increase in the number of stamens is associated with an increase in the number of carpels. In short, the numerical relations of the members of the floral whorls are commonly maintained.

In occasional vines the stigma is, throughout, only partially developed. This condition may be regarded as an intermediate form between the pistil-bearing and the staminate forms, both in structure and function. The staminate flowers have rudimentary pistils, in which the stigmas and ovules are abortive.

The variations in the flower of *Vitis* may be grouped into two classes: first, meristic, which would include differences in the number of the organs per flower; and, second, functional, including variations in the extent of development of the pollen, stigma, and ovules.

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Explanation of plates 1–3

PLATE 1

FIG. 1. The perfect flower with upright stamens.

FIG. 2 and 6. The perfect flower with reflexed stamens; FIG. 6, wild *Vitis vulpina*.

FIG. 4 and 5. The position of the stamens and corolla in different stages in the opening of the grape flower.

FIG. 3 and 5. United petals forming the "cap," also differences in the number of petals in the corolla.

FIG. 7, 8, and 9. Different forms of nectariferous glands in staminate flowers

PLATE 2

FIG. 10. Photograph of two clusters from the same cane of a Marian × Pocklington cross, showing enlargement of the pistil in cases where only partially developed stigmas were present.

FIG. 11–18. A series of photomicrographs of median sections through pistils having stigmatic tissue developed in different degrees.

PLATE 3

FIG. 19–24. A continuation of the series 11–18, PLATE 2, showing median sections through the pistils of the grape; these would usually be classed as staminate flowers.

FIG. 21, 22, 23, and 24 are median sections of unopened buds showing the relative position of the calyx, corolla, stamens, and pistil. The crouched position of the filaments is shown in FIG. 22.

The relation of Ohio bog vegetation to the chemical nature of peat soils*

ALFRED DACHNOWSKI

The ecological relation of plants to soils, particularly to the chemical nature of the substratum, is especially interesting and has been extensively studied from the standpoint of the distribution of species, the succession of vegetation, and the adaptability of crops to certain soils. In mountainous countries and even in states like Ohio, with soils of morainal and of varied geognostic nature, one can observe sharply delimited distinctions in the distribution and in the whole appearance of vegetation units. And yet, though many species are confined to soils with a definite chemical relationship, a great many plants can grow on soils widely dissimilar in kind. Are the reasons for the generally observed distinctions to be sought in the chemical constitution of the soil, or is the distributional relationship due to the physical characters, particularly to relations prevailing in regard to the amount of available water and the specific quantity required by the plants, and to the thermal condition in the soil?

Not all field work is adapted to throw light on this vexed question of a long standing dispute. Difficult as is the attempt to establish a correlation between vegetation and any one factor of the environment, it is possible, however, to make such a correlation with peat soils, within the area here investigated.

It is now generally recognized that the nature of a lake and bog environment is constantly selective, and that the associations and societies of plants succeeding one another are each characterized by a definite physiognomy in response to their dependence upon soil conditions under atmospheric influences essentially similar otherwise. In an earlier paper the writer has listed the successions of the more genetically related vegetation units, their associations and societies, occurring in Ohio lakes and peat deposits (Plant World 15: 25–39. 1912).

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In connection with the problem of the utilization of Ohio peat, both chemical and calorimetric analyses were made of the peat samples collected. With the exception of the potash, phosphoric acid, and lime analyses, and the analyses of TABLES II and III, all determinations were made under the auspices of the United States Bureau of Mines as a part of more general investigations of the fuels of the United States. This cooperative work between the State and the Federal Government has been made possible through the considerate and helpful interest of Dr. Charles A. Davis, in charge of the peat investigations of the U. S. Bureau of Mines.

The analyses, as might be expected, vary widely, but there is a certain uniformity in regard to their chemical character. The analyses show the following range in chemical composition:

TABLE I

CHEMICAL ANALYSES OF OHIO PEAT. RANGE OF CHEMICAL COMPOSITION

	Minimum	Maximum
Volatile combustible	50.99	74.79
Fixed carbon	16.56	33.64
Ash	3.65	25.44
Nitrogen	1.01	3.68
Potash (K_2O)	0.10	0.98
Phosphoric acid (P_2O_5)	0.03	0.50
Lime (CaO)	0.00	4.52
Thermal value: calories,	3,962.00	5,409.00

Through the courtesy of Professor J. W. Ames of the Wooster (Ohio) Experiment Station a more detailed analysis of the ash of peat soil is here appended in TABLE II.

TABLE II

ANALYSES OF PEAT SOILS, CHEMICAL DEPARTMENT, OHIO AGR. EXP. STATION
TOTAL AMOUNTS FOUND

Lab. no.	Locality	Ash	Mn	SiO_2	SO_3	Al_2O_3 and Fe_2O_3	CaO	MgO	Na_2O	P_2O_5	K_2O	N
5302	Akron	9.66	.0056	3.21	1.20	2.04	2.390	.311	——	.299	.1594	3.42
5303	"	14.58	.0099	6.18	.97	2.91	2.870	.331	——	.345	.3117	3.24
5304	"	9.84	.0220	4.05	1.03	2.19	3.580	.361	——	.342	.1531	3.38
5305	"	14.38	.0332	5.26	1.03	2.44	3.650	.297	——	.469	.2956	3.10
5306	"	11.65	.0515	4.01	.88	2.65	2.800	.345	——	.337	.1860	3.18
14460	Lodi	——	——	——	——	5.15	4.529	.570	2.366	.506	.4753	——
14461	"	——	——	——	——	4.24	2.570	.420	3.373	.342	.3239	——
14462	"	——	——	——	——	5.62	4.060	.650	2.040	.374	.3569	——
14463	"	——	——	——	——	11.15	2.210	.660	1.944	.256	.9835	——
14464	"	——	——	——	——	4.08	3.050	.630	1.066	.373	.3376	——
14465	"	——	——	——	——	4.18	2.340	.420	2.018	.429	.3445	——
14162	McGuffey	——	——	——	——	——	3.585	——	——	.370	.4720	2.48

The water from peat soils is relatively clear; in several places of the state it is used occasionally for drinking purposes. The suspended particles impart to it a tinge of color from olive green to brown. Analyses of samples of bog water and bog lake water give the following results:

TABLE III

CHEMICAL ANALYSES OF BOG WATER AND LAKE WATER FROM CRANBERRY ISLAND, BUCKEYE LAKE

Constituents in parts per million	Bog water from cranberry-sphagnum association	Bog water from alder-shrub association	Lake water
Nitrogen as albuminoid ammonia	10.34	11.48	4.50
Nitrogen as free ammonia	15.19	8.24	2.95
Nitrogen as nitrites	0.0005	0.0003	0.00000
Nitrogen as nitrates	0.20	0.20	0.1000
Chlorin	0.30	1.00	1.00
Required oxygen	71.80	70.30	3.70
Alkalinity (as $CaCO_3$)	30.00	40.00	75.00
Incrustants (as $CaCO_3$)	74.00	72.00	76.00
Total solids	140.00	160.00	200.00
Loss on ignition	100.00	20.00	4.00

The osmotic pressure of these solutions is the same as that of Ohio lakes, the average lowering of the freezing point varying between 0°.005 and 0°.010 when compared with that of distilled water. The acidity of the solutions varies from less than 0.00075 to 0.004 normal acid when titrated with an 0.05 NaOH solution and phenolphthalein.*

The several analyses submitted do not reveal the obvious distinction between successions of vegetation on peat soils and the changes in the chemical character of the peat. The fact that certain plant associations have an absolutely defined morphological and topographic distinction, and the fact that these contrasts must be attributed to conditions prevailing in the soil, directs special attention to the contrasts between peat soils of the various vegetation units or groups of plants. The following series in TABLE IV is especially suggestive in showing the more typical features of the correlation.

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* Livingston, B. E. The physiological properties of bog water. Bot. Gaz. **39**: 348–355. 1905.

The correlation phenomena between vegetation units in bogs and the character of the peat soil are not in all cases as those given in TABLE IV. There are many exceptions to the rule for reasons that will be stated below. On the whole, however, the results may be summarized in the following well-defined relations:

TABLE IV

CORRELATION BETWEEN VEGETATION UNITS IN OHIO BOGS AND CHARACTER OF PEAT SOILS

Vegetation unit Locality	Moisture in air-dried sample.	Volatile matter	Fixed carbon	Ash	Nitrogen	Potash, K_2O	Phosphoric acid P_2O_5	Sulphur	Calorific value: calories
Bog meadow succession. Cranberry-sphagnum association.									
Buckeye Lake, No. 41 . . .	9.23	67.99	24.46	8.45	1.01	0.12	0.03	0.43	4792
Lakeville, Holmes, No. 72	6.96	69.15	25.04	5.81	2.38			0.23	5317
Lakeville, No. 73	7.14	67.42	24.91	7.67	2.39			0.28	5039
Bog shrub succession. Alder-maple association.									
Buckeye Lake, No. 43 . . .	9.90	61.63	27.11	11.26	2.21	0.12	0.03	0.64	4512
Orrville, No. 44	9.08	63.24	26.18	10.58	2.45			0.46	4981
Bog forest succession. Tamarack association.									
Canton, No. 76	8.01	62.03	31.84	6.35	3.39			0.33	4912
Fox Lake, No. 78	8.99	54.46	25.02	20.52	2.41	0.15	0.28	0.89	4375
Mesophytic forest succession. Maple-ash-elm association.									
Mantua Bog, No. 47	10.40	56.33	26.16	17.51	2.46	0.19	0.42	0.86	4550
Bradley Pond, No. 51 . . .	10.11	60.09	27.96	11.95	2.24	0.27	0.19	0.29	4856
Copley Bog, No. 59	11.35	56.85	31.87	11.28	2.72			0.89	4923

1. In color Ohio peat ranges from a greenish and grayish brown, due to the presence of clay and marl, through various shades of brown to an almost black variety. In texture peat varies from a loosely compacted fibrous heterogeneous meshwork of plant debris to the fiberless, homogeneous variety.

2. The physical water content of peat is higher in the coarser fibrous substratum of the bog meadow association. The mat, when adjoining open water, adjusts itself easily to changes in the water level of the basin. With the disintegration of the plant tissues the water-holding capacity of peat is higher. The concentration of the peat solutions is very low, varying in parts per million

between 40 and 260 parts of total solids. The osmotic pressure and the acidity of the soil solutions differ but slightly between the various grades of peat soil.

3. Reducing processes in peat soils, judged by methylene blue or a one per cent starch-iodid solution, increase from any marginal point of a peat-depositing lake to the bog meadow association and decrease as the deciduous forest association is approached.

4. The nature of the changes which have taken place in the transformation of vegetable debris into peat is only partly understood. The principal changes are a relative loss in oxygen and hydrogen and a progressive increase in carbon and nitrogen. This is clearly shown in passing from the fibrous peat substratum of bog meadows to the structureless peat occupied by bog forests and deciduous trees.

5. In poorly decomposed peat the percentage of volatile combustible material is high, the percentage of fixed carbon, of nitrogen and ash is low. In well decayed peat the reverse is true.

6. The higher ash content in peat from bog shrub and bog forest associations is believed to be due largely to windblown silt; a bog meadow association interferes less with wind work than the timbered area of a deposit.*

7. Peat contains potash and phosphoric acid in comparatively inconsiderable quantities, only a fraction of one per cent, whereas the percentage of calcium and nitrogen is very high, varying from one to almost four per cent. The capabilities of a soil for crop production are usually judged from the study of the chemical character of the soil, and soils markedly deficient in phosphates, potash, and other salts, are looked upon as barren and sterile. Maintenance of fertility is connected with abundance of these constituents. In peat soils, it seems, the essential mineral salts of the agricultural tripod play only minor rôles for protoplasmic activities and in the growth and ripening of bog plants.

8. More systematic investigations from the standpoint of agricultural chemistry have shown that the number of possible inorganic nitrogenous substances, the quantity of nitrites, nitrates, and ammonia is quite small, ranging from a few thousandths to a few hundredths of one per cent. Practically all the nitrogen contained is, therefore, of organic nature.

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* Beyer, S. W. Peat deposits in Iowa. Iowa Geol. Sur. **19**: 698. 1908.

9. Only a small amount of nitrogenous bodies can be extracted from peat by means of water. The relatively low free ammonia and the large amount of oxygen consumed indicate that the organic matter is not in an advanced state of decomposition.

10. The solubility of a coarsely fibrous peat is less than that of peat in a finer state of division and more advanced stage of disintegration. This condition seems to point to the fact that the organic compounds arise mainly through the action of microorganisms. Compounds associated with the decomposition products of proteids by mineral acids, are here practically out of the question.

11. Little is known as to the chemical constitution of peat and of the transition and decomposition products of proteids and carbohydrates arising in peat soils. Biochemical technique has not permitted, as yet, the analysis or the preparation of isolated peat soil constituents of comparative purity. They are undoubtedly of access for chemical investigation and isolation. Known methods of investigation of proteids have been applied in the study of the decomposition products of organic compounds in soils. Schreiner and Schorey,* Jodidi,† and Robinson‡ have more recently isolated and identified a number of these bodies. In peat soils, however, the compounds are present in small amounts, the number of transition products is undoubtedly larger, and their effects upon living plants is as yet unknown. It is difficult to understand how a substance present in peat soils or in bog water in such minute concentration that for ordinary chemical analysis its influence is negligible, may nevertheless exert a profound effect upon the growth of plants. It is not necessary to assume that this distinctly disproportionate effect is produced by external chemical action, by enzymes, or by biological metabolic products. Peat is a heterogeneous system of substances, and its variable composition renders it difficult to determine what substances are injurious and what substances can actually be absorbed and

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[*] Schreiner, O., and Schorey, E. C. Chemical nature of soil organic matter. U. S. Dept. Agr. Bur. Soils Bull. 74. 1910.

[†] Jodidi, S. L. Organic nitrogenous compounds in peat soils. Michigan Agr. Coll. Exp. Sta. Tech. Bull. 4. 1909.

[‡] Robinson, C. S. Organic nitrogenous compounds in peat soils. II. Michigan Agr. Coll. Exp. Sta. Tech. Bull. 7. 1911.

assimilated by plants. The presence of one substance or the concentration of another constituent as determined by quantitative analysis may have only an apparent relation but not necessarily a causal value. This might be for the reason that the substances are differently distributed on account of differences in solubility or oxidation, are absent in one phase of the decomposition process because of differences in the bacterial flora at work in different layers, or vary greatly with reference to the diosmotic properties of the absorbing organs of plants. Humus has long been recognized as a very important factor in soil fertility, and yet almost all the difficulties in any special problem with humus or peat arise in the lack of knowledge of the chemical nature and the effects on plant life of the various organic compounds resulting from weathering processes and from the activity of microorganisms. The complexity of the problem emphasizes the need of physiological studies. The bacteriological-chemical and the physiological analyses deserve on that account a closer consideration. The writer's method of determining the transformation products in various media inoculated with bog bacteria should possess the exactness and reliability necessary for the solution of this problem. The determination of these bodies by chemical means alone will be only in part of value for investigations in ecology.

Numerous problems of experimentation have arisen quite apart from the main question itself.

It would be interesting to determine the water requirement of bog plants for a growing period and to compile the results on a basis of the water needed for one part of ash yielded. Data on the specific differences in the ratio, i. e., on the water requirements of bog plants and the percentage of ash in herbs, shrubs, and trees covering peaty basins, are not at hand. The analyses reported by C. S. Sargent in the ninth Census of the forest trees of North America give the percentages for some of the trees common to bogs. The data are interesting in showing that the majority of trees frequenting bogs have a percentage of ash less than 0.5, and only a few of the deciduous species occurring on Ohio peat deposits have a percentage of ash as high as 1.5. Comparisons of the quantities of mineral salts contained in peat deposits, differing so widely in ash constituents from land soils, point also to the fact that differences in mineral components are trifling as compared with the biological processes in the substratum and the differences in the available water.

It remains to be ascertained to what extent the absence of any mineral salt may lead to the unbalanced condition which induces the general pathological effects upon agricultural plants, and whether any one of the salts employed in fertilizers may in part or entirely counteract the injurious effects of peat and humus soils. Plant physiological and particularly agricultural literature contains numerous references to the rôle of mineral salts as nutriments. It must be candidly admitted, that the effects of the various mineral salts produced upon the plant or the cell are far more easily formulated than proved and that a satisfactory interpretation is not possible as yet. It is now known that in the preparation of mineral solutions for plants a certain ratio of the different salts is required. It would be of special interest to note in some detail the relation of potassium and calcium compounds, and the suitable concentrations required to counteract the toxicity of the deleterious bodies in peat soils. The fact that water and salts are as a general rule taken up in a different ratio, differing also according to the species of plants used as an indicator, shows that the relation in balanced solutions affects and is determined primarily by the diosmotic properties of the protoplasmic membrane and its accommodatory processes. The direct effect of mineral salts on the protoplasmic membrane is undoubtedly of greater importance than their supposedly special nutrient value. Tolerance and resistance of plants to physiologically deleterious substances, it may be added, is not one of osmotic relations to bog water, nor is the absorption of water a function of it. A study of the magnitude of the internal osmotic pressure occurring in the roots and in the foliage of bog plants as related to bog conditions has not been carried very far as yet. Wheat plants growing in bog soils do not, however, show more than the usual pressure* isotonic with a 0.3 normal solution of potassium nitrate.

Elsewhere (Bot. Gaz. **49**: 325–339. 1910; and **52**: 1–33. 1911) the writer has shown that contrary to the position taken by

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* Fitting, H. Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen. Zeits. Bot. 3: 209–275. 1911.

several investigators, peat soils contain bacteria inducing diastatic, inverting, proteolytic, cytohydrolytic, and reducing actions during the digestion of the plant debris in the upper layer of the peat substratum. A marked interdependence was shown to exist between the organisms; and the fact that many organisms are obligate saprophytes capable of growing only on a substratum similar in composition to the character of the respective plant association, is indicative of a close relation between a specific bacterial flora, the progressive disintegration of organic material, and the successions of vegetation in bogs and peat deposits. The characteristic xerophily of ancient* and modern bogs the writer attributes to the edaphic adversities encountered rather than to climatic differences. Though the biological processes in the soil thus appear to be more essential than the quantity of mineral components, there yet remains the question how far microorganisms are active in the change of vegetable matter to peat and lignite, and in the formation of gases and of coal. To what extent is the cooperation either essential, useful, or dangerous in the formation and character of organic compounds available for assimilation? What are the factors affecting and limiting the decomposition of organic matter?

What is the nutritive value of the different carbon and nitrogen compounds arising through the activity of microorganisms? Toxic substances possess an unlike physiological value to different plants and hence it is but one step further to raise the question of the comparative nutrient value of these organic compounds.† More recent experiments with isolated bog bacteria show very clearly the ability of a number of the organisms to increase the amount of assimilable compounds in peat soils. The transpiration values of these cultures for wheat plants lie 200 per cent above that of the control. The fact that to many plants bog toxins are injurious at one concentration but not at another, and that further dilution carries with it a corresponding intensification in

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* Dachnowski, A. The problem of xeromorphy in the vegetation of the Carboniferous Period. Am. Jour. Sci. IV. **32**: 33–39. 1911.

† Haskins, H. D. The utilization of peat in agriculture. Massachusetts Agr. Exp. Sta. Rep. **1909**^{2}: 39–45. 1909.

Lipman, F. G. Report of the Soil Chemist and Bacteriologist of the New Jersey Agr. Exp. Sta. 188–195. 1910.

growth rate, shows the inefficiency of the usual analytical methods of the organic chemist. Neither the properties, the chemical formula, nor their effect upon transpiration, alone afford an indication of their physiological importance. In addition new analyses of peat, wood, and of bog plants from various zones with reference especially to the ratio between the carbon and nitrogen content, are much to be desired. A study of the relative toxicity of the substratum is not independent from a study of the energy needs of the organism. Both are equally important and must be approached from the point of view of the possible absorption and transformation of the compounds or their neutralization into insoluble, impermeable compounds, and the specific structural and functional peculiarities in plants enabling the change.

Aside from the nutritive inequalities of organic peat soil constituents it is worth while to study more closely the various structural modifications that appear in plants indigenous to the habitat, in the less fit invading plants, and in those which survive. In another paper the writer has shown that the phenomena of absorption and tolerance of plants in bogs deal with consideration of the permeability of the absorbing protoplasmic membrane, its power of endurance and its ability either to absorb and assimilate or to transform injurious bodies into impermeable compounds. The form of invading plants is frequently altered, as is shown by dwarfing, the reduction of number and size of leaves, the loss of buds and branches, and the rapid aging of the plants. This indicates the extent to which the various functional mechanisms involved, such as absorption, conduction, and growth, are interrelated and coordinated. Every green plant is undoubtedly able to a certain extent, to assimilate nitrogenous and other organic compounds. Plants that grow preferably on humus and peat soils must have special absorptive powers, but little is known, as yet, to what extent the roots themselves exert a direct solvent action, enzymatic or otherwise, in rendering the peat available for assimilation, and how far fungal mycorhiza, which form symbiotic unions, are of importance.

The possible scope of this study has been barely indicated.

BOTANICAL LABORATORY,
OHIO STATE UNIVERSITY.

Studies in pyrophilous fungi—III.* The viability of the spores of Pyronema

Fred J. Seaver

(with plate 4)

In the first paper of the present series, in attempting to impress upon botanists the value of *Pyronema* as a plant to be used in regular class study, it was stated that no data were at hand as to the length of time during which the spores of this fungus would keep their viability. As a knowledge of this point is of vital importance in determining whether the teacher is able to tide over this plant in the laboratory from year to year, it is deemed worthy of special study and mention at this time.

As has been previously stated, when once this fungus has been cultivated it is comparatively easy to "get a catch" from the air by simply exposing properly heated soil and keeping it moist for a few days. Especially is this true in greenhouses. To my knowledge, since this fungus has been under observation here, steamed or heated soil used for planting in the propagating houses of the New York Botanical Garden has never failed to develop the fungus. Some time ago the spores of the fungus were sent to Purdue University for experimental purposes, and recently in a conversation with Dr. F. D. Kern he informed me that this fungus also now made its appearance in their greenhouse whenever heated soil was exposed. While the fungus may usually be obtained in this way when once it is started, this method is uncertain and the occurrence of the plant is likely to be delayed when it is most needed. It is therefore better to develop and rely upon some more certain methods of securing and preserving it.

During the present winter the fungus was desired for study in classes at Columbia University, and several pots of heated soil were exposed to the air, as formerly, in the laboratories of the

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* Studies in pyrophilous fungi—II. Changes brought about by the heating of soils and their relation to the growth of *Pyronema* and other fungi, was published in Mycologia 2: 100–124. *pl. 24–26.* 1910.

New York Botanical Garden. As it had been some time since the fungus had been under cultivation at the Garden, the spores were apparently not very numerous in the air, for after several days the plant failed to appear. Search was then made for some recently collected spores for inoculation. No attempt had been made to keep the spores for this purpose and the youngest specimens available in the herbarium of the Garden had been collected nearly three years before. The soil was inoculated with these aged spores, and within a few days a good growth of *Pyronema* was produced, the infection apparently proceeding from the point of inoculation. As this experiment did not prove with certainty that the old spores germinated, it was decided to test them out in hanging drop culture.

A complete history of the specimen used in the above experiment is as follows. In the spring of 1909, a pile of leaves and brush was burned, and this opportunity was taken to test the growth of *Pyronema* under natural conditions, as the fungus was at that time under cultivation in the laboratory. Spores were taken from the plants grown in the laboratory and with these the burned place was inoculated. In a reasonably short time our burned place showed a good growth of the fungus. One good specimen was collected and placed in the herbarium of the Garden in an ordinary paper packet. In January 1912 the spores from this specimen were used for the experiment described above, and while many of the spores failed to germinate, there was enough growth in a hanging drop culture to form a web of mycelium over the cover glass on which the spores were planted.

The spores of *Pyronema* are rather thin-walled and are not the kind of spores, so far as general appearance is concerned, that would be expected to keep their viability for a long period of time. Also, it would naturally be thought that spores which are adapted to withstand long periods of unfavorable conditions as resting spores would not germinate readily when fresh. The spores of this fungus are an exception in both of these particulars, for the fresh spores germinate very readily in hanging drop culture and very old spores germinate with equal facility; also, the walls of the spores do not appear to be thicker than the walls of the young mycelium and show no protective structures.

The spores germinate by putting out a germ tube from each end, one end, however, growing much faster than the other. The young mycelium is very coarse, the diameters of the main branches being fairly constant. The whole mycelium is filled with vacuoles, giving it a characteristic appearance. The spore before germinating swells much, becoming large and very granular. The germ tube as it issues from the spore is slightly smaller in diameter than the spore but often swells to about the same diameter. The contents of the spore after germination are similar in appearance to the contents of the young mycelium, and there appears to be no difference between the wall of the old spore and that of the young mycelium, the spore forming one segment in the growing mycelium, usually of a little larger diameter and shorter but often so nearly like the other segments of the mycelium that it is difficult to determine the position of the old spore. In some cases the spore seems to swell up and begin to grow by simply cutting off new segments at either end.

The spores of *Pyronema*, as shown in the present experiment, will keep their viability for nearly three years; as to how much longer they will remain good we cannot at present say. Griffiths* in his work on Fimetariaceae (Sordariaceae) found one species in which the spores kept their viability for more than three and one-half years.

The demonstration of the long viability of the spores of *Pyronema* is one more argument in favor of the introduction of this fungus into college and university courses in botany which deal with a general knowledge of the subject. The cultivation of the fungus requires no complicated technique, and the rapidity with which the plant grows would enable the student to study all of the stages from the germinating spore to the production of sex organs and mature ascocarps within a period of about ten days. Also, the asci of *Pyronema* when mounted in water illustrate very nicely the common method of spore dissemination among the ascomycetes.

Claussen† in his recent paper on the development of *Pyronema*

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* Griffiths, D. The North American Sordariaceae. Mem. Torrey Club **11**: 1–134. *pl. 1–19.* 30 My 1901.

† Claussen, P. Zur Entwicklungsgeschichte der Ascomyceten, *Pyronema confluens.* Zeit. Bot. **4**: 1–80. *pl. 1–6.* 1902.

states: "Es wirt angegeben dass *Pyronema* auf Brandstellen häufig vorkomme. Häufig kann aber wohl der Pilz nicht sein, da ich ihn bisher nur ein einziges Mal—bei Eberswalde—im Freien fand. So oft ich sonst sowohl bei Freiburg wie bei Berlin solche Stellen absuchte, hatte ich keinen Erfolg."

While nothing can be said here as to the occurrence of the fungus in Europe, the fact remains that it is fairly common in America so far as our knowledge goes. Of course its occurrence in nature depends upon the presence of recently burned areas accompanied by a reasonable amount of precipitation. Given these conditions, and the fungus is common. It has been collected by the writer in Indiana, Iowa, New York, and North Dakota and has been frequently reported by collectors from other states.

If it should happen that the fungus is not common in a given locality, or as is more likely to be the case, has never been recognized, it has been shown in previous papers that the fungus is easily cultivated in the laboratory; and now having proved the long viability of the spores which enables the plant to be carried over for an indefinite length of time in the laboratory, there is no longer any reason for considering *Pyronema* an uncommon fungus. If the fungus is worth knowing from a morphological point of view it is also worth seeing.

DIRECTIONS FOR CULTIVATION AND PRESERVATION OF THE SPORES

Heat good rich, unfertilized, garden soil by placing it in pots or other receptacle. The heating can be accomplished by steam or dry heat in an autoclave or sterilizing oven. If dry heat is used run the temperature up to 150°–170° C. If neither autoclave nor sterilizing oven is available, bake in an ordinary oven for an hour or more at ordinary baking temperature. Cool and water with tap water. Plant the spores and place the pot under a bell jar. Growth of mycelium should be abundant in two or three days at room temperature; sex organs should appear in about a week and mature ascocarps a few days later.

When through with the study of plants, scrape off the old ascocarps together with a little dirt, place them in an envelope and keep dry until they are desired for study the next year, then prepare substratum and plant as before.

NEW YORK BOTANICAL GARDEN.

Explanation of plate 4

Pyronema omphalodes

1. Normal ungerminated spore.

2. Spores slightly swollen and apparently about to germinate.

3–7. Stages in the germination of spores on the third morning after planting.

8. Young ascogonia.

9–10. Ascogonia and antheridia, side and end view.

11. Mature ascus.

12. Ascus showing dissemination of spores.

13. Anastomosing mycelium.

All figures are drawn with the camera lucida; 1–7 and 13 show stages in the developing spores collected in the spring of 1909 and germinated January 1912, as they appeared on the third morning after planting.

The ferns and flowering plants of Nantucket—IX

Eugene P. Bicknell

CAESALPINIACEAE

Cassia Chamaechrista L.

Sandy tracts and roadsides east of the town beyond the Creeks, extending locally as far as Quaise; also south of the town on the road to Surfside. Remaining in flower late in September. Usually undersized, often even less than 4 cm. high, with flowers only 1 cm. long and leaves 5 mm. in length, their minute leaflets reduced to three or four pairs.

Note.—The honey locust (*Gleditsia triacanthos* L.) is sparingly spontaneous about a row of rather large trees bordering the Wauwinet road at Eatfire.

PAPILIONACEAE

Baptisia tinctoria (L.) R. Br.

Scattered widely over the plains and moorland, often forming open groups, but nowhere thickly massed in extensive growths as on Long Island. On June 3, 1909, the most advanced plants were about one foot high; a precocious flower June 17, 1908.

Ulex europaeus L.

Mrs. Owen has told us (Cat. p. 22) that the furze or gorse was introduced on Nantucket by John O'Connell about the year 1860, and that at the time she wrote, in 1888, it was still growing on his farm near Hummock Pond, where it had spread both within the fence and along the road on the outside. Today the O'Connell farm belongs wholly to the past and little evidence remains of the enterprise of the pioneer who there once gave cultivation to the land. Not even the remains of any building mark the wild surroundings, and the road and old fence of which Mrs. Owen has spoken may be traced only by those who know where to look among the growth of pines and shrubbery which has all but completed its work of obliteration. Where the labor of the early settler has left scarce a vestige to tell its tale, the gorse and the Scotch broom bear their witness to the human sentiment which here had its dwelling place in days now over half a century gone. At this spot, on June 6, 1909, the broom, almost dazzling in its wealth of bloom, everywhere spread its golden masses along the dark background of the pines and with a glow like sunshine lighted up the recesses among the shrubs and trees. Blooming with it in scarcely paler brightness, but nowhere far strayed from the course of the vanished roadway, the gorse, in spiny clumps and formidable thickets was also in strong possession of its conquered ground. Its greatest continuous growth exceeded one hundred and ten paces in longer extent and twenty paces in maximum transverse breadth, the stouter shrubs having reached a height of four to six feet, with stems four to six inches in circumference. It had flowered earlier than the broom, some of the blossoms having already begun to fade. In June 1911, both the gorse and broom were found to have suffered severely, probably from the long-continued drought, and much of both was either partially or wholly dead and brown.

CYTISUS SCOPARIUS (L.) Link.

Now extensively naturalized on Nantucket, the Scotch broom is steadily increasing and spreading to new localities year by year. Writing in 1888, Mrs. Owen included the species in her catalogue on the evidence of a single plant reported by Mr. J. H. Redfield as growing among the furze bushes on the O'Connell farm. At that locality in 1906 the broom was found to have spread extensively in a contest for supremacy with the young pines among which it grew, and the larger plants had attained a height of eight to ten feet and their stems a basal girth of four to six inches. In 1899, when this locality was unknown to me, the broom was observed at only three stations, east, west, and south of the town. On my next visit to the island, five years later, small clusters were seen at three places on the Wauwinet road between Shawkemo and Polpis, and an extensive growth formed a stubborn thicket along the western border of Trot's Swamp on the site of the old Barrett farm. In 1906 it had appeared here and there along an old cart-road in Polpis and was first observed on the bluff at Siasconset, extending down the steep slope from the top, where it had doubtless been planted. The following year new localities were noted about one mile southeast of the county fair grounds, near Almanac Pond and on the roadway through Spotsor country, new stations having become established also along the Wauwinet road. In 1908 many scattered colonies were found in the neighborhood of the long-abandoned Barrett farm. It was also seen that year for the first time near Reed Pond and east of the county fair grounds. In 1909 it had sprung up at a number of suburban localities and was first observed as far east as Squam towards Quidnet, as far southeast as the abandoned Kimball farm in the south pasture, and on the south side of the island near Miacomet Pond; it was also well established along the old south road about two miles from the town. A thriving colony in private grounds among the pines at Wauwinet had doubtless been planted there, and a considerable thicket east of Shimmo farm was so well founded that it could scarcely have been of very recent origin. In 1911 the plant was first seen on the Madequet road towards Long Pond.

As early in the season as May 30, 1909, the broom was in full flower; it was in equally conspicuous bloom on June 6, 1909, and from June 15 to 20, 1910, although on June 20, 1908, it was passing out of flower. Occasional single flowers are to be found in August and September. It fruits freely, maturing abundant seed.

On a visit to Marthas Vineyard in October, 1909, it was found that the broom had effected a lodgement on that island. A group of four bushy plants or clusters, the tallest about four and one-half feet high, grew by a thicket on the west side of Sengekontacket Pond, and a solitary plant two feet high near the shore road three miles or so north of Edgartown. In 1911 a tuft had sprung up by an old roadway near the golf links at Edgartown, and a small clump was observed on the northwestern side of the island near Lambert's Cove.

*MEDICAGO SATIVA L.

Frequent in grassy lots and in outlying fields near the town. First flowers June 18, 1908; in full flower at the middle of September 1907. Siasconset, 1886, Mr. Nickerson, fide F. G. Floyd.

MEDICAGO LUPULINA L.

Rather common, mainly along roadsides and in the more inhabited parts of the island. First flowers, May 30, 1909; in full flower at the middle of September 1907.

MELILOTUS ALBA Desv.

In 1904 this plant was found only along the railroad in the town, where it was well established; two years later it had extended in detached groups here and there along the Siasconset and Wauwinet roads and in 1908 had sprung up at several places about the town. First flowers June 18, 1908; June 23, 1910.

*MELILOTUS OFFICINALIS (L.) Lam.

First observed by me on Aug. 11, 1906, a cluster in full flower in a field near Miacomet Pond; in 1908 a solitary plant was seen below the "Cliff," and a patch south of the town; in 1910 it had appeared at another station south of the town and was found on June 25 at Sankaty Head, extending in a wide breadth of bloom down the face of the bluff. Many years before, it grew at this spot, having been found there in abundance in 1888 by Miss Elizabeth S. Kite and again, in 1891, by Mrs. Mabel P. Robinson.* It was also observed by Mr. Floyd as early as 1895 at Brant Point, where it still persists and showed its first opened flowers June 3, 1911.

TRIFOLIUM AUREUM Poll.

Common in sandy soils and grassy places. First flowers June 10, 1908; June 12, 1909; June 15, 1910; also in full flower late in September.

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* For these records I am indebted to Mr. Frederick G. Floyd, who has sent me a manuscript list of additions to Mrs. Owen's Catalogue, which he has had in preparation since 1905. My own explorations on Nantucket had been carried on in the belief that since the publication of Mrs. Owen's list the island had remained an almost neglected botanical field. How mistaken was this belief is disclosed by Mr. Floyd's manuscript, which shows that the island has continuously inspired the active botanical interest of many collectors, one or more of whom have made new discoveries in its flora almost from year to year. And not less an occasion of surprise to me is this, that in the many absorbing botanical days I have myself passed exploring this garden of the sea it has never been my fortune to encounter a kindred spirit, neither a botanist nor an explorer in any branch of nature study.

It appears from Mr. Floyd's notes that some of my own supposed discoveries were earlier made by others, and it will be a pleasure here to make record of all such additions to the island's flora that have received Mr. Floyd's or other adequate verification. To Mr. Floyd I extend my appreciative acknowledgments for his generous contribution to the greater completeness of the present paper.

TRIFOLIUM PROCUMBENS L.

Gravelly and sandy fields and dry grassy slopes, mainly in the more settled parts of the island, usually growing in close beds or smaller isolated patches. Very common in the neighborhood of the town and from Reed Pond to the county fair grounds, extending as far east as Shawkemo; common in Madequet and about Siasconset. First flowers May 30, 1909; just in flower June 7, 1911; blooming abundantly during June. Some flowers Sept. 16, 1907.

*TRIFOLIUM DUBIUM Sibth.

Roadsides, fields, and grassy places. Abundant throughout the north side of the island from Madequet to Squam; abundant also in the southwest quarter and about Siasconset. Apparently beginning to bloom rather earlier than *T. procumbens* and having a briefer flowering period. First flowers May 30, 1909; much of it past flowering June 18, 1908, and June 26, 1910. Mr. Floyd's notes contain a reference to this species on Nantucket as far back as 1889, when it was collected by Miss Elizabeth S. Kite.

*TRIFOLIUM INCARNATUM L.

Occasional in old fields, persisting where it has been sown, but apparently never becoming permanently established. Siasconset 1899. In full flower May 30, 1909, and late in September. North Beach Street—meadow—evidently introduced in grass seed, 1895, F. G. Floyd; yard in town, 1896, Mrs. Mabel P. Robinson, fide F. G. Floyd.

TRIFOLIUM ARVENSE L.

Abundant in dry sterile soils. When almost in flower it often remains a long time without coming actually into bloom. Appearing to be in flower June 15, 1910, but no flowers fully opened until June 27. In September many young plants often come into bloom among others that had completely dried up long before.

TRIFOLIUM PRATENSE L.

Very common. In early June it is conspicuous from its luxuriance and profuse bloom in low-lying grassy lots in the town. First flowers May 30, 1909.

TRIFOLIUM HYBRIDUM L.

Common in and about the town; less frequent at more distant points. Comes into flower later than either *T. repens* or *T. pratense;* first flowers June 3, 1911, June 15, 1910; not blooming freely until June 20, 1908; remaining in flower through September.

TRIFOLIUM REPENS L.

Very common either in dry or moist soils and varying greatly both in size and habit. First flowers June 2, 1909; in full flower June 15, 1910; blooming through September.

CRACCA VIRGINIANA L.

Abundant on the plains west of the middle of the island and towards the south shore; Great Neck; north of Siasconset; nowhere seen on the northern half of the island. Plants just appearing May 31, 1909; leaves beginning to unfold June 9, 1908; first flowers June 17, 1908; abundant fruit at the middle of September, 1907.

*ROBINIA PSEUDACACIA L.

Well established along the old south road, and spontaneous at several places on the outskirts of the town; sparingly at the Miacomet pines. In 1889 a thicket or close growth of young trees had become established in open ground north of the town; this has since developed into rather a conspicuous grove, the larger trees having a height of not less than twenty feet and a basal girth of 17 inches. First flowers June 15, 1910, June 16, 1911; still in full bloom June 27, 1910.

*ROBINIA VISCOSA Vent.

Occasional by roadsides near the town and at Siasconset. Has spread little if at all since 1889, when it was first observed. First flowers June 22, 1910.

CORONILLA VARIA L.

Along a neglected roadside and in a waste yard in the town, where it was first observed in 1906; a luxuriant growth in full bloom in a grassy field border south of the town June 18, 1908; at Siasconset along a roadside fence (1906) and on the bluff (1908). Not yet in flower June 17, 1911.

MEIBOMIA OBTUSA (Muhl.) Vail.

Rather common on the eastern side of the island, especially in Squam and in the region about Saul's Hills; occasional on the plains towards the south shore but not seen west of Hummock

Pond; on the north side of the island not seen west of Shawkemo. In full flower and abundant fruit Sept. 1, 1904; last flowers Sept. 11, 1899.

Except on Nantucket I have not noticed that this plant may relax from its erect or stiffly ascending habit. Here it is frequently quite prostrate, the slenderly elongated stems and branches of the panicle proceeding almost in the trailing manner of a *Lespedeza* among the grass and low plants of the dry open places where it grows. These prostrate forms are more slender and less pubescent than normal suberect states of the plant and have less numerous and crowded leaves with thinner leaflets.

*MEIBOMIA RIGIDA (Ell.) Kuntze.

Growing sparingly on a dry open slope in Squam, Sept. 21, 1907, and bearing abundant fruit; rather a small form of the plant becoming 6 dm. high, the leaflets 3–4 cm. long by 1.5 cm. wide.

*MEIBOMIA CANADENSIS (L.) Kuntze.

Mrs. Nellie F. Flynn has sent me a flowering specimen of this tick trefoil, which was collected on Nantucket Aug. 13, 1904, by Mrs. Eleanor W. Morgan, no locality being given.

*MEIBOMIA SESSILIFOLIA (Torr.) Kuntze.

In the herbarium of the Nantucket Maria Mitchell Association I found a sheet of this species, which had been collected on Nantucket by Mrs. Nellie F. Flynn Aug. 23, 1901. In regard to this specimen Mrs. Flynn has written me that she collected it "by a roadside just west of the farm house near and west of Nobadeer Pond," where it grew very sparingly.

LESPEDEZA PROCUMBENS Michx.

Locally common in open pine scrub and on the plains and commons, occurring in all quarters of the island. Stems a few inches long June 7, 1909; small flower buds Aug. 11, 1906; first flowers Aug. 29, 1904; in full flower Sept. 1 to 15.

On Nantucket this species is subject to much variation in degree of pubescence and in other characters. Two varieties are especially to be noted, one whitened with a dense velvety pubescence, the other having a looser pubescence of shorter, less spreading hairs and flowers tending to be smaller and of somewhat different proportions, the petals narrower, the wings often surpassing the keel, the standard paler and less distinctly lineate; also, the pods are commonly smaller and more orbicular.

*LESPEDEZA BRITTONII Bicknell.

Found in much the same situations as the preceding and sometimes growing with it but less widely spread. It is often quite prostrate, and on the open plains towards the south shore of the island forms close mats three or four feet in diameter of radiating and flatly interlaced stems and branches, which in August and September are loaded with the flowering racemes. First flowers Aug. 11, 1906; in full flower Aug. 29, 1904, Sept. 15–23, 1907. Often develops an unusual degree of dense cinereous pubescence.

*LESPEDEZA NUTTALLII Darl.

Met with at only two stations: between Siasconset and Tom Never's Pond, Aug. 31, 1904, the flowers rather pale pinkish white with the standard medially purple-lineate; and near the railroad about the fifth mile, Sept. 2, 1904, the flowers deeply purple-tinged. At both stations the plants were rather low, 3–6 dm. high, with unusually contracted inflorescence, which appeared capitate by reason of the short, densely floriferous racemes massed together at the end of the stem. The plants were perfectly healthy, but their repressed inflorescence seemed to announce that some factor of their environment had been unfavorable to their freest development.

*LESPEDEZA STUVEI Nutt.

A small group of plants in full flower Aug. 31, 1904, near Siasconset towards Tom Never's Pond; two stations in Saul's Hills, Sept. 19, 1907, the plants well fruited and with some late flowers. Plants 2–3 dm. high were observed in Saul's Hills June 8, 1908.

*LESPEDEZA VIRGINICA (L.) Britton.

Occasional, and locally common on the eastern half of the island, especially along the state road. The Nantucket plant is often notably pale in color from an investiture of appressed sericeous pubescence densely clothing the younger parts and the lower surface of the leaves, and to a less extent the upper surface also. Flower buds barely discernible Aug. 13, 1906; in full flower Sept. 15, 1907; last flowers Sept. 12, 1899.

LESPEDEZA FRUTESCENS (L.) Britton.

Infrequent. Bank near the Creeks; near Tom Never's Pond and westward on the moors; Shawkemo. On the western side of the island it was met with only at one station, on the plains towards Hummock Pond. In full flower Aug. 31, 1904, Sept. 4, 1899, abundant fruit and some late flowers; no flowers remaining Sept. 17, 1907.

Probably the *Lespedeza violacea* of Mrs. Owen's list.

LESPEDEZA HIRTA (L.) Hornem.

Not uncommon but somewhat local and not seen at all in the western half of the island. Frequent over the south pasture and on the moorland toward Siasconset; Shawkemo; Saul's Hills; Polpis; Squam. Just in flower Aug. 13, 1906; in full flower Sept. 13, 1907.

On the open moorland a form occurs—it grows also in the pine barrens of Long Island—in which the crowded leaves are densely villous-tomentose beneath and almost felted on the upper surface with a densely appressed soft pubescence; their petioles are commonly shorter than in the usual form of the plant and the leaflets elliptic to obovate-oblong and suborbicular; the pubescence is often notably ferrugineous. This plant is undoubtedly a well characterized variety, yet if it were to receive a name as such, consistency would require that names be given to other only less markedly set apart forms of this bush clover and of all our other species as well.

LESPEDEZA BICKNELLII House, Torreya 5: 167. 1905.

L. velutina Bicknell, Torreya 1: 102. S 1901. Not *Lespedeza velutina* Dunn; Hooker, Icones Pl. IV. 7: *pl. 2700*. F 1901. A native of China.

The only abundant and generally distributed bush clover of Nantucket, found everywhere in dry open places, even growing in white sand among the beach grass along the shores. Although sometimes erect or ascending to a height of one or two feet, it is more often nearly or quite prostrate. Even the early shoots are often declined and in June are to be seen radiately decumbent or prostrate around dead suberect stems of the preceding year. On Marthas Vineyard this bush clover is also the prevailing species, but it is there mostly erect, although on the plains sometimes becoming quite prostrate. On Chappaquiddick Island, where the vegetation in general is more like that of Nantucket than on Marthas Vineyard proper, no plant of this species was found that showed any prostrate tendency.

On Nantucket, like several other Lespedezas, this species develops as unusual degree of pubescence, the stems becoming velvety-cinereous, the leaflets conspicuously whitened and almost felted on both surfaces with a velutinous canescent or appressed silky indument. Stems a few inches long June 2, 1909; first flowers Aug. 11, 1906; in full flower Aug. 28, 1904; no flowers left Sept. 2, 1907.

Nothing was seen of *L. capitata* Michx., although it may be expected to occur since it was found at one station on Marthas Vineyard. The name appears in Mrs. Owen's catalogue but of course refers to the allied species, which was not recognized until many years later.

*VICIA VILLOSA Roth.

Occurs sparingly at one locality in Quaise, where it is found running through the grass about an isolated and long-abandoned dwelling. First flowers June 15, 1911; in full flower Aug. 16, 1906, Sept. 17, 1907.

*VICIA TETRASPERMA (L.) Moench.

Not observed until 1909, when it was found not far from the old mill along a roadside bank and intricately entangled over many rods of an adjoining field. The next year it was seen at the foot of the "Cliff" and in quantity by a roadside southwest of the town. Near Union Street, 1904, Mrs. Nellie F. Flynn; near Orange Street, 1905, J. R. Churchill, fide F. G. Floyd. Just in flower June 15, 1910; in full flower June 13, 1909, June 26, 1910. Corolla larger than in *V. hirsuta*, purplish and pinkish tinged, the standard purple-lineate.

*VICIA HIRSUTA (L.) Koch.

One station north of the town, where there is a tangled growth in a hollow of a sloping sandy field; near the docks, 1895, Mrs. Nellie F. Flynn, fide F. G. Floyd. Not yet any flower buds May 30, 1909; first flowers June 12, 1909; June 15, 1910; June 15, 1911. Corolla smaller than in *V. tetrasperma*, bluish and white, the standard without darker lines.

VICIA SATIVA L.

Abundant in the town and suburbs, running rife amid the grass in fields and meadows and along roadsides In full flower May 30, 1909; June 7, 1908. Appears to have increased remarkably within very recent years. Mrs. Owen mentions it as occasional in dooryards and old fields.

*VICIA ANGUSTIFOLIA Roth.

Now very common but not noticed before 1907, when it was seen at two stations in the town and in an old field a mile out; the next year it was found to be frequent in the general town region and was observed at Monomoy, Shawkemo, Madequet, and in the southwest quarter. In full flower June 7, 1908; June 15, 1910. Like the preceding, this vetch seems to have increased greatly in recent years. The two are often found growing together and appear to hybridize, since examples are frequent which it is scarcely possible to assign conclusively to one or to the other.

LATHYRUS PILOSUS Cham.

Borders of brackish or fresh-water meadows along the harbor, locally common from the Creeks to Pocomo; Squam Pond; Sachacha Pond; Little Neck. Under the name *Lathyrus palustris* L., Mrs. Owen has recorded that it was found at Hummock Pond by Mr. J. H. Redfield. First flowers May 30, 1909; June 7, 1911; a few flowers remaining Aug. 28, 1904. Stems, leaves, calyces, and even the tendrils more or less pubescent, the younger parts pilose-canescent; stems commonly broadly winged, at least above; leaflets 2 or 3 pairs (rarely 1 pair or 4 pairs), narrowly linear to lanceolate or narrowly oblong, 2.5–7 cm. long; peduncles 2–4-flowered, the flowers 1.5–2 cm. long, bright crimson changing to clear deep blue.

LATHYRUS MARITIMUS (L.) Bigel.

Common along the coastal sands, often extending back among the dunes; along the top of the bluff on the north shore; abundant at the western end of the island. First flowers June 7, 1909; just in full flower June 7, 1908; occasional flowers in September. At one locality near the bathing beach, in June 1910, many plants bore only pale flowers, white with lavender standard. Varies from glabrous to densely short-pubescent.

*LATHYRUS TUBEROSUS L.

In Quaise, making a luxuriant tangle among the grass along and near an old fence. Not yet with any signs of flower buds June 9, 1911.

APIOS APIOS (L.) MacM.

Rather common in low grounds and on the borders of swamps. In full flower at the middle of August, 1906; no flowers seen in September.

FALCATA PITCHERI (T. & G.) Kuntze.

Sparingly in Watt's Run bog at the border of a wet thicket, Sept. 17, 1907, well fruited and with some faded flowers remaining. Stems retrorsely rusty-villous; larger leaflets oblong-ovate, 7 cm. long by 4 cm. wide, appressed-hairy on both surfaces; calyx 7 mm. long; pod 3 cm. long or longer, the margins retrorsely hispid-villous; sides of the mature valves glabrous.

Referred to *F. Pitcheri* with reservations pending a more critical study of our hog peanuts than seems yet to have been attempted. The indications appear to point to more than two species in our flora. The Nantucket plant is scarcely identical with typical *F. Pitcheri*, ordinarily an inhabitant of low open thickets, yet it is certainly closer to that species than to *F. monoica*, a smaller and more delicate woodland plant. The latter was not seen on Nantucket, but it is locally common on Marthas Vineyard in the hilly woodland on the western side of that island. It is mentioned in Mrs. Owen's catalogue but the exact plant intended cannot now be known.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1910-1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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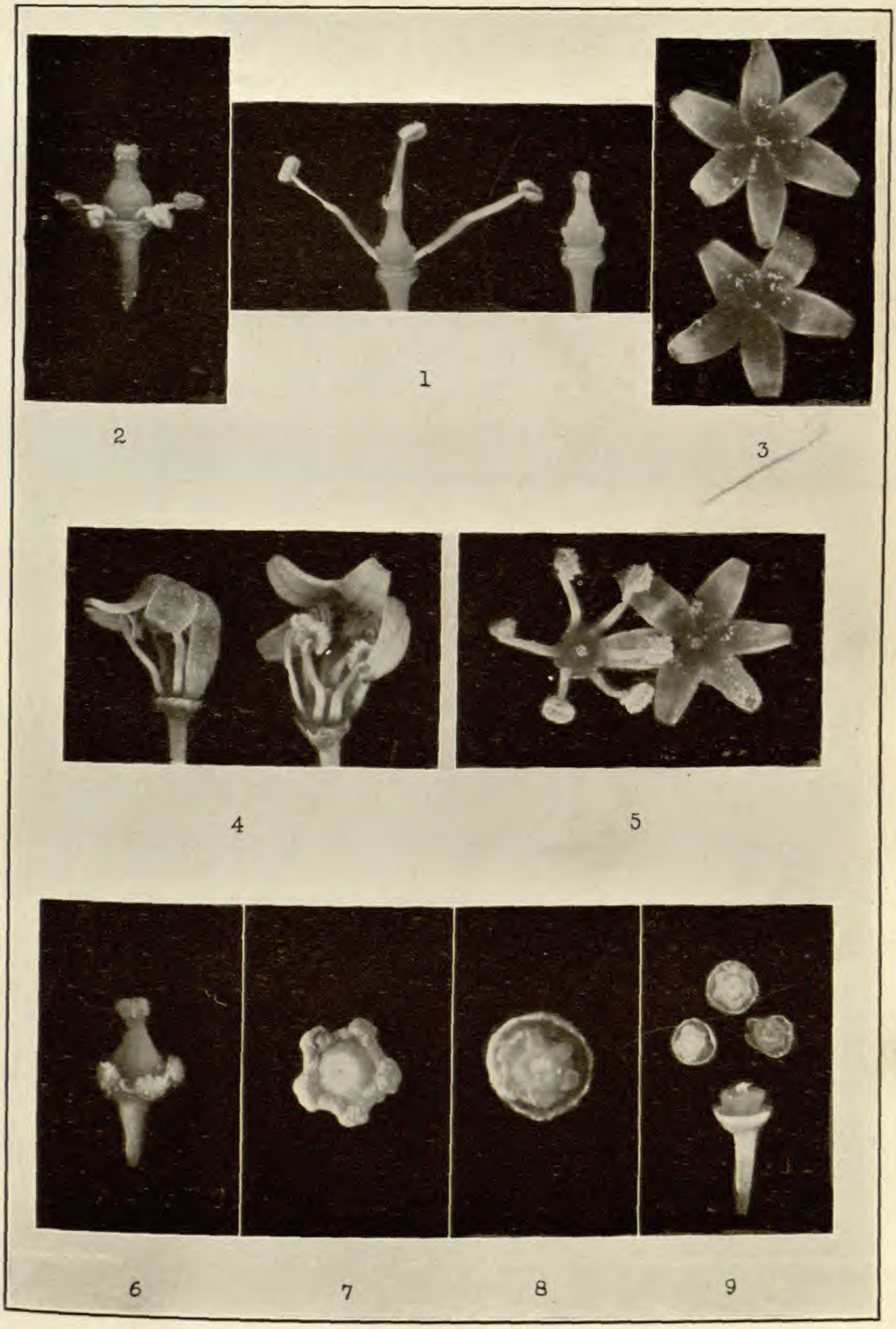

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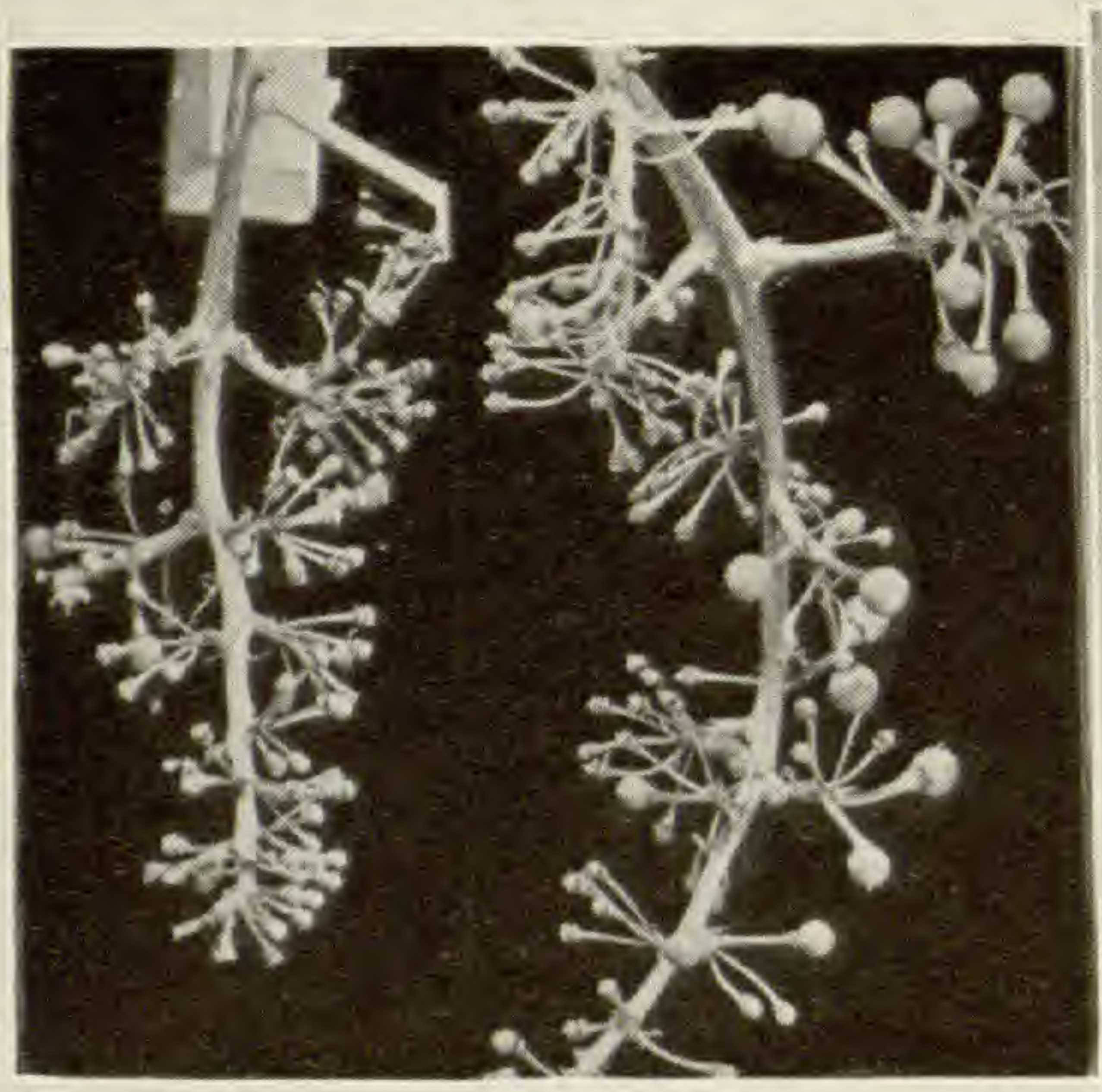

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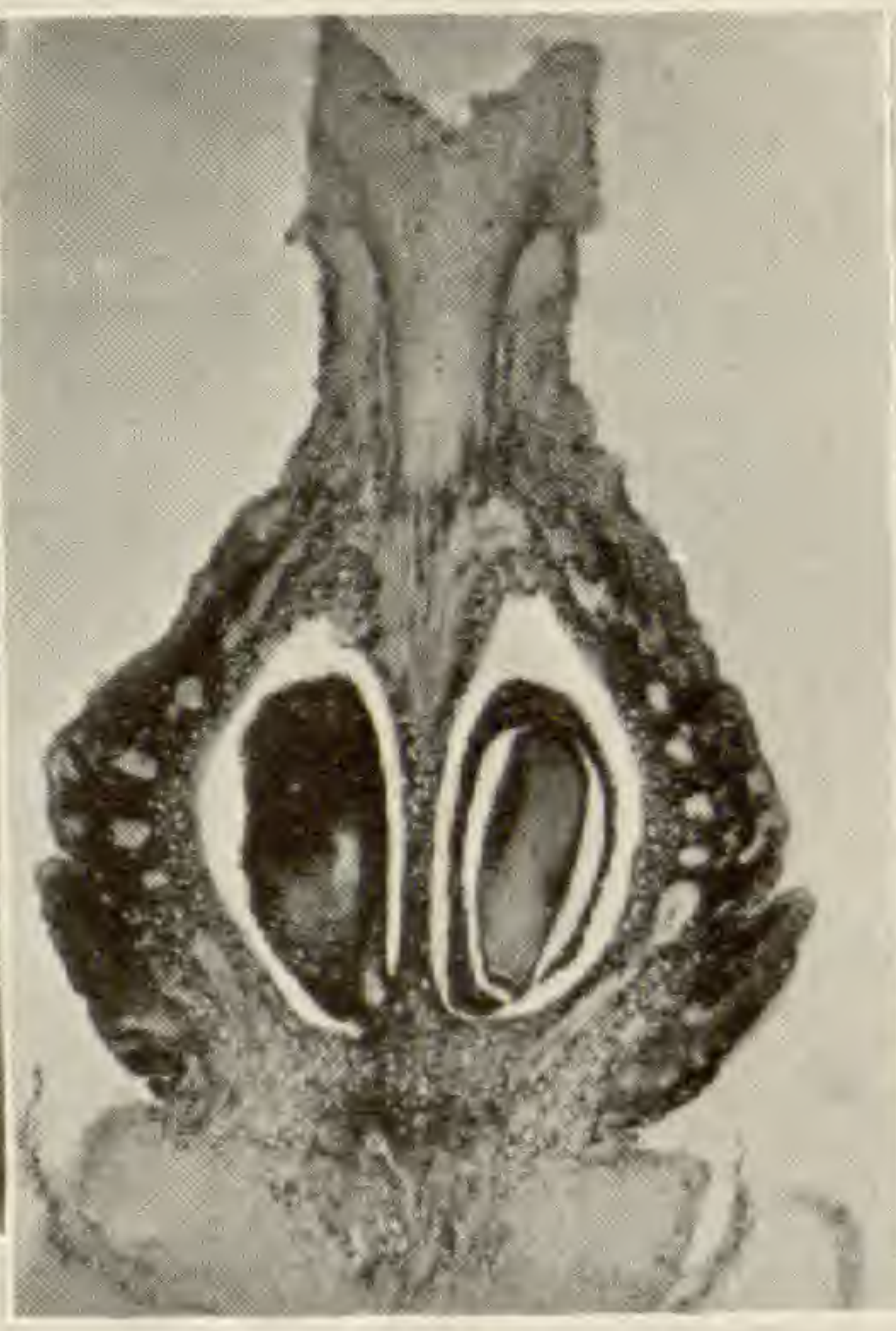

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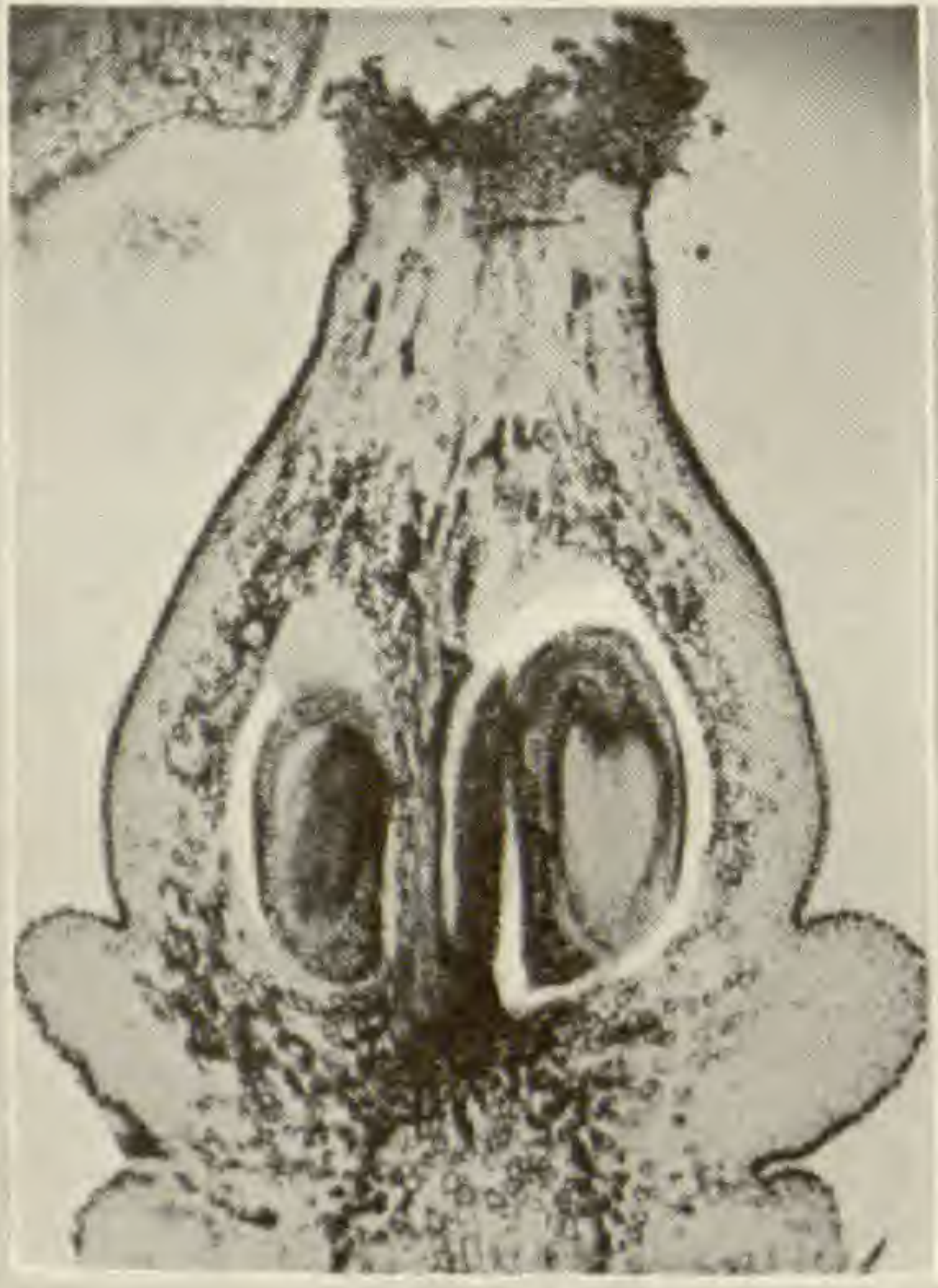

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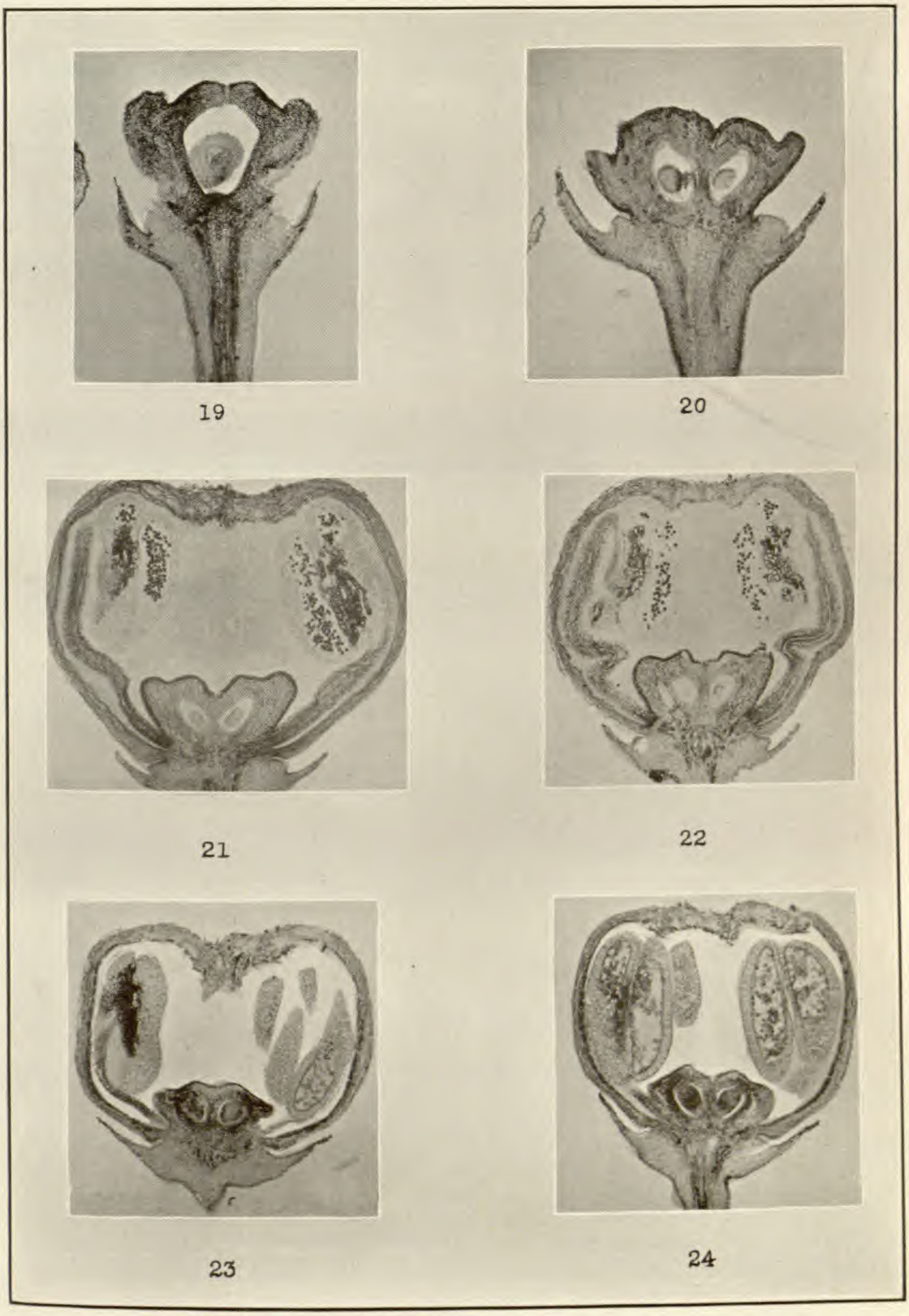

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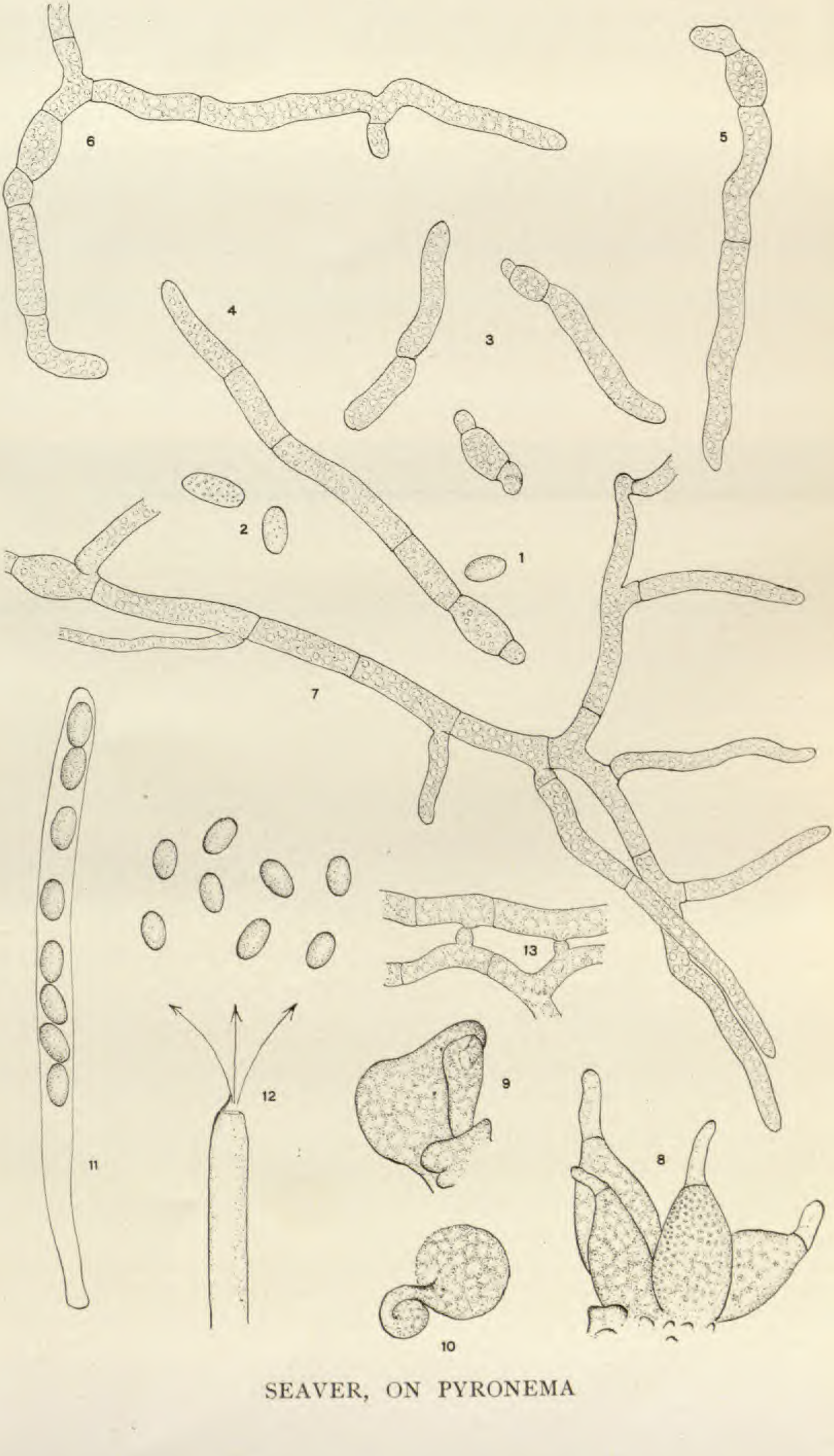

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MARCH 1912

Violet hybrids between species of the palmata group

EZRA BRAINERD

(WITH PLATES 5–7)

In my last paper on violet hybrids, published over six years ago, and in the one preceding it,* I described only one hybrid whose parents were both in the natural group represented by *Viola palmata*. I recognized the fact, however, that these closely allied species seemed "to be confluent when growing together," and stated my belief that "they can and do interbreed." It has been often observed that natural hybrids between doubtfully distinct species, or between a species and its variety, are the most difficult to determine with certainty; the less remote from each other the two species that hybridize, the less marked and less numerous are the signs of hybridity in the offspring. For six seasons now, I have had many suspicious intermediates of this group under cultivation, raising sometimes a hundred or more offspring from one plant, extending through three or four generations. Some of the results of these experimental cultures, I trust, will prove of interest to students both of systematic botany and of heredity.

VIOLA PALMATA × PAPILIONACEA Brainerd.†

Leaves cordate-ovate as in *V. papilionacea*, lobed after the manner of *V. palmata*, but less deeply so; the capsules from cleistog-

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* Rhodora 6: 213–223. N 1904; and Rhodora 8: 49–60. Mr 1906.

† Dowell, Ph. The violets of Staten Island. Bull. Torrey Club 37: 177. Ap 1910. At least one of the specimens there cited (*4777*), Dr. Dowell would now call *V. papilionacea* × *triloba*.

[The BULLETIN for February 1912 (39: 37–84. *pl. 1–4*) was issued 9 Mr 1912.]

amous flowers ovoid-conical, 5–7 mm. long, or half as long as the normal capsule in either parent, containing in the 48 capsules examined an average of 4½ seeds to the capsule. (PLATE 5, *Aa*.)

In June 1906 Mr. W. DeWitte Miller sent me from Plainfield, N. J., a plant that he considered this hybrid. Three years after transplanting, the rootstock was much branched and 8–10 inches broad; in the spring of 1909 part of it was broken up and ten new plants obtained, which in a year or two became so luxuriant that half of them were purposely destroyed. From the original plant 23 offspring have been raised. Of these, 6 had deeply lobed leaves like those of *V. palmata;* 4 had uncut leaves like those of *V. papilionacea;* and the remaining 13 had leaves somewhat lobed as in the hybrid. (See PLATE 6.) In 1909 numerous offspring were raised from 8 of the above 23 plants, with the following results: (1) The seedlings from a plant with uncut leaves (in one instance 18) had always uncut leaves like the parent. (2) The seedlings from a plant with deeply cut leaves (in one instance 19) had always deeply cut leaves like the parent. (3) The seedlings of plants with leaves somewhat lobed as in the original hybrid, in the five instances tested, always gave plants of the three forms given by the original hybrid. In more technical language, the form of the hybrid leaf displays no dominance of the form of either parent but is a compromise between the two forms. But when plants having this hybrid form of leaf reproduce, the offspring present variously the two extreme forms of the original species and the compromise form of the hybrid, in this conforming to the Mendelian law of 'segregation.'

There is also approximate conformity to the Mendelian ratio of 1:1:2 in the number of each of the three kinds of offspring. The total progeny raised from plants having the hybrid form of leaf was 49; of these, 13 had deeply cut leaves (form *A*); 12 had uncut leaves (form *a*); and 24 had the compromise leaf (form *Aa*). This is as near to the above ratio as is practically possible with a total of 49 plants.* The further Mendelian principle is illustrated: that when an offspring of a hybrid reverts to a pure character of either parent species, that character continues pure in succeeding generations if the plant is self-fertilized. In this

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* The theoretical ratio 12¼ : 12¼ : 24½ cannot be concretely realized, as the number of each kind of hybrid forms must necessarily be a whole number.

particular hybrid, when the leaf form of *V. papilionacea* once reappears, it is kept up in the subsequent progeny; so, when the leaf form of *V. palmata* once comes back, it comes to stay.

Another instance of a cross between *V. palmata* and *V. papilionacea* was found among several plants of *V. palmata* from Orange, N. J., exhibited by Miss Angell at the "violet symposium" at Bronx Park, May 1905. The plants were later set out in the New York Botanical Garden. On examining them the following September, my attention was called to a stocky plant with leaves wider and less deeply lobed than the rest; cleistogamous flowers were abundant, but their capsules were nearly sterile. From the few ripe seeds obtained, plants were propagated for three generations, with results quite the same as in the hybrid from Plainfield.

In the autumn of 1906 I received from Miss A. M. Ryan of New London, Conn., fresh leaves and a few ripe seeds of a plant collected by Miss Pauline Kaufman in the vicinity of New York City. The leaves were quite the same as those of Mr. Miller's hybrid. Two plants only were raised from the seeds sent; but later, a brood of offspring from each of these. The first brood (sowing 320) consisted of nine heterogeneous plants, proving the hybrid nature of the mother, as well as of the plant collected by Miss Kaufman. Of the second brood (sowing 592) eight plants were raised, all with deeply lobed leaves like the mother, and hardly distinguishable from normal *V. palmata* except by smaller capsules and greatly impaired fertility.

I have said nothing as yet of the inheritance in these hybrids of pubescence from *V. palmata*, or of the lack of it from *V. papilionacea;* this, however, was quite similar to the inheritance of lobation, or the lack of it, though not as conspicuous. The most interesting circumstance was that frequently the lobed leaves and the pubescence of *V. palmata* were not both inherited by the same offspring. A seedling with lobed leaves would often be glabrous; and on the other hand, one with uncut leaves would often be pubescent and might have easily passed for *V. sororia* except for its infertility.

Such aberrant forms occasionally appear in the wild. In May 1909 I saw some excellent photographs taken by Miss E. M. Kittredge of certain anomalous violets found near her home in

Spring Valley, N. Y. One showed plainly a glabrous specimen of *V. palmata* in flower. By the kindness of Miss Kittredge the live plant was presented to me in June. On collecting close-fertilized seeds the following August, I found on the average 16 seeds to the capsule; that is, about three fourths of the ovules were undeveloped. Among the offspring raised the following season, were plants representing not only the deeply lobed leaves of *V. palmata* but also the uncut leaves of *V. papilionacea*. Both forms, however, were glabrous, as was to be expected; for a dominant character like pubescence, when once lost, never reappears. Nevertheless, the hybrid origin of the wild plant was clearly established. Let me cite one further instance.

On April 15, 1909, I found at Tryon, N. C., what seemed to be a colony of this glabrous *V. palmata*. In the vicinity grew both the normal hairy *V. palmata* and the glabrous *V. papilionacea*. Of the anomalous plants six with leaves moderately lobed were shipped to Vermont to be grown and studied in the garden. All proved to be more or less infertile, averaging about 20 seeds to the capsule. Offspring were raised from all six; and in each brood but one were to be seen plants with uncut leaves, indicating that one parent of the original hybrid was *V. papilionacea;* from which, doubtless, was also inherited the glabrous character of the plants at Tryon.

Viola palmata × triloba hyb. nov.

First 1–3 leaves of spring often uncut as in *V. triloba*, followed by others more or less 5–7-lobed, much like those of *V. palmata* but the basal lobes broadly dilated and coarsely toothed as in *V. triloba;* later leaves less dissected, mostly 3-lobed or obscurely lobed; capsules infertile, about one third of the ovules maturing into seeds; offspring multiform, often bearing on the middle segment of the trilobed leaves 4–8 undulations or coarse teeth.

The genuine *V. Angellae* Pollard (Torreya **2**: 24. 1902), proves to be this hybrid, as the original description and the type sheet of mature plants (U. S. National Herbarium no. 352,093) clearly show. One of the flowering plants on sheet no. 364,862 may, however, be pure *V. palmata*. It would seem that the original collection by Miss Angell, June 1899, contained many specimens of *V. palmata*, as some of them are to be seen mounted in the National Herbarium, and others were distributed only last summer with the name "*V. Angellae*" on the printed labels. Possibly some of these plants may be imperfect reversions to *V. palmata*. Furthermore, as already stated, most of the specimens of "*V. Angellae*" exhibited at Bronx Park May 1905 were *V. palmata*. Others also have erroneously assumed that plants that they collected at the type station were therefore typical *V. Angellae*. Mr. Pollard distinctly states that his new species is associated with *V. palmata* in the Orange Mountains.

In May 1908 Dr. E. L. Greene kindly sent me a dozen plants of his *V. variabilis* from the type station, opposite Harpers Ferry and named by him Maryland Heights. Most of these plants have since been growing in the garden, and from some of them have been raised two generations of offspring. These plants I make out to consist of two different hybrids of *V. triloba*, one being the *V. palmata* × *triloba* above described. A close comparison of the characteristic leaf of this hybrid (PLATE 7, FIG. 3 and 4) with the leaves of the supposed parents (FIG. 1 and 2) will disclose its compromise outline. The leaves of Dr. Greene's plant, though at first suggesting *V. palmata*, differ in having the broad basal lobes of *V. triloba* even as early as May 31; while specimens collected July 22 and September 16 display leaves decidedly trilobed, and some hardly lobed at all. This tendency towards uncut leaves in autumn is characteristic of *V. triloba* but not of *V. palmata*. Furthermore, in some of the segregating offspring (PLATE 7, FIG. 5 and 7) may we not see in the oddly shaped middle segment the resultant of opposite impulses, one demanding 9–11 lobes, the other forbidding more than 3?

So much for the evidence from the living plant, cultivated for four seasons and through three generations. The conclusion drawn from this experiment is well sustained by a careful study of the seven sheets of "*V. variabilis*" at the National Museum. Four were collected May 14, 1898—two by Dr. Greene, and two by Mr. Pollard, who accompanied him—and three others by Dr. Greene May 10, 1903; all from Maryland Heights opposite Harpers Ferry. The 17 plants here mounted I regard as a medley of at least five distinct forms, three of which are represented in the live plants sent in 1908. I shall here speak of only the palmatifid form, which Dr. Greene says "is exceedingly similar to Mr. Pollard's recently proposed *V. Angellae*, indeed so much like it that I have little if any doubt they are one, specifically."* In this I agree with Dr. Greene; and in both cases plants of pure *V. palmata* were collected with the hybrid *V. palmata* × *triloba*, three of the former and four of the latter appearing among the 17 mounted specimens labeled by Dr. Greene *V. variabilis*. One of each kind is to be seen on U. S. National Herbarium sheet no. 328,245, collected by Mr. Pollard and labeled by him in pencil "*V. palmata*."

A plant distributed by Mr. Witmer Stone, as *V. palmata variabilis* (Greene),† seems to be, at least in part, the hybrid under discussion. I have observed also several other specimens that appear to be this; but one may not with confidence identify a hybrid between two species so closely allied without abundant material or the data obtained by experimental cultures.

Viola papilionacea × triloba hyb. nov.

Leaves of late spring and summer shallowly, often obscurely, 3–5-lobed, uncut leaves subcordate, often broadly reniform; capsules even from cleistogamous flowers infertile; offspring inheriting diversely the opposed characters of the parent species.

My first acquaintance with this hybrid was through some anomalous living plants sent from Washington, D. C., in May 1906, by Mr. E. S. Steele, along with samples of pure *V. triloba*. The six plants of the latter were quite alike—pubescent, cut-leaved, buff-seeded, fertile, and easily separated by the purple tinge of the early spring foliage from the anomalous plants. These were of three forms: (1) One plant fairly fertile, with pubescent uncut leaves as in *V. sororia* but bearing buff seeds. (2) Two plants fairly fertile, with uncut leaves and dark brown seeds as in *V. papilionacea* but pubescent. (3) One plant nearly sterile, averaging 6½ brown seeds to a capsule, the leaves glabrous and somewhat 3-lobed. Offspring were raised from all of these: those from (1) and (2), 6 plants from each, seemed to be stable, that is, in each instance all had characters like those of the mother; the offspring from (3) were only two, one with uncut leaves, one with 3-lobed leaves.

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* Pittonia 5: 91. 1902.

† No. *5111*, colony 5, Argus, Pa., June 8, 1903, Dr. C. D. Fretz.

The problem is to account for the presence in a colony of normal *V. triloba* of three plants so variant from *V. triloba* and from each other. But however confused the situation may appear, all may be accounted for by regarding the three odd plants as the descendants of a cross between *V. triloba* and *V. papilionacea*, a common species of the region. Plant (1) seems to have escaped the conflict of characters forced into the make-up of the original hybrid and attained to stability and relative fertility, inheriting uncut leaves from *V. papilionacea* but pubescence and buff seeds from *V. triloba*. Plant (2) seems to be another stable ex-hybrid, inheriting also pubescence from *V. triloba* but dark brown seeds as well as uncut leaves from *V. papilionacea*. Plant (3) is partly rescued from hybrid instability, at least as regards pubescence, but is still hybrid as regards leaf form — what we may call a subhybrid, still bearing in its infertility the stigma of its irregular parentage.

Of the twelve plants of "*V. variabilis*" sent me by Dr. Greene in 1908 I regard nine as the progeny of *V. papilionacea* × *triloba;* and the case is exactly parallel to the one just described, though on a somewhat larger scale. The differing characters of Dr. Greene's plants are presented in the following synopsis, and will be found in all cases to be only new combinations of those found in the putative parents. The numbers given are those that the several plants bear in my notebook.

Leaves with uncut blades.
  Blades broadly cordate-ovate, blunt-pointed, pubescent beneath.
    Seeds buff, about 11 in a capsule.......... 2, 12
    Seeds dark brown, about 14½ in a capsule.......... 5, 6, 7, 10
  Blades much dilated, subglabrous; seeds brown.......... 4
Leaves slightly lobed in spring, later leaves uncut, broadly reniform, truncate or subcordate; seeds brown.......... 9
Leaves 3–5-lobed, subglabrous; seeds brown.......... 8

On the seven sheets of "*V. variabilis*" in the U. S. National Herbarium there are only six plants that represent this group, and they all have uncut leaves. As none were collected later than May 14, the color of their seeds is unknown; nor has any plant developed leaves with subcordate reniform outline. These forms and the two with lobed leaves (no. 4, 9, and 8 above) indicate that Dr. Greene sent me a fuller representation of this hybrid group than he had previously collected for himself.

Dr. Greene's conception of a species, which without hybridizing appears "under forms enough to make three," is quite contrary to the latest inductions of biology. The law that "like produces like," even through seed (when pure or not affected by foreign pollen), is confirmed by numerous experimental tests. If we except the extremely rare cases of observed mutation, the offspring of a species or of a natural variety is always uniform.* Whenever a miscellaneous offspring appears, we may be confident that at no very remote past, species or varieties, as unlike or more unlike than the offspring, were sexually united in the parentage.†

Several other examples of *V. papilionacea* × *triloba* might be cited, but I name only two from well known collections: No. 34, North American Violaceae, Greene and Pollard; "*V. palmata dilatata* Ell." New Springville, Richmond Borough, N. Y., Wm. T. Davis, July 17, 1903; also no. *5108*, colony 3, Violets of Philadelphia and vicinity; "*V. palmata dilatata* Ell." Sherwood, Pa., June 17, 1903.

Viola sororia × triloba hyb. nov.

The confluence of these two species is generally recognized, and it is so common that many students of *Viola* have regarded them as forms of the same species; just as, because of a similar confluence, *V. sagittata* has been held to include *V. fimbriatula*. The shallow and obscure lobes of the hybrid leaf are the same as in *V. papilionacea* × *triloba*, but the foliage is never glabrous. But more satisfactory than this negative test is the discovery of the intermediate forms in a region from which *V. papilionacea* is absent. Along a shady limestone ledge in Orwell, Vt., where *V. triloba* and *V. sororia* were abundant, but no *V. papilionacea*, was found in 1904 a large colony of intermediates that will pass muster as *V. sororia* × *triloba*. In this case the most satisfactory evidence would come from the artificial production of the hybrid; this I trust will soon be attempted.

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* Dimorphism, such as the constant reproduction of both staminate and pistillate plants, or of long-styled and short-styled forms, belongs to another class of phenomena.

† See DeVries, H. Species and varieties. Lectures 6 & 7, on stability and vicinism.

It may be noted that the leaf outline in *V. triloba* is relatively broader and less deeply cordate than in *V. sororia* (or in *V. papilionacea*), and that the hybrid offspring may inherit the uncut leaves of the latter and the broad outline of the former, thus presenting a decidedly reniform leaf. Such stable forms often emerge in experimental cultures and are occasionally met with in the wild near stations for *V. triloba*. I have usually found such broad-leaved specimens of "*V. sororia*" to be infertile. It seems to be this that Dr. Greene has named *V. populifolia*. (Pittonia 3: 337. S 1898.)

The two hybrids of *V. Stoneana* that follow are analogous to the two last described.*

Viola papilionacea × Stoneana hyb. nov.

Glabrous; first one or two leaves uncut, succeeded by larger ones 5–7-lobed; the middle segment broad, the basal lunate coarsely serrate, the lateral but slightly if at all narrowed at the base; autumn leaves often much dilated and obscurely lobed; capsules more or less infertile, 7–12 mm. long; offspring diversiform as to lobation.

A plant of this was taken from Ivy Hill Cemetery, Philadelphia, September 1905. From close-fertilized seed collected and sown in the autumn of 1906 were grown the following season, plants that had three distinct leaf forms: (1) the uncut leaf of *V. papilionacea;* (2) the 5-parted leaf of *V. Stoneana* with segments much narrowed toward the base; (3) the 5-lobed leaf of the original plant. From six of these plants a third generation was grown in 1909, in which all from (1) and (2) were homophyllous, and those from (3) heterophyllous, as in the brood obtained in 1907. From (1) a fourth generation was raised in 1910, all like the parent.

Viola Stoneana × triloba hyb. nov.

Leaves 5-lobed; lower surface and petioles somewhat pubescent; capsules infertile; seeds buff; offspring in part glabrous, in part quite pubescent.

The original plant was collected at Ivy Hill Cemetery, Philadelphia, in 1905, with the one last described. Four seedlings

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* Cf. The evolution of new forms in *Viola* through hybridization. Am. Naturalist 44: 231. Ap 1910.

were grown in 1907: one quite glabrous, in this reverting to *V. Stoneana;* the other three more or less pubescent. From each of the four plants offspring were obtained in 1909. Those from the glabrous plant were also all glabrous; two of the pubescent plants bore both pubescent and glabrous offspring; the remaining pubescent plant bore nine offspring, all pubescent, thus indicating that in this instance the pubescence of the mother plant was a stable character. This happens to be exactly the relative number of these three forms of offspring required, on the average, by the laws of Mendel.

Viola latiuscula × triloba hyb. nov.

Leaves moderately 3–5-lobed, sparsely pubescent on the petioles and veins of the young leaves; capsules about 8 mm. long, maturing 10 or 12 brown seeds; progeny heterogeneous.

For my acquaintance with this hybrid I am indebted to the discernment and diligence of Mr. B. H. Slavin of the Park Department of the City of Rochester, N. Y. On June 19, 1909, he sent me from Salamanca, N. Y., six odd-looking plants, all glabrous; four with leaves somewhat lobed, subcordate-ovate, blunt-pointed; two with leaves uncut. As they flowered and matured the following season, I detected certain marks of *V. latiuscula:* a crimson tinge in the early spring foliage, and a granular roughness along the upper edges of the petiole. At my request Mr. Slavin revisited the station for further collections July 6, 1910, and sent me in the autumn an excellent suite of the various forms to be seen in that colony. For a better apprehension of their relation to each other, I borrow some of the symbolism of Mendel. For brevity he uses letters instead of phrases, somewhat in this fashion:

Let A = cut-leaved
" a = with leaves uncut
" Aa = with leaves somewhat uncut

Let B = pubescent
" b = glabrous
" Bb = somewhat pubescent

All of these six characters are found in the above described hybrid or in the parent species; in the offspring of the hybrid they should be redistributed in all possible combinations. It is evident that each one of the three characters in the first group may combine with each of the three in the second group, making in all nine different combinations. These are given in the following table, the asterisk after any form denoting its occurrence at the Salamanca station.

1	A	B	*	Reversion to typical *V. triloba.*
2		b	*	New and stable form, glabrous *V. triloba.*
3		Bb	*	Cut-leaved form, hybrid as respects pubescence.
4	a	B	*	New and stable form, pubescent *V. latiuscula.*
5		b	*	Reversion to typical *V. latiuscula.*
6		Bb		
7	Aa	B	*	Pubescent form, hybrid as respects lobation.
8		b	*	Glabrous form, hybrid as respects lobation.
9		Bb	*	Dihybrid, *V. latiuscula* × *triloba.*

The one form lacking should be a somewhat pubescent plant with uncut leaves. The proof that we have here a colony of *V. latiuscula* × *triloba* will be convincing to one familiar with the behavior of hybrids.

Three hybrids of *V. hirsutula*, one with each of our three cut-leaved species, call for a few brief comments.

Viola hirsutula × **triloba** nom. nov.

V. palmata × *villosa* Brainerd, Rhodora **8**: 56. Mr 1906. Cf. House, H. D. Violets of the District of Columbia, Rhodora **8**: 121. Jl 1906. The former name of each parent species has proved to be untenable.*

This beautiful and easily recognized hybrid is of frequent occurrence from northern New Jersey to the mountains of North Carolina and eastern Tennessee. A most interesting colony, of a hundred or more plants, was found at Morristown, Tenn., on a tract of woodland recently cleared and worked to be made an addition to a cemetery. The plants were reverting in various ways to the characters of one or the other of the original parents. Some were large in size, others small; some had lobed leaves, others not; most had both the silvery pubescence of *V. hirsutula* on the upper surface of the leaf and the villous pubescence of *V. triloba* on the lower surface of the leaf, but occasionally one or the other form of pubescence was nearly or quite lacking. Not only from these, but from a plant sent me October 1907 from Orange, N. J., by Miss A. M. Ryan, I have raised unlike offspring, some with uncut leaves, some with leaves mostly lobed. In Mr.

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* See Rhodora **9**: 96–98. Je 1907; and Bull. Torrey Club **37**: 584–587. D 1910.

Witmer Stone's Violet Distribution no. *5107*, colony 3, "*V. palmata dilatata* Ell.," Sherwood, Philadelphia, May 17, 1903, is plainly this hybrid. So also is *H. D. House 823*, Glen Echo, May 25, 1905, Violets of the District of Columbia. The name on the label, "*V. villosa* × *palmata asarifolia*" would indicate that Mr. House considered it *V. hirsutula* × *sororia;* but my specimen bears one *lobed* leaf.

Viloa hirsutula × palmata hyb. nov.

Plant small, cespitose; leaves all palmatifid, the incisions becoming shorter toward the base; the blades somewhat pubescent beneath, finely ciliate and bearing minute white hairs along the veins above; capsules nearly sterile.

One plant only was found in an open woods near Plainfield, N. J., September 1906, with both parents growing near. This was transplanted to the Middlebury garden and later multiplied by division, but I have failed to obtain sufficient seeds for a sowing. However, the marks of its double parentage are pronounced.

Viola hirsutula × Stoneana nom. nov.

V. Stoneana × *villosa* House, Rhodora **8**: 121. *pl. 72.* Jl 1906. The plants seem to be rare; Mr. House got it only from the type station, Hyattsville, Md. I collected a specimen at Ivy Hill Cemetery, Philadelphia, Sept. 6, 1905; and in April 1908 Dr. Theo. Holm kindly sent me a live plant from Brookland, D. C. From the latter plant I obtained in 1909 three offspring that differed widely from each other in the relative number of cut and uncut leaves, and in that the cut leaves of the several plants were quite unlike each other in the number and length of the lobes.

In two of the ten hybrids discussed in this paper, both parents are cut-leaved species: *V. palmata* × *triloba* and *V. Stoneana* × *triloba;* in the remaining eight the leaves of one parent are cut, of the other uncut. In all cases the leaf of the first hybrid (F_1) has an intermediate form. This rule regarding hybrid leaf form holds in all observed cases in the genus *Viola*. The same rule prevails to a large extent as regards pubescence; but here there are also cases of more or less complete dominance, as in *V. Stoneana* × *triloba*, where it is impracticable without an experimental test to distinguish among pubescent offspring which is stable and which unstable. Even in the character of seed color, or of capsule color, Mendelian dominance of brown over buff, or of purple over green, is usually somewhat imperfect; so that after some practice one can distinguish fairly well between pure and hybrid dominants. Details of this behavior will be given in a further paper, on the hybrids of *Viola pedatifida* of the Middle West.

MIDDLEBURY, VT.

Explanation of plates 5–7

PLATE 5

$\frac{3}{5}$ natural size

Aa. *Viola palmata* × *papilionacea* Brainerd, transplanted from Plainfield, N. J., June 1906; ex horto, Middlebury, Vt., Sept. 6, 1909.

A. Leaf of *Viola palmata* L., Yonkers, N. Y., Sept. 9, 1905.

a. Leaf of *Viola papilionacea* Pursh, Plainfield, N. J.

PLATE 6

$\frac{2}{3}$ natural size

Three offspring in third generation of *Viola palmata* × *papilionacea* shown in PLATE 5, *Aa;* grown from close-fertilized seeds of one plant. Ex horto, Oct. 2, 1909.

A. Reverting to *V. palmata* L.

a. Reverting to *V. papilionacea* Pursh.

Aa. Repeating hybrid leaf form.

PLATE 7

$\frac{3}{5}$ natural size

1. Leaf of *V. palmata* L., Orange, N. J.

2. Leaf of *V. triloba* Schwein., New Haven, Conn.

3 and 4. Two leaves, lower surface and upper, of *V. palmata* × *triloba*, transplanted from Maryland Heights, Md., May 1908; ex horto, May 31, 1911.

5–7. Three leaves of offspring of hybrid in third generation, grown from close-fertilized seeds of one plant.

Studies on the Rocky Mountain flora—XXVI

PER AXEL RYDBERG

PINACEAE and JUNIPERACEAE

In the New Manual of Botany of the Central Rocky Mountains no reference is made to *Picea canadensis*, although it has been collected in the Black Hills of South Dakota and Wyoming. Blankinship in his supplement to the Flora of Montana,* reports *P. alba*, which is the same, from four localities in Montana. This, however, I think is erroneous. All specimens from Alberta, British Columbia, and Montana, that I have seen determined as *P. canadensis* or *P. alba*, belong to *P. albertiana* S. Brown. Probably the specimens reported by Blankinship belong there also. *Abies grandis* is also omitted in the New Manual. This is not uncommon in Montana west of the continental divide. Perhaps that part of the state is not intended to be included in the range covered by the New Manual, as it includes only "most of Montana." The species has been reported from the Yellowstone Park, but the reference is uncertain. Blankinship, loc. cit., also reports *Juniperus virginiana* from Montana and cites three localities. I have no evidence that the determinations were correct nor have I seen any specimens from the state. What makes me more doubtful as to the correctness of the determination is that two of the localities are situated west of the continental divide, and at Bozeman, the third locality, I have myself collected during parts of three summers and have not seen it.

I doubt very much if *Juniperus Knightii* A. Nelson can be upheld as a species distinct from *J. utahensis* (Engelm.) Lemmon. The characters given, apparently do not hold. The leaves are supposed to be 2-ranked in *J. monosperma* and *J. utahensis* and 3-ranked in *J. Knightii*. I know that in the first two they are both 2- and 3-ranked. I have not seen the type of *J. Knightii*, but in a specimen distributed under that name by Professor Nelson

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* Montana Agr. Coll. Sci. Stud. Bot. 1: 39. 1905.

himself the leaves are both 2- and 3-ranked on different twigs of the same branch. The seeds in *J. utahensis* are either obtuse or acutish at the apex, and these characters do not furnish any distinction. I have spoken to Dr. J. A. Shafer, who helped Dr. N. L. Britton in preparing North American Trees, and he told me that he had come to exactly the same conclusion as I.

The following two changes in the nomenclature seem to be advisable.

Hesperopeuce Mertensiana (Bong.) Rydb. comb. nov.

Pinus Mertensiana Bong. Mem. Acad. Sci. Nat. St. Petersb. VI. 2: 163. 1832.
Abies Mertensiana Lindl. & Gord. Journ. Hort. Soc. Lond. 5: 211. 1850.
Abies Pattoniana Jeffrey; A. Murray, Rep. Oregon Exped. 1. 1853.
Tsuga Pattoniana Sénéc. Conif. 21. 1867.
Hesperopeuce Pattoniana Lemmon, Rep. Calif. State Board Forestry 3: 126. 1890.
Tsuga Mertensiana Sargent, Silva 12: 77. 1898. Not *T. Mertensiana* Carrière, 1867.

I agree fully with Mr. Lemmon that this species should be removed from *Tsuga*. Both its cones and its leaves are more like those of a spruce than those of a hemlock, and the habit of the tree is different from both. Mr. Lemmon, however, did not adopt the oldest available specific name.

Sabina horizontalis (Moench) Rydb. comb. nov.

Juniperus horizontalis Moench, Meth. 699. 1794.
Juniperus prostrata Pers. Syn. 2: 632. 1807.
Juniperus Sabina procumbens Pursh, Fl. Am. Sept. 647. 1814.
Sabina prostrata Antoine, Cupress. Gatt. 57. 1857–70.

EPHEDRACEAE

Marcus E. Jones* reduced *Ephedra viridis* Coville to a variety of *E. nevadensis*. I do not know exactly what *E. viridis* is, as I have not seen the type, but the Utah plant which Jones had in mind, does not seem to agree with the description. We have duplicates of some of the numbers cited by Jones, and these seem to be typical *E. nevadensis*.

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* Proc. Calif. Acad. II. 5: 726. 1895.

SPARGANIACEAE

Sparganium simplex L. has been reported again and again from the Rocky Mountains, but all the specimens I have seen under that name belong either to *S. longipedunculatum* (Morong) Rydberg or to *S. angustifolium* Michx. *S. longipedunculatum* resembles *S. simplex* much in habit but is usually more slender, and the leaves are not so triangular-keeled as in that species. The main difference is, however, in the shorter style and stigma. *S. simplex* is very rare in the United States. I have seen specimens only from the State of Washington. It is otherwise found in British Columbia and along the St. Lawrence River in Ontario and Quebec.

ZANNICHELLIACEAE

Potamogeton perfoliatus is not found in the Rocky Mountain region. It is there represented by *P. Richardsonianus*. Notwithstanding the fact that N. Taylor includes the latter in the former, I am convinced that they are distinct. This opinion is based on field studies. My contentions are also supported by M. L. Fernald.

I cannot find any specific distinctions between *Ruppia curvicarpa* A. Nels. and *R. maritima* L. The length of the pedicels is merely a matter of age and other conditions; the typical *R. maritima* has strongly oblique fruit, gibbous at the base as described in *R. curvicarpa;* slender or stout, straight and curved styles are found in the same individual even. Taylor, also, could find no distinctive characters.

ALISMACEAE

Alisma Plantago-aquatica L. is not found in America. In this European species the achenes have different beaks from those found in the North American species. The common species of the Rocky Mountain region should be known as *A. brevipes* Greene. *Alisma Geyeri* Torr. is also found in the regions. (See my Flora of Montana.) It has been collected later in Utah.

Blankinship* described one new species and one new variety of *Sagittaria*. *S. paniculata* Blank. is but a well developed *S.*

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* Loc. cit. 40.

arifolia Nutt.,* and *S. arifolia tenuior* is but a depauperate form of the same. Both *S. paniculata* Blank. and *S. arifolia* Nutt. have to give way for the older name *S. cuneata* Sheldon,† which was described from the deep-water form of the same species.

POACEAE

Blankinship reported *Panicum nitidum* Lam. from Columbia Falls, Montana. This must be an error, for that species is known only from the eastern seaboard from southern Virginia to eastern Texas. *Aristida fasciculata Hookeri* of Blankinship's list is the same as *A. longiseta.*

Professor Nelson reports *Aristida oligantha* from Colorado. I have seen no specimens from that state and none from west of central Nebraska. Perhaps *A. bromoides* might have been mistaken for it.

The oldest available specific name for *Eriocoma cuspidata* is *hymenoides*, which is therefore adopted, and its name and synonymy is as follows:

Eriocoma hymenoides (R. & S.) Rydb. comb. nov.

Stipa membranacea Pursh, Fl. Am. Sept. 728. 1814. Not *S. membranacea* L. 1753.
Stipa hymenoides R. & S. Syst. **2**: 339. 1817.
Eriocoma cuspidata Nutt. Gen. **1**: 40. 1818.
Oryzopsis cuspidata Benth.; Vasey, Special Rep. U. S. Dept. Agr. 63: 23. 1883.

The following species of *Muhlenbergia* should be added to the flora of the Rocky Mountain region: *M. pauciflora* Buckl. (*M. neomexicana* Vasey; *M. Pringlei* Scribn.), *M. polycaulis* Scribn., and *M. curtifolia* Scribn., which were collected by Professor A. O. Garrett and myself in southeastern Utah last summer. *Alopecurus fulvus* Smith is not found in America, except perhaps in Greenland. *A. aristulatus* Michx. is not the same, differing not only in the general habit, not being depressed-geniculate, but also in the different position of the awn of the floral glume. *Alopecurus pallescens* Piper has been collected in both Idaho and Montana.

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* J. G. Smith. Rep. Missouri Bot. Gard. **6**: 32. 1894.

† Bull. Torrey Club **20**: 283. 1893.

Professor Nelson, in the New Manual, includes *Sporobolus vaginaefolius* and *Cinna arundinacea*, which I think are erroneously reported for the region.

The following species of *Calamagrostis* have to be included in the Rocky Mountain flora: *C. Vaseyi* in Montana, *C. rubescens* and *C. lucida* in Wyoming.

Professor Nelson reduced *Avena americana* to a synonym of *A. Mortoniana.* I think they are distinct, but if united, they should bear the name *Avena Hookeriana*, an older name for the former. *Arrhenatherum elatius* has been collected in Colorado, and *Danthonia spicata* is common in the Black Hills.

Deschampsia pungens sp. nov.

A densely tufted perennial; stem 3–4 dm. high, glabrous and shining; basal leaves numerous, the old subchartaceous sheaths from preceding season remaining, strongly striate, glabrous, often slightly tinged with purplish; ligules triangular-lanceolate, 4–5 mm. long: blades spreading, more or less arcuate, strongly involute, bluish green or in age straw-colored, strongly striate, minutely scabrous-pruinose, stiff and with a callous pungent point; stem leaves few; blades 2–5 cm. long, similar; panicle open, branches in age spreading; peduncle and its branches more or less purplish, glabrous or minutely scabrous; empty glumes subequal, 3.5–4.5 mm. long, lanceolate, acute, purple, with scarious margins; rachis long-hairy; floral glumes 3–3.5 mm. long, similar to the empty glumes; awn attached near the base, equaling or barely exceeding the floral glume.

This species is closely related to *D. caespitosa* but differs in the stiff, involute, pungent-pointed leaves and in the position of the dorsal awn of the floral glumes. This is attached near the base of the glume, while in *D. caespitosa* it is attached one fourth or one fifth the distance from the base. It grows near hot springs.

ALBERTA: Along stream below warm sulphur springs, vicinity of Banff, July 10, 1899, *McCalla 2309* (type in herb. N. Y. Bot. Gard.).

WYOMING: Lower Geyser Basin, Yellowstone Park, August 4, 1897, *Rydberg & Bessey 3590.*

Chloris brevispica Nash has been collected at Wray, Colorado, and *Blepharidachne Kingii* (S. Wats.) Hackel (*Eremochloa Kingii*

S. Wats.) in eastern Utah, *Eragrostis lutescens* Scribn. and *E. hypnoides* Nees in Idaho, *E. secundiflora* Presl in Colorado, and *E. neomexicana* Vasey in southern Utah. *Briza maxima* L. has become introduced in Colorado.

Poa Multnomae Piper and *P. ampla* Merrill have been collected in Montana since 1909. *Poa flava* L. is not a *Poa* at all, as shown by Professor A. S. Hitchcock, and the name to be used for *P. serotina* Ehrh. is *P. triflora* Gilib. *Poa laxa* Haenke is not found in the Rocky Mountains, and what has been masquerading under that name is *P. alpicola* Nash. *Poa paddensis* Piper is an older name for *P. subpurpurea* Rydb., both being based on *P. purpurascens* Vasey. In the New Manual no reason is given why *P. Buckleyana* Nash, published in 1895, should be used instead of *P. Sandbergii* Vasey of 1893. They may be the same. *P. Buckleyana* Nash was a substitute for the untenable *P. tenuifolia* Buckl., while *P. Sandbergii* was described independently. I have not seen Buckley's type, but it is supposed to have been based upon the manuscript *P. tenuifolia* Nutt. Dr. A. Gray accused Buckley of having pilfered the species from Nuttall. There is in the herbarium of the New York Botanical Garden a specimen named by Nuttall *P. tenuifolia*, and this specimen belongs to *P. Sandbergii*. What has usually passed under the names *P. tenuifolia* and *P. Buckleyana* is different, and I think represents a distinct although closely related species. The grass common in Wyoming and Colorado belongs to this and not to the typical *P. Sandbergii*, which ranges only west of the continental divide.

Although *Poa pseudopratensis* Scribn. & Rydb. resembles the common bluegrass in habit it is entirely distinct from it and more closely related to *P. arida* Vasey. Like that species it lacks the cobweb at the base of the floral glumes altogether, while *P. pratensis* has the best developed cobweb of all our species. Likewise *P. phoenicea* Rydb., also cited as a synonym under *P. pratensis* in the New Manual, has no cobweb and belongs in another section of the genus. I am inclined to think that *P. phoenicea* Rydb. is the same as the original *P. Grayana* Vasey, while *P. Grayana* of my Flora of Colorado is a large-flowered *P. Pattersonii* or a closely related species.

Poa crocata Michx. is the same as *P. caesia strictior*. In the

Torrey Herbarium there are a few spikelets of *P. crocata* Michx., and I have seen the type of *P. caesia strictior.* The plant is the most common species that has been known under the name *P. nemoralis* in the Rockies. It is intermediate between *P. interior* Rydb. and *P. rupicola* Nash, in habit resembling more the latter, but the cobweb is present.

In the New Manual of Botany of the Central Rocky Mountains, *Poa Tracyi* Vasey, *P. flexuosa occidentalis* Vasey, *P. occidentalis* Rydb., and *P. callichroa* Rydb. are given as synonyms under *P. nervosa* (Hook.) Vasey. In *P. callichroa* the cobweb is present, and that species is related to *P. arctica* although much larger. In the rest the cobweb is wanting. The plant described by Professor Nelson is *P. occidentalis* (Vasey) Rydb. If *P. Tracyi* Vasey is the same I do not know, but *P. nervosa* (Hook.) Vasey is a different plant. A duplicate of the type is in the Torrey Herbarium. In this species the glumes are very thin and the nerves very prominent, stronger than in any other species of *Poa* known to me.

Poa californica, P. andina Nutt., and *P. brevipaniculata* S. & W. are given as synonyms under *P. Fendleriana. Poa brevipaniculata* is very hard to distinguish from *P. Fendleriana* and may well be reduced to synonomy. *Poa californica,* under which name *P. Fendleriana* has been masquerading and under which it is described in the old Coulter's Manual, is an entirely different plant, related to *P. nevadensis* and *P. Buckleyana* and not found in the Rocky Mountain region. *P. andina* Nutt. is also entirely distinct. *P. arida* Vasey and *P. pratericola* Rydb. & Nash were based on *P. andina* Nutt. These two as well as *P. juncifolia* Scribn. are cited by Nelson as synonyms under *P. Sheldonii* Vasey. *P. arida* and *P. Sheldonii* are closely related to each other but *P. juncifolia* is more closely related to *P. laevigata.*

In *Festuca* the following species have been collected in the Rocky Mountains: *F. pacifica* in Utah and Idaho, *F. reflexa* in Utah, *F. megalura* in Idaho, *F. ovina calligera* Piper in Utah, *P. idahoensis* Piper in Idaho, *F. viridula* Vasey in Idaho, and *F. dasyclada* in Utah. *Festuca Thurberi* is one of the best species in the genus, characterized by its long acuminate ligules. It stands in the same relationship to *F. campestris* and *F. scabrella,* as *Poa longiligula* does to *Poa Fendleriana* and *P. brevipaniculata.*

I regard the subgenus *Hesperochloa* of *Festuca*, proposed by Piper, as representing a distinct genus and here propose it as such.

HESPEROCHLOA (Piper) Rydb. gen. nov.

Festuca subgenus *Hesperochloa* Piper, Contr. U. S. Nat. Herb. **10**: 10. 1906.

Densely tufted dioecious perennial, occasionally stoloniferous. Inflorescence a narrow panicle. Spikelets turgid, 3–5-flowered; rachilla scabrous on the basal half. Empty glumes 2, broadly lanceolate, subscarious, shining, the lower 1-nerved, the upper 3-nerved. Floral glumes ovate, acuminate, rounded on the back, faintly nerved. Petals scabrous-ciliate on the keels. Styles obsolete; stigmas hispidulous on all sides, not plumose; ovary deeply sulcate near the apex, sparsely hispidulous; grain beaked and bidentate at the apex.

Hesperochloa Kingii (S. Wats.) Rydb. comb. nov.

Poa (*?*) *Kingii* S. Wats. Bot. King Exped. 387. 1871.

Festuca confinis Vasey, Bull. Torrey Club **11**: 126. 1884.

Festuca Kingii Scribn. U. S. Dept. Agr. Agrost. Bull. 5: 36. 1897. Not *Festuca Kingiana* (Endl.) Steud. 1855.

Festuca Watsonii Nash, Britt. Man. 148. 1901.

This was originally described as a doubtful *Poa* and afterwards transferred to *Festuca* because the floral glumes are rounded on the back. There are, however, certain characters in the stigmas and the grains that make it fit poorly in either genus. In both *Poa* and *Festuca* the stigmas are plumose, that is, the branches are spreading bilaterally, while in *Hesperochloa* the short bristlelike branches stand out in all directions, a condition rather rare among the grasses.

Hordeum caespitosum Scribn. is found locally throughout the range, *H. montanense* was described from Montana, *H. murinum* and *H. Aegiceras* have been introduced and are locally established, especially in Utah.

Sitanion Raf. is a very perplexing genus, and it is very doubtful if the many species proposed by J. G. Smith can be upheld. It is evident that *S. longifolium* and *S. brevifolium* are but local forms of one species, depending on the amount of moisture. As this species is the only one found anywhere near the type locality of

S. elymoides Raf., I think that the latter name should supplant the other two. *S. lanceolatum* J. G. Smith from Montana and *S. marginatum* Scribn. & Merrill from Wyoming are the two species of the range best differentiated and seem to connect the genus with *Elymus*. *S. insulare* was described from northeastern Utah, and *S. ciliatum* has been collected in Wyoming.

ARACEAE

This family is omitted altogether in the New Manual, although *Acorus Calamus* is recorded in my Flora of Colorado and *Lysichiton camtschatcense* (L.) Schott in my Flora of Montana. The former has also been collected in Montana by Butler.

LEMNACEAE

Lemna perpusilla Torr. is included by Nelson in his Manual with the remarks: "Frequent; northern Wyoming to New York." So far as I know this is wholly an eastern species. Specimens so labeled from the Rockies, which have come under my observation, are *L. minor*, *L. minima*, or *L. cyclostasa*, which all have been confused with it.

COMMELINACEAE

Professor Nelson admits two species of *Tradescantia* and gives the following key:

Freely branched; filaments folded; ovary pubescent in riblike lines.	1. *T. laramiensis.*
Simple; filaments straight; ovary pubescent at the apex.	2. *T. occidentalis.*

If these characters hold, as to separating the two species known to Professor Nelson, the second one is not *T. occidentalis*, for the specimen designated by Dr. Britton as the type of *Tradescantia virginica occidentalis*, viz., *Rydberg 1380*, from Thedford, Nebraska, has a branched stem and an ovary pubescent not only at the apex but almost to the base. It is not exactly like the type of *T. laramiensis*, however, for the lateral branches are shorter than the stem proper, the sepals are broader, the leaves broader, and the plant more glandular. In *T. laramiensis* the lateral branches about equal the stem, giving the plant a flat top. If these are specific characters, I do not know. If the two species of the New Manual are distinct, the second one should bear the name *T. universitatis* Cockerell, for it was this form that Professor Cockerell described.

Under the second species is given the following synonym and remark: "(*T. scopulorum* Rose, Contr. U. S. Nat. Herb. 5: 205. 1899, as to the specimens from Colorado and northward)." This would have been correct if the word "mainly" had been inserted, for I have seen at least one specimen from Colorado that I refer without hesitation to *T. scopulorum*.* The latter differs from the other species of the region by its glabrous or nearly glabrous sepals, its smaller petals, only 10 mm. long, and its subglobose capsule. There is also another species, which should have been included, viz., *T. bracteata* Small, the type of which was from the Black Hills.

MELANTHACEAE

Tofieldia occidentalis S. Wats. has been collected in Idaho; *T. coccinea* Richards. in the Canadian Rockies; *Stenanthella occidentalis* and *Veratrum Eschscholtzianum* in Montana and Idaho.

To me both *Zygadenus dilatatus* Greene and *Z. alpinus* Blankinship seem to be but synonyms of *Z. elegans* Pursh or *Anticlea elegans* Rydb. *Anticlea porrifolia* (Greene) Rydberg (*Zygadenus porrifolius* Greene) was collected last summer in southeastern Utah. So also an undescribed species:

✓ **Anticlea vaginata** sp. nov.

Perennial, growing in big clumps; cormlike rootstock fully 2 cm. thick; stem 7–10 dm. high, at the base covered with numerous scarious sheaths; leaf blades linear, 3–7 dm. long, 6–10 mm. wide, with numerous veins; inflorescence paniculate, branched; lower bracts linear or subulate, 3–6 cm. long, green, the upper ones ovate, 5–10 mm. long, white; pedicels 5–10 mm. long, often recurved; petals and sepals white, elliptic, obtuse, 7–8 mm. long, usually 7-nerved, the former sometimes a little longer than the latter; filaments linear-subulate, broad at the base, white, slightly shorter than the sepals; anthers nearly round; styles slightly exceeding the perianth, curved.

This differs from the other species of *Anticlea* in its habit of growing in big clumps, and in its numerous loose sheaths at the base of the stem. In the perianth segments it resembles *A. coloradensis*, and *A. porrifolia* in the few veins, the segments are smaller than in the former and broader than in the latter. It resembles

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* Garrett and myself collected it also in southeastern Utah last summer.

also *A. porrifolia* in the branched inflorescence but has shorter pedicels and broader leaves. *A. vaginata* grew in loose rich soil under overhanging canyon walls.

UTAH: Armstrong Canyon, near the Natural Bridges, August 4–6, 1911, *Rydberg & Garrett 9407* (type in herb. N. Y. Bot. Gard.).

Professor Nelson gives *Zygadenus gramineus* Rydb. as a synonym of *Z. venenosus* S. Wats. It is evidently *Z. gramineus* he described, although some modification was made. *Z. venenosus* is not found in Wyoming, the most eastern stations known are in the Snake River Valley of western Idaho. It is characterized by the long-clawed petals and sepals and the thick gland. Professor Piper, some years ago, criticized me for redescribing *Z. venenosus*. I think he referred to *Z. intermedius* Rydb. After some arguments on both sides he said that he would look up Watson's type. I do not know that he did, but evidently he came to the same conclusion as I, for in his Flora of Washington* he limited the range of *Z. venenosus* to "British Columbia to California" and hence excluded the Rockies. I have also been criticized for the same thing by Mr. M. E. Jones. Mr. Jones† remarked: "Part of his type of *Zygadenus intermedius* is my No. 2091 from Farmington, Utah. These specimens have no distinct sheath to any of the leaves, except the basal ones. . . . This is a fair sample of Rydberg's accuracy in dealing with *Zygadenus*. . . ." Turning to my original paper,‡ one may see that *J. H. Sandberg 10564* is expressly designated as the type and not *Jones 2091*, which I included in the species. I do not know what Mr. Jones' own specimens show, but there are two of Jones' specimens from Farmington distributed under the number *2091* in the Columbia University herbarium and in these even the upper leaves show short sheaths. One leaf attached near the middle of the stem shows a sheath 1.5 cm. long. I do not think that the presence or absence of a sheath on the upper part is a specific character, but this as well as the citing of a wrong type shows that Mr. Jones is not more accurate than I am.

For my part, I think that *Z. gramineus* can not be upheld as a

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* Contr. U. S. Nat. Herb. 11: 198. 1906.

† Contr. West. Bot. 12: 77. 26 Mr 1908.

‡ Bull. Torrey Club 27: 536. 1900.

species distinct from *Z. intermedius*, being a dry hill state of the same with smaller flowers and narrower leaves. *Z. falcatus* Rydb., which Nelson reduced to a synonym, I think is perfectly distinct and nearer related to *Z. paniculatus*. It is what has been known as *Z. Nuttallii* from Colorado. The latter is not found in the range and should have been excluded.

I have here used the name *Zygadenus*, as the species were first described under that name. I have shown that this name belongs to *Z. glaberrimus* and that the plants here discussed should be known as *Toxicoscordion*.

JUNCACEAE

The following species of *Juncus* are found in the Rockies: *Juncus uncialis* Greene, *J. Jonesii* Rydb., *J. Regelii* Buch., *J. Tracyi* Rydb., and *J. mexicanus* in Utah; *J. columbianus* Coville and *J. Regelii* Buch. in Montana; and *J. arizonicus* in Colorado. Professor Nelson includes Colorado in the range of *J. ensifolius* Wikstr. I have seen no specimens of it from that state. The best character, beside the difference in the number of stamens, by which one can distinguish this from *J. saximontanus*, is that the scarious margin of the leaf sheaths in the latter ends in a small auricle, while in *J. ensifolius* the margin gradually diminishes and disappears in the blade.

ALLIACEAE

DIPTEROSTEMON gen. nov.

Plants with fibrous-coated bulbs, few basal elongated narrow leaves and naked scapes. Flowers in subcapitate umbels; bracts 3–5, membranous, colored, usually purple; perianth funnelform or campanulate, purple; segments united about half their length; lobes elliptic, ascending; stamens six; filaments subulate, adnate to the tube, becoming distinct at the throat; those opposite the sepals naked; those opposite the petals at the base with two lanceolate wings or lobes, surpassing the anthers; anthers basifixed; capsule ovate, 3-locular; cells many-seeded.

Some of the species formerly included in *Brodiaea* and lately in *Dichelostemma* differ from the rest enough, I think, to deserve generic rank. The type of *Brodiaea* is *B. grandiflora* Smith. This is the same as *Hookera coronaria* Salisb., published a few months earlier. As the latter is the type of *Hookera*, *Brodiaea* becomes a pure synonym. Dr. Greene,* who was the first to segregate into genera the members of *Brodiaea* taken in the sense of Dr. Watson, retains both genera. Evidently he regarded Smith's second species, *Brodiaea congesta*, as the type. This can scarcely be done, as *B. grandiflora* is not only the first species, but it is more extensively described and discussed. Greene himself afterwards discarded *Brodiaea* and adopted *Dichelostemma*, proposed by Kunth on *Brodiaea congesta* Smith. Alphonso Wood had extended Kunth's genus to include also *B. capitata* Benth. and *B. volubilis* Baker (*Stropholirion californicum* Torr.). Wood was followed by Greene in including these species in the genus. *Stropholirion* has been generally recognized as a genus, even by S. Watson. The typical species of *Dichelostemma*, i. e., *D. congesta* (Smith) Kunth and its relative *D. multiflora* (Benth.) Heller, have only 3 stamens alternating with 3 staminodia and differ from the typical species of *Hookera* only in the rounded base of the perianth and the subcapitate inflorescence. If they are kept distinct then *Seubertia* should be regarded distinct from *Triteleia*. *Brodiaea capitata* has 6 fertile stamens with subulate filaments. At the base of each of the inner three there are two lanceolate lobes partly adnate to the perianth, forming together a crown of 6 instead of 3 members. To the new genus proposed here, belong:

Dipterostemon capitatus (Benth.)

Brodiaea capitata Benth. Pl. Hartw. 339. 1857.

Dipterostemon pauciflorus (Torr.)

Brodiaea capitata pauciflora Torr. Bot. Mex. Bound. Surv. 218. 1859.

Dipterostemon insularis (Greene)

Brodiaea insularis Greene, Bull. Calif. Acad. Sci. **2**: 134. 1887.

Dipterostemon pulchellus (Salisb.)

Hookera pulchella Salisb. Parad. **2**: *pl. 117*. 1808.

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* Bull. Calif. Acad. Sci. **2**: 125–144. 1886.

Sexual fusions and spore development of the flax rust

FRED D. FROMME

(WITH PLATES 8 AND 9)

The variations found in different species of rusts so far investigated as to their sexuality, have made evident the desirability of further investigating a large number of forms, if we are to arrive at a definite understanding of the sexual processes in the Uredineae in general. From this standpoint I have taken up the study of the flax rust, *Melampsora Lini* (Pers.) Desm. The caeoma type of aecidium has in all cases proved favorable for the study of sexual fusions. The flax rust is no exception in this respect, and the abundance of the fusion stages in my material leaves little to be desired. Dr. E. W. Olive suggested the problem to me, and the results here recorded were largely worked out under his direction at Brookings, S. Dak.

A summary of the literature prior to 1908 has been given by Olive ('08) and still more recently by Maire ('11), so that the later papers only will be discussed here. While the sexual nature of the fusions in the rusts may be regarded as definitely established, the morphological character of the two cells involved and the phylogenetic significance of the process are still points of contention. Two more or less distinct types of fusion have been recognized. (1) A "partial cell fusion" where fertilization is effected by the migration of the nucleus of a vegetative cell into a special "fertile cell," as found by Blackman in *Phragmidium violaceum*. (2) A complete cell fusion between equal gametes, as figured by Christman in *Phragmidium speciosum* and suggested for *Uromyces Caladii* and *Caeoma nitens*. This type of fusion was later substantiated by Blackman in *Melampsora Rostrupi*, and by Olive in *Triphragmium Ulmariae* and *Gymnoconia interstitialis* (*Caeoma nitens*). Both of these processes Blackman considers as reduced types of fertilization that have supplanted a true fertilization, in which the spermatia functioned as male cells and the "sterile cells" above the "fertile" or female cells as trichogynes. On this view the Uredineae are derived from the red algae. Christman considers the "fusion of equal gametes" as a true fertilization in which a "non-resting zygospore" is produced. He suggests that the nuclear migrations of Blackman may be pathological in nature like similar migrations observed by him in the teleutosorus of *Puccinia Podophylli.* The sterile cells are merely "buffers" and the spermatia may be degenerate gametophytic conidia. Christman has also found a fusion of equal cells in the formation of the primary uredospores in *Phragmidium Potentillae-canadensis*, thus showing the morphological equivalence between the primary uredospores and aecidiospores.

Olive, in his 1908 paper, described a further series of forms: *Triphragmium Ulmariae*, *Gymnoconia interstitialis* (*Caeoma nitens*), *Phragmidium Potentillae-canadensis* and the microform *Puccinia transformans.* He also studied nuclear divisions in three other species: *Uromyces Scirpi*, *Uromyces Lilii*, and *Puccinia Cirsii-lanceolati. Triphragmium Ulmariae* has a crustlike primary uredosorus very similar to that of *Phragmidium Potentillae-canadensis*, studied by Christman. In this form Olive finds numerous cases of wide open cell fusions of the type described by Christman. The fusion pores, however, may be of varying diameters. In most cases they are broad, the intervening cell walls being entirely absorbed, but occasionally the pore is narrow so that the nucleus is constricted somewhat in passing. He found no cases, however, where the nucleus is drawn out in a fine thread in passing through an imperceptible pore as figured by Blackman. He further observed, that although the fusing cells may be placed side by side in the same plane, as Christman found them, one of the gametes is perhaps more often found to lie somewhat below the other. In such instances only the upper of the fusing cells appears to have cut off a sterile cell. When the two gametes are not in direct contact a very short conjugation tube may apparently be formed (*fig. 26*). In all cases figured in *Triphragmium*, only one of the fusing cells enlarges and becomes the basal cell. This method of forming the basal cell is quite different from that described by Christman for *Phragmidium Potentillae-canadensis*, where the fusing cells combine to form the basal cell.

The subsequent budding off of the primary uredospores in a fashion similar to that described by Christman confirms his evidence that the primary uredospores and aecidiospores are morphologically equivalent. Although Christman did not find the fusion stages in *Caeoma nitens*, his material being rather old, Olive figures two cases (*fig. 35* and *36*) for this form, where the fusion occurs between cells placed adjacent and parallel, similar to Christman's figures of *Phragmidium speciosum* but without showing sterile cells. He also figures a third case where the nucleus of one cell is passing into a cell placed immediately above it but belonging to a distinct hypha. This as he points out is very similar in appearance to Blackman's ('04) *fig. 66* and *68*. *Fig. 34* and *36* were drawn from the same section and were but a short distance apart. This instance, in conjunction with his observations on *Triphragmium*, convince him that Blackman's "nuclear migrations" and Christman's "fusion of equal gametes" may occur in the same rust and in the same pustule. Sexual fusions may begin through a pore which is narrow at first so that the nucleus is constricted in passing. Later this pore may broaden and the entire contents of the two cells fuse. He would distinguish between such cases and cases of undoubted pathological migrations such as he finds between the multinucleated cells of the aecidium of *Puccinia Cirsii-lanceolati*. In the typical microform, *Puccinia transformans* on *Tecoma stans*, fusion is shown in the teleutosorus between the end cells of two hyphae in one instance, while in another the end cell of one is fusing with the penultimate cell of the other. The fusions here are immediately followed by growth which results in teleutospores borne on several binucleated cells. The sporophyte generation in this case consists, then, of only a few, three or four, cells. In *Uromyces Scirpi* and *Puccinia Cirsii-lanceolati*, as well as in some eight other species, he found one or more large multinucleated cells at the base of the young aecidium cups. He is inclined to interpret these as sporophytic cells in which nuclear division has proceeded faster than cell division, due possibly to the stimulus to growth derived from the sexual act. He suggests the possibility that the solution of the problem as to the development of the aecidium cup with its peridium and apparent centralized structure may be found in these multinucleated cells. Especially striking were the cases found in *Puccinia Cirsii-lanceolati.* Fifteen nuclei in a single cell were figured in one instance. From his study of *Triphragmium* and other forms, Olive concludes that only one of the gametes ordinarily bears a sterile cell and that one gamete generally lies somewhat below the other. This leads him to believe that the two gametes differ somewhat in the time of their development. The first hyphae to form the upright layer under the epidermis do not fuse among themselves but cut off sterile cells and are fertilized by the tip cells of hyphae that push up later from below. Olive does not differentiate these cells as "fertile and vegetative," as Blackman has done, but believes they are entirely equal in size and contents and differ only in time of development. He agrees with Christman that the sterile cells are merely "buffers" and cannot be considered phylogenetically as trichogynes.

In two shorter articles, published earlier in the same year ('08), Olive calls attention to the similarity between the multinucleated cells, which he found at the base of a number of young aecidium cups, and the archicarps of De Bary, Massee, and Richards. He thinks it quite probable that the basal cells of the aecidium are the ultimate branches of these multinucleated cells. The cup type of aecidium was probably derived from the more simple caeoma type. He has found as many as six nuclei in a fusion cell of the caeoma type, due probably to nuclear division proceeding faster than cell division, and points out that a still further development of such a cell coupled with partial suppression of other neighboring cell-fusions, especially in a deep lying caeoma, might give rise to the cupshaped type of aecidium.

Kurssanow ('10) reinvestigated *Puccinia Peckiana* (*Caeoma nitens* of Christman and *Gymnoconia interstitialis* of Olive). He agrees with Christman in all essentials. The conjugation is between entirely similar gametes. Sterile cells are normally formed from both conjugate cells, but these have degenerated or have been lifted off by the rupture of the epidermis before the time of fusion. These are mere "buffer" cells and cannot be interpreted as trichogynes. Kurssanow does not accept Olive's attempt to harmonize the observations of Blackman and Christman. Either the two methods of conjugation are limited to the different forms studied, or Blackman's "partial cell fusions" must be regarded as pathological in nature. Kurssanow has also observed undoubted pathological migrations in his material aside from the normal conjugations.

Maire ('11) has reviewed the numerous problems in the study of the Uredineae and given a résumé of our present knowledge of the cytology of the group. He regards the sexual fusions as well established for forms possessing an aecidium. In reexamining his preparations of *Puccinia Bunii*, an opsis form, he has been able to find the isogamous fusion of two cells to bring about the formation of the primary "synkaryocyte" but is not able to see the stages clearly. He does not regard the question of the isogamous or heterogamous nature of the fusion as of great importance and thinks cases may be found of the union of sister cells or even confirmation of the method of forming a binucleated cell originally described by Sappin-Trouffy and later by Maire, in the microform, *Puccinia Liliacearum*. Maire holds that the present sexual fusions have replaced a primitive sexuality analogous to that in the red algae, in which the spermatia functioned as male cells. The interpretation of the sterile cell as a trichogyne he considers as extremely hypothetical. He holds that the Uredineae and the Basidiomycetes have a common origin, but the latter have perhaps lost all trace of sexuality. He favors the view that the primitive rust forms had spermatia and teleutospores only, and that the aecidiospores and uredospores have been intercalated in the life history to provide for rapid distribution.

Olive, in a recent paper ('11), has also discussed the character of the primitive rusts and the origin of heteroecism. He also holds to the theory that the more complex types were derived from the simpler lepto- and microforms by a progressive development of the sporophyte. This is substantiated by analogy with the higher plants. The primitive forms were probably autoecious. The alternation of hosts was made possible by the production of aecidiospores which are invigorated by the stimulus derived from the sexual act and therefore better able to make the transition to a new host than the uninucleated sporidia. This would mean that the present hosts of the gametophytic stage of the rusts (aecidium), of the heteroecious forms, were the hosts of the original autoecious ancestors. The prevalence of heteroecious forms with pleophagous sporophytes and the fewness and evident close relationship of the hosts of the aecidial stages in these cases, as well as the multiplicity and remote relationship of the hosts of the sporophyte, support this conclusion.

Melampsora Lini is quite abundant on cultivated flax, *Linum usitatissimum*, in the vicinity of Brookings, S. Dak. A considerable quantity of rusted flax straw was collected in the fall of 1910 and was exposed during the winter in a cloth bag suspended from a window. In the spring a small plot was sown to flax and the rusted straw scattered over the plot. This was watered frequently and numerous infections were obtained, the sori appearing when the young plants were about five inches high. These sori are quite small and it is difficult to distinguish spermogonia from aecidia. Small portions of the leaves and stems were fixed in Flemming's medium fixing solution, imbedded, sectioned, and stained with Flemming's triple stain and Bendas' iron haematoxylin. Sections of the uredo- and teleutosori were kindly furnished me by Dr. Olive from material previously prepared by him.

Melampsora Lini is an autoecious eu-form, i. e., the complete series of spore forms, spermatia, aecidia, uredo, and teleuto, are all borne upon the common host, flax. The aecidium is of the caeoma type, which has been found most favorable for the study of cell fusions, and the teleutospores show the nuclear fusions very clearly.

SPERMOGONIA

These are rather inconspicuous in color and occur on both sides of the leaves and occasionally on the stems. They are produced only by infections with sporidia. They are typically flaskshaped, without ostiolar filaments and are placed subepidermally. Sometimes the spermogonium is merely a diffuse layer of spermatiophores without a definite flasklike structure. Several of these spermogonia may occur in the same localized area but they are seldom confluent. Their frequent close association with the aecidia will be discussed in connection with the development of the aecidium. The spermatiophores from which the spermatia are abstricted arise from large rectangular cells which are arranged in a regular series at the base of the spermogonium. The spermatiophores differ from those described by Blackman in that they are divided into a number of uninucleated cells, usually four, each of which puts out a fingerlike process from its upper end on the tip of which a single spermatium is produced. See FIG. 1 and 2. The spermatiophores of *Gymnosporangium clavariaeforme* and *Phragmidium violaceum*, as described by Blackman, are single elongated, uninucleated cells. The single nucleus divides successively to form the nuclei for a number of spermatia which are abstricted from the elongated fingerlike tip of the spermatiophore. FIG. 4 shows two spermatia fully formed while a nucleus still remains in the base of each cell. This seems to indicate that two or more generations of sporidia are produced from the same cell of the spermatiophore.

AECIDIUM

The aecidium arises from a uninucleated mycelium, which in the vegetative condition cannot be distinguished in any way from that which produces spermogonia. It is confined chiefly to the intercellular spaces of the host. The nuclei at this stage are rather small but exhibit a clearly defined chromatin network and a definite nucleole. After a period of vegetative development the filaments grow up between the cells of the mesophyll and reach the epidermis. Here they branch laterally to form a weft of hyphae. The branches next push up vertically and form a sort of palisade of large cells which contain very large nuclei and more compact cytoplasm than the ordinary vegetative cells. See FIG. 5. Each cell now divides somewhat unequally, producing a smaller cell above, which again divides so that two smaller cells are formed above a single larger cell. See FIG. 5. The larger cells are the future gametes and at this stage form a rather even dense layer below the two sterile cells. The shape of the sterile cells is determined by the pressure of the epidermis and that of the surrounding cells. When they press directly against the epidermal cells they are flattened laterally and the upper cell conforms to the outline of the overlying epidermal cell. At other points where the pressure is not so direct they may be somewhat elongated. In either case they soon become vacuolate and disappear usually by the time of sexual fusions. These are the "buffer" cells of Christman, and we see that they are here in two layers instead of a single layer as he found in *Phragmidium speciosum.* The entire sorus at this time is a group of vertically placed hyphal branches without pseudoperidium or paraphyses. It cannot be considered as a unit in any proper sense but rather as a collection of reproductive units. The development of the sorus proceeds in a more or less centrifugal fashion, the older branches being found at the center while the younger are at the outer borders of the group. The various stages in the degeneration of the sterile cells are well seen in passing from the outer borders toward the center. Christman's interpretation of these sterile cells as "buffers" seems entirely adequate, as their function is evidently a protective one. They relieve the pressure of the epidermis on the underlying reproductive cells and then degenerate to provide room for the subsequent development of the latter. As noted, in all the forms so far investigated only one layer of sterile cells has been observed, while in *Melampsora Lini* two layers of sterile cells are normally produced. In his investigation of *Melampsora Rostrupi*, Blackman occasionally found a double layer of short crushed cells lying above the fused cells, but owing to the age of his material he did not note the method of their formation. In view of the facts above described it seems quite reasonable to assume that Blackman's observation shows that a similar condition is found in *M. Rostrupi.* It is possible that all the Melampsoras develop their gametes at a deeper point in the sorus than the more superficial caeomas of the *Phragmidium* type.

The frequent intimate association between the spermogonia and aecidia, referred to above, is an interesting feature of the flax rust. In rusts bearing both spermogonia and aecidia the former usually precedes the latter in time of development by a period of several days or weeks. In this form, however, a marked difference in time of development does not exist. In general the spermogonia appear somewhat earlier than the aecidia, but they are often found developing simultaneously and intimately associated. Spermogonia may bound the aecidium on either side or may even be included in it. It is very difficult to trace the origin of the mycelium from which the two sori arise on account of the interweaving of the hyphae, but there is no sharp boundary between the two and they cannot be distinguished in the vegetative condition. It seems quite probable that they arise from common points and that branches from the same mycelium may form both kinds of sori. The aecidium and spermogonium are frequently separated only by the outer sterile layers of the spermogonium. Their development proceeds simultaneously, spermatia and aecidiospores being formed at the same time and often found lying in the same cavity under the epidermis. Sometimes the spermatia are already present when the aecidium has just reached the stage of sexual fusions. One of the difficulties in assuming that the spermatia are male cells has been the inaccessibility of the cells of the aecidium to fertilization by them and the production of the spermatia prior to the development of the aecidium. Here we have a case, however, where the two develop at the same time, and so near together that fertilization might easily be accomplished.

The large vertical cells of the aecidium now begin to conjugate in pairs. This conjugation is brought about by an absorption of the intervening cell walls at the area of contact. The upper portions of the cells involved are usually in contact so that the absorption takes place in this region. See FIG. 7. The lower portions of the cell walls are usually not absorbed and the fusion cells formed remain with a conspicuous two-legged base. At the time of fusion the cytoplasm of the gametes is quite dense and stains readily, consequently they stand out quite sharply differentiated from the vegetative cells below, which have lost most of their contents. They can readily be distinguished under the low powers of the microscope without the aid of the oil immersion. Sometimes the tips of the gametes converge and the point of contact and absorption is at the center, as in FIG. 8. The area absorbed may be of varying diameters, as Olive holds, but the passage of a nucleus through an imperceptible pore has never been observed in the case of the true fertilizations. Certain cases of nuclear migrations which are apparently of an abnormal nature, will be referred to later. The fusing gametes do not always lie side by side at the same level in the sorus. They may meet at various angles, and frequently one of them lies somewhat below the other. See FIG. 9. I do not believe, however, that in *Melampsora Lini* this indicates a difference in the time of development of the gametes, as Olive finds for *Triphragmium Ulmariae*. In the early stages of the sorus the gametes are not always placed in an even parallel layer but may vary in elevation. The irregularities due to the loose indefinite nature of the caeoma quite fully account for the unequal position of the gametes. The presence or absence of sterile cells at the time of fusion, again does not seem a good criterion for determining the relative age of the two gametes. I have observed several cases where both gametes at the time of fusion still have two sterile cells intact. See FIG. 10. As I have pointed out, however, these sterile cells have usually disappeared at the time of fusion.

The abundance of sexual fusions in *Melampsora Lini* is most striking. The sexual fusions figured by earlier students have been scattered and disconnected and apparently only occasionally found. In my material I have sections showing practically every pair of gametes in the sorus in some stage of fusion. These stages are so abundant that there can remain no doubt whatever that the binucleated condition in this form is always instituted by means of a cell fusion between entirely equivalent gametes. FIG. 11 shows a collection of "fusion cells" that were especially well situated for drawing. A triple cell fusion is shown in the center of the group with three ordinary fusions on either side. The "fusion cells" are rather old here, one or more aecidiospores having been produced in most cases, but the double "basal cells" still show the original fusions distinctly. FIG. 12 shows another series of cell fusions. The five pairs of gametes in this instance are of about the same age as those shown in FIG. 11. Younger pairs are shown in FIG. 13. The gametes on the left have just completed the fusion while those on the right have cut off the first aecidiospore mother cell. FIG. 14 shows a mature, binucleated aecidiospore with a chain of intercalary cells and young aecidiospores ending in a double cell fusion below. The process by which the chain of spores and intercalary cells are formed has been fully described and need not be taken up here.

As previously mentioned, Olive has figured a somewhat different method of forming the "basal cell," in *Triphragmium Ulmariae*, from that shown by Christman in *Phragmidium Potentillae-canadensis* and *P. speciosum*. As found by Christman, the "basal cell" is formed by the equal enlargement of the two fused cells, and the aecidiospore mother cell lies directly over the fused cells. The cases figured by Olive, on the other hand, show that the nucleus of one gamete passes into the other, and the gamete which is now binucleated elongates and functions directly as the "basal cell." Cases of this nature also occur in *Melampsora Lini.* It will be seen in the fusion shown in FIG. 15 that the gamete on the right has elongated and become the "basal cell" and has cut off the first aecidiospore mother cell. The nucleus of the gamete on the left lies in the opening between the two fused cells. A comparison of this figure with FIG. 13 and 14, which are cases of equal contribution to the "basal cell," will illustrate the difference between these two methods. It is interesting to find both of these methods occurring here in the same rust.

Reference has already been made to a triple cell fusion, shown in FIG. 11, which lies in the center of a group of ordinary cell fusions. There can be no question that the condition there shown has been brought about by the fusion of three gametes instead of two. FIG. 16 shows an early stage of a triple cell fusion. The intervening cell walls are absorbed just as in the case of a double cell fusion, and a "basal cell" is produced which contains the nuclei and cytoplasm of three gametes. FIG. 17 is a case of a triple cell fusion where the three-legged base is especially distinct. These triple fusions are of comparatively frequent occurrence in my material. FIG. 18 (PLATE 9) shows a triple fusion which presents a still further complexity. It will be seen from the figure that two adjoining cells in the same filament on the right have fused with a single cell in another filament on the left. This has also resulted in a trinucleated "basal cell" but differs from the usual triple fusions in that two of the gametes come from the same filament. I have observed several other cases of this nature. It seems, then, that not only a single layer of gametes are produced, in this form, but occasionally another cell placed below the ordinary functional cells also has the capacity for effecting fertilization. The three nuclei thus associated in the same "basal cell" probably divide "conjugately" to produce trinucleated aecidiospores. FIG. 19 shows a trinucleated aecidiospore mother cell which has just been formed by the division of the trinucleated "basal cell" on which it is borne. A later stage is shown in FIG. 20. The trinucleated spore at the top of the chain has cut off a small intercalary cell while the spore mother cell just below is as yet undivided. FIG. 21 shows a mature aecidiospore which contains three nuclei. Such spores are frequently found lying free in the cavity under the epidermis among the ordinary binucleated type. A mature aecidiospore containing six nuclei was also found. See FIG. 22. This condition might have been brought about by the division of three original nuclei without the formation of the intercalary cell.

Cell fusions between four gametes are sometimes found along with the two- and three-celled types but are relatively infrequent. I have observed only three well-defined cases of this nature. Two of these cases are shown in FIG. 23 and 24. The four cells that have participated in the fusion can be seen distinctly, but the cell contents were stained so strongly that the nuclei could not be distinguished.

Still more striking are the large multinucleated spore mother cells which are occasionally found in the aecidium. One of these, FIG. 25, contains eleven nuclei. The cell is being divided by an ingrowing cell wall near the center. The uneven number of nuclei is probably due to the sectioning, but it is impossible to locate it with certainty on the next section. Another of these large structures is shown in FIG. 26. The evident pairing of the eight chromatin masses indicates that a division of four nuclei is just being completed. The base of the cell is indistinct and I am not able to determine its origin. FIG. 27 shows a case of a completed division of a four-nucleated cell forming a distinctly four-nucleated aecidiospore and an intercalary cell in which the nuclei are less distinct but evidently four in number. It seems quite probable that the conditions shown in FIG. 26 and 27 have resulted from an original four-cell fusion. Attention has been called to Olive's observation of large multinucleated cells at the base of certain young aecidium cups especially in *Puccinia Cirsii-lanceolati.* He was inclined to interpret these as sporophytic structures resulting from the greatly stimulated growth following sexual fusions. Whether these are really central organs from which the aecidium develops, has not been established. There is perhaps some similarity between them and the multinucleated cells that I have found.

I have examined my material carefully to determine whether the binucleated condition is ever brought about by the migration of the nucleus of one cell into an adjoining cell, as described by Blackman, and have found no such cases in the fertile layer of the aecidium, or such as could be considered true fertilizations. Occasionally, however, in the vegetative mycelium below the fertile layer of the aecidium, I have found cases that are very similar in appearance to some of Blackman's figures. One of these is illustrated in FIG. 28. The nucleus here is evidently passing through a very small pore in the walls between two adjoining cells and is drawn out in a very fine thread in the passage. The two cells are small, contain but very little cytoplasm, and lie some distance below the surface of an old sorus which has already produced aecidiospores in the regular manner. Another case of migrations of nuclei is shown in FIG. 29. Two nuclei from neighboring vegetative cells are migrating into the same vegetative cell. It does not seem possible to connect any of these cases with the normal process of fertilization in any way, and the interpretation of Christman, Olive, and Kurssanow of similar phenomena as "pathological" seems most natural.

UREDO

The uredosori arise from a binucleated mycelium which results only from infections with aecidiospores. They are found on both sides of the leaves and on the stems. The sori are indefinite in extent, without pseudoperidium or paraphyses except for a few sterile, capitate filaments, which sometimes occur at the outer borders of the sorus and less frequently are interspersed among the spores within the sorus. The uredospores are borne upon long stalks which are made up of two or three elongated cells. See FIG. 30. They are large, ovate to elliptical in form, and contain two nuclei, as do all of the stalk cells upon which they are borne. The walls are thin and finely and evenly verrucose with low papillae and equatorial, rather indistinct germ pores. The sterile filaments, commonly called paraphyses, which are found among the spores, are long and extremely slender and terminate in somewhat irregular knoblike cells, which are usually somewhat larger that the uredospores. The walls are somewhat thicker than those of the uredospores and perhaps a little smoother, although the older ones are roughened like the uredospores. Young paraphyses were found to contain two nuclei at the base of the apical knob. See FIG. 30. The stalks were undivided and very slender and contained but very little cytoplasm. The nuclei evidently degenerate very rapidly, as in the older filaments they have disappeared entirely. Of the cytoplasmic contents only a few shriveled threads remain. The nature of these sterile filaments is perhaps not entirely clear, but the observation that they are binucleated when young suggests that they have a common origin with the functional uredospores.

TELEUTO

The teleutospores appear later in the season than the uredospores and are associated with the ripening of the flax. The sori are found on both sides of the leaves and more frequently on the stems. They are sometimes round and isolated but are more often confluent in long areas, which are reddish brown when young and become quite black when old. The spores are of the elongated one-celled type of the Melampsoras and are cemented together above in a firm, waxy layer. See FIG. 31. They are sessile on the short cubical cells at the base of the sorus, which lose their contents with the development of the teleutospores. The young teleutospores are binucleated but soon become uninucleated through a fusion of the two nuclei into one. Occasionally a secondary layer of teleutospores forms an overgrowth above the first. This is apparently brought about by the growing up of the mycelium around the borders of the primary layer of teleutospores to form a secondary layer of shorter teleutospores above the first.

DISCUSSION

The existence of sexuality in the rusts may be considered as well established for those forms that have the caeoma type of aecidium. The cup type of aecidium, however, needs much further study, though Christman's figure for *Uromyces Caladii* shows that the fusions there are probably essentially similar to those in the caeoma type, and Olive's multinucleated cells may be correlated with the more definite form and structure of the cup. The double layer of sterile cells in *Melampsora Lini* may possibly be comparable to the pseudoparenchyma of an aecidium cup and indicate a transition between the more superficial caeoma and the deeper cup type of aecidium. The evidence seems to point to the conclusion that the short-cycled micro- and leptoforms are the more primitive and that such a form as the flax rust with its five spore forms is more highly specialized. It is interesting to note that the less differentiated caeoma type of aecidium can persist in these higher types of rusts.

As to the relationships of the Uredineae with other fungi or algae, the preponderance of evidence at present seems to favor the view that the present sexual fusions are a substitute for a more primitive type in which the spermatia functioned as male cells. The existing sexual processes are certainly of a zygosporic character. The conjugation is betwen two entirely similar cells, which participate equally in the formation of a double cell from which a series of spores are produced. This is of course no proof that the primitive form of sexuality was zygosporic. Blackman, as previously stated, would derive the Uredineae from the red algae. While this connection is as yet doubtful, it is perhaps the most plausible view of the origin of the group.

Although Blackman's observation of a "partial cell fusion" by means of "nuclear migrations" in *Phragmidium violaceum* has never been directly disproved, the indirect evidence shown in the equal cell fusions that have been found in all other aecidia of the caeoma type, so far investigated, leads to the conclusion that this form is somewhat aberrant or that the true fertilization has not been observed. The further observations of "pathological" migrations by other investigators and the existence of very similar migrations between vegetative cells of *Melampsora Lini*, which cannot be regarded as true fertilizations, are striking facts. While the area of absorption between two gametes may be small at first and later broaden, as Olive has shown, there still remains a considerable difference between the passage of a nucleus as a fine thread through an extremely small pore, which cannot be seen before or after the passage, and the passage of a nucleus through a rather small pore which later broadens to permit the entire contents of the two cells to fuse.

The fusions of three and four cells, which are occasionally found in *Melampsora Lini*, are perhaps to be compared with cases of di- or polyspermy in animals. The first beginnings of triple cell fusions are of rather common occurrence in the group of the Conjugatae, but the complete fertile product of such a fusion is at least a rare occurrence. De Bary figures one case in *Zygnema pectinatum* of a completed conjugation between three cells, but the resulting zygospore has not rounded up, as do the zygospores formed by the fusion of two cells, and remains partially distributed in a horseshoe form between the three fused cells. As I have shown, the triple fusions in the flax rust are functional in the production of trinucleated aecidiospores. It would be very interesting to determine whether these spores in turn produce a mycelium with trinucleated cells. Blackman has also observed trinucleated "basal cells," aecidiospore mother cells, and aecidiospores in *Phragmidium violaceum* but did not determine the manner in which this condition is brought about. He observed that the size of these nuclei is usually somewhat less than that of the normal paired nuclei, and suggests that one of the nuclei of a binucleated cell may have divided while the other remained in the resting condition. He also suggests that a migration of two nuclei into one cell would bring about a similar result. In the short-cycled form *Puccinia Malvacearum*, abnormal vegetative cells and teleutospores containing three nuclei were found by Blackman. Triple and even quadruple fusions are certainly to be reckoned with as widespread and fairly common phenomena in the sexual reproduction of the rusts. They show a certain elasticity in the relations of the gametes, which may be further evidence that the sexual process, as at present found, is secondary and highly modified from the primitive condition in the group.

SUMMARY

The spermatia of the flax rust are produced on septate branching spermatiophores, which differ in this respect from the unbranched non-septate spermatiophores described by Blackman for *Phragmidium violaceum* and *Gymnosporangium clavariaeforme.*

This feature may furnish a further basis for use in the classification of the Uredineae.

The fusing cells in the aecidium are entirely similar and form a fairly even series at the base of the sorus. Two short sterile cells are normally formed above each gamete. Their function is evidently protective and they may correspond to the pseudoparenchyma of young aecidium cups. Sexual fusions are very abundant in this form, and many pairs of gametes in various stages of union can be found side by side in the same preparation.

Fusions of three and four cells have also been found in addition to the normal two-cell fusions and are perhaps to be regarded as further evidence that the sexual processes as found in the rusts are of a secondary character. Large multinucleated cells are also present in the same sorus with two-, three-, and four-cell fusions.

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Explanation of plates 8 and 9

PLATE 8

FIG. 1. A branching, septate spermatiophore bearing spermatia on the fingerlike elongations of the cells. × 1,500.

FIG. 2. Another branched spermatiophore. The two upper cells have not as yet produced spermatia. The penultimate cell shows the beginning of the fingerlike outgrowth. × 1,500.

FIG. 3. A septate, unbranched spermatiophore. × 1,500.

FIG. 3a. A spermatium. × 2,250.

FIG. 4. A two-celled spermatiophore bearing spermatia. × 1,500.

FIG. 5. A portion of a young aecidium showing a single layer of larger cells, the gametes, with two layers of short sterile cells above and vegetative mycelium below. The upper sterile cells show conformity to the outline of the overlying epidermis. An early stage of fusion is shown between the second pair of gametes from the right. × 1,000.

FIG. 6. A young pair of gametes more highly magnified. Two short, crushed; sterile cells are present above each gamete. × 1,500.

FIG. 7. Cell fusion between two equal and parallel gametes. The upper portions of the intervening cell walls have been absorbed. × 1,500.

FIG. 8. An early stage in the fusion of two gametes. The absorption is at the center of the two cells, as the tips are not in contact. × 1,000.

FIG. 9. One of the gametes lies somewhat below the other. × 1,000.

FIG. 10. Fusion between two gametes, both of which still have two sterile cells intact. × 1,000.

FIG. 11. A group of seven "fusion cells." A triple cell fusion lies in the center of the group with three double cell fusions on either side. One or more aecidiospores have been produced from most of the "fusion cells." × 750.

FIG. 12. A group of five "fusion cells." × 750.

FIG. 13. A pair of younger "fusion cells." The gametes on the left have just completed the fusion while those on the right have cut off the primary aecidiospore mother cell. × 1,000.

FIG. 14. A mature aecidiospore and a chain of intercalary and spore mother cells which have been cut off from the "basal cell" below. × 750.

FIG. 15. Only one of the gametes functions as the "basal cell." The cell on the right has elongated after the fusion and has cut off the primary aecidiospore mother cell. × 1,000.

FIG. 16. An early stage of a triple cell fusion. × 1,000.

FIG. 17. A completed fusion between the tips of three gametes. × 1,000.

PLATE 9

FIG. 18. Another type of triple cell fusion. Two adjoining cells in the same hypha have fused with a single cell on the left. × 1,000.

FIG. 19. A trinucleated spore mother cell borne on a trinucleated "basal cell," which has been formed by a triple cell fusion. × 1,000.

FIG. 20. A trinucleated "basal cell" which has produced the second aecidiospore mother cell. The primary aecidiospore mother cell has divided to form an aecidiospore and intercalary cell. × 1,000.

FIG. 21. A mature trinucleated aecidiospore. × 1,000.

FIG. 22. A mature aecidiospore containing six nuclei. × 1,500.

FIG. 23. A quadruple cell fusion. The "fusion cell" is stained so heavily that the nuclei are not distinguishable. × 1,000.

FIG. 24. Another quadruple cell fusion. × 1,000.

FIG. 25. A large spore mother cell, of the aecidium, containing eleven nuclei. A cell wall is being formed near the center of the cell. × 1,000.

FIG. 26. A cell containing eight paired chromatin masses indicating that a simultaneous division of four nuclei is just being completed. × 1,500.

FIG. 27. A four-nucleated aecidiospore and intercalary cell. × 1,500.

FIG. 28. Migration of a nucleus through the walls of two adjoining vegetative cells which lie below the fertile layer of an old aecidium. × 1,500.

[The nucleus is not as distinct in the plate as in the original drawing, and the disposition of the cytoplasm has been somewhat changed in the reproduction of the figure on the plate.]

FIG. 29. Migration of two nuclei from two vegetative cells into a third vegetative cell. × 1,500.

FIG. 30. A portion of an uredosorus. The binucleated uredospores are borne on long stalks made up of two or three binucleated cells which arise from binucleated mycelium. Sterile, capitate paraphyses are shown at the outer borders of the group. The knoblike apical cell is somewhat irregular in outline and the stalk is non-septate and very slender. The young paraphyse on the right is binucleated and contains a small amount of cytoplasm while the older one on the left has lost its contents. (Slightly diagrammatic.) × 750.

FIG. 31. A portion of a teleutosorus showing the appressed layer of one-celled teleutospores, the tips of which are imbedded in a waxy substance. The spore on the right is binucleated while the others have become uninucleated through a fusion of the primary nuclei. × 750.

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(1910-1912)

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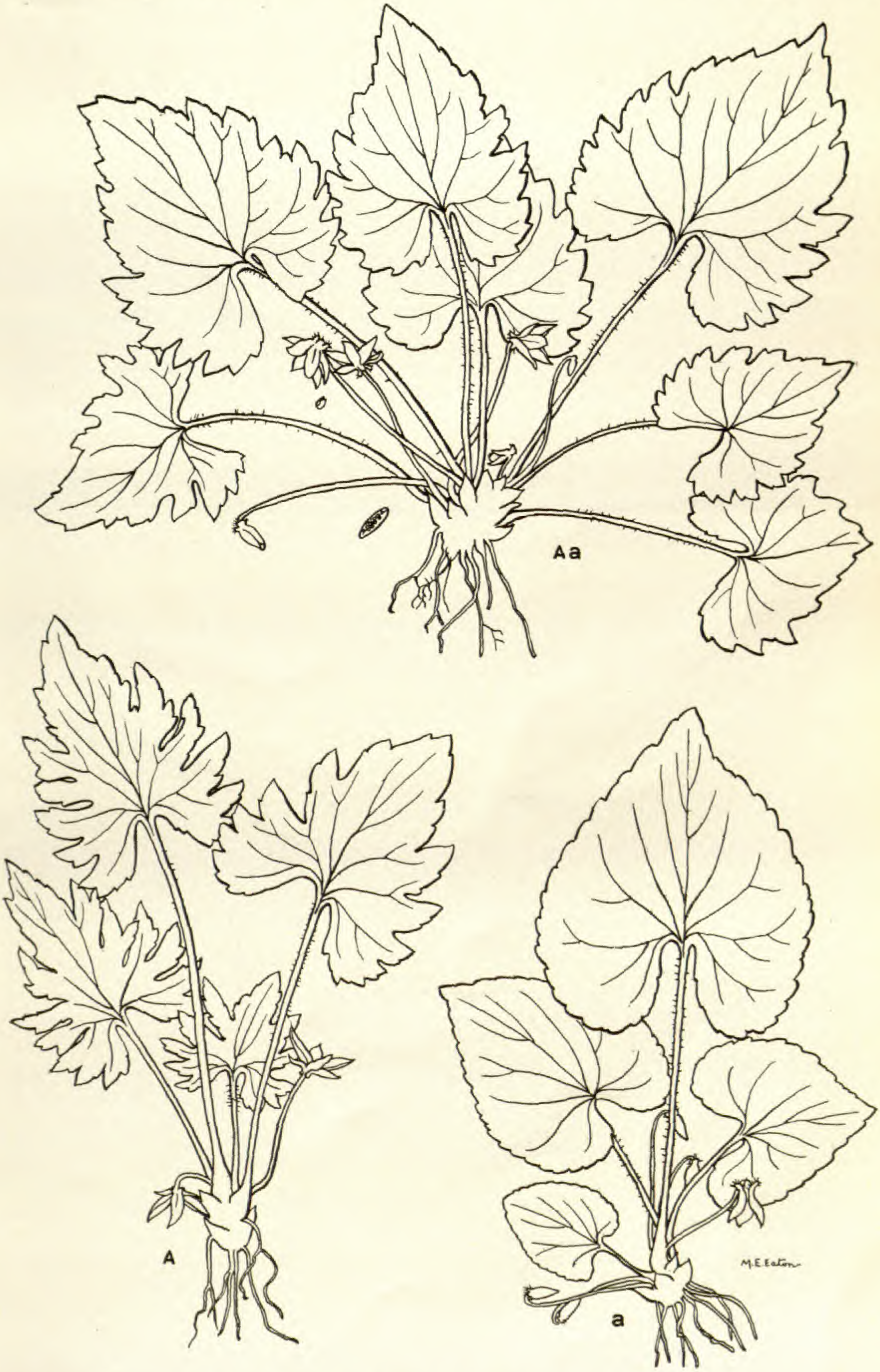

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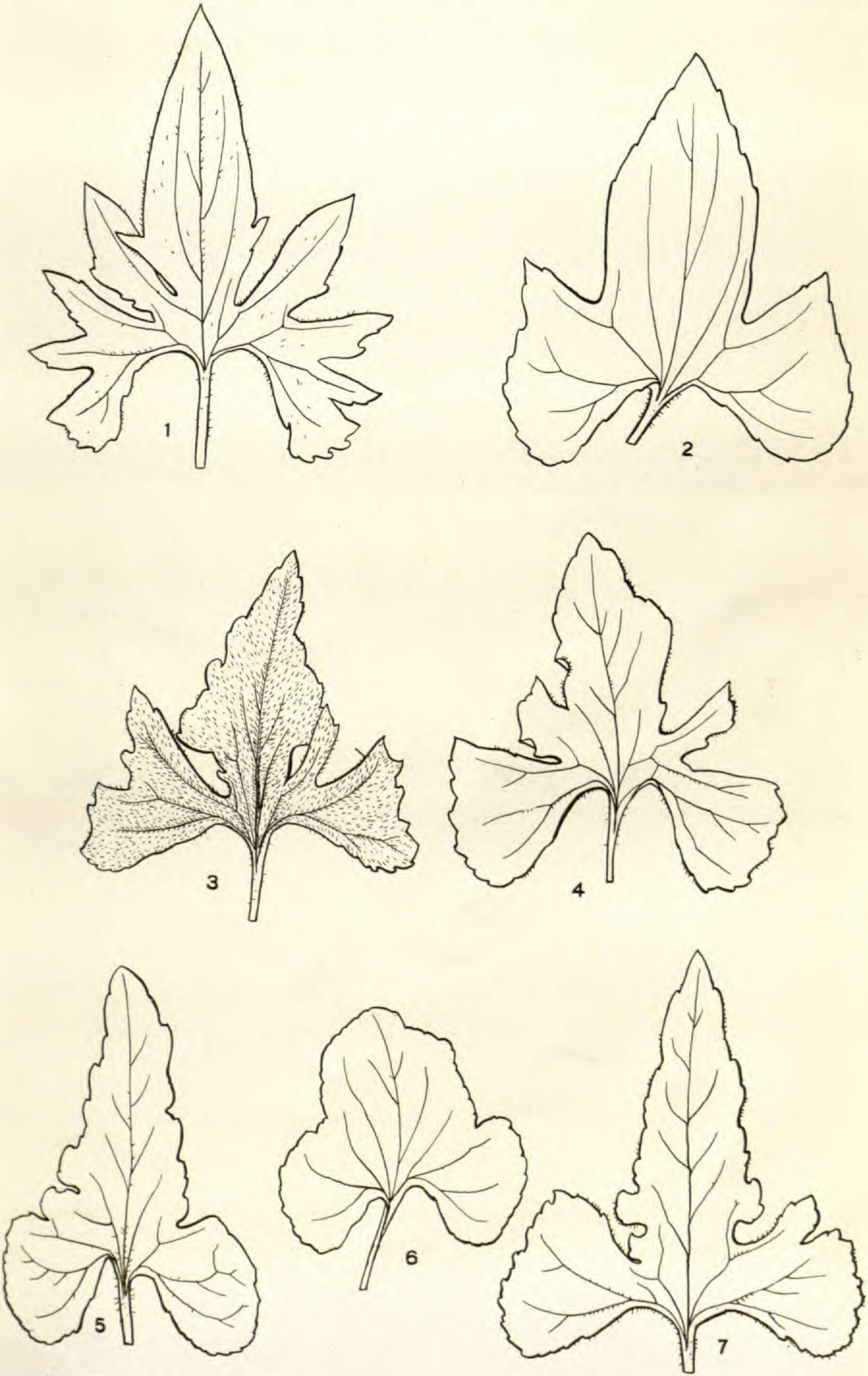

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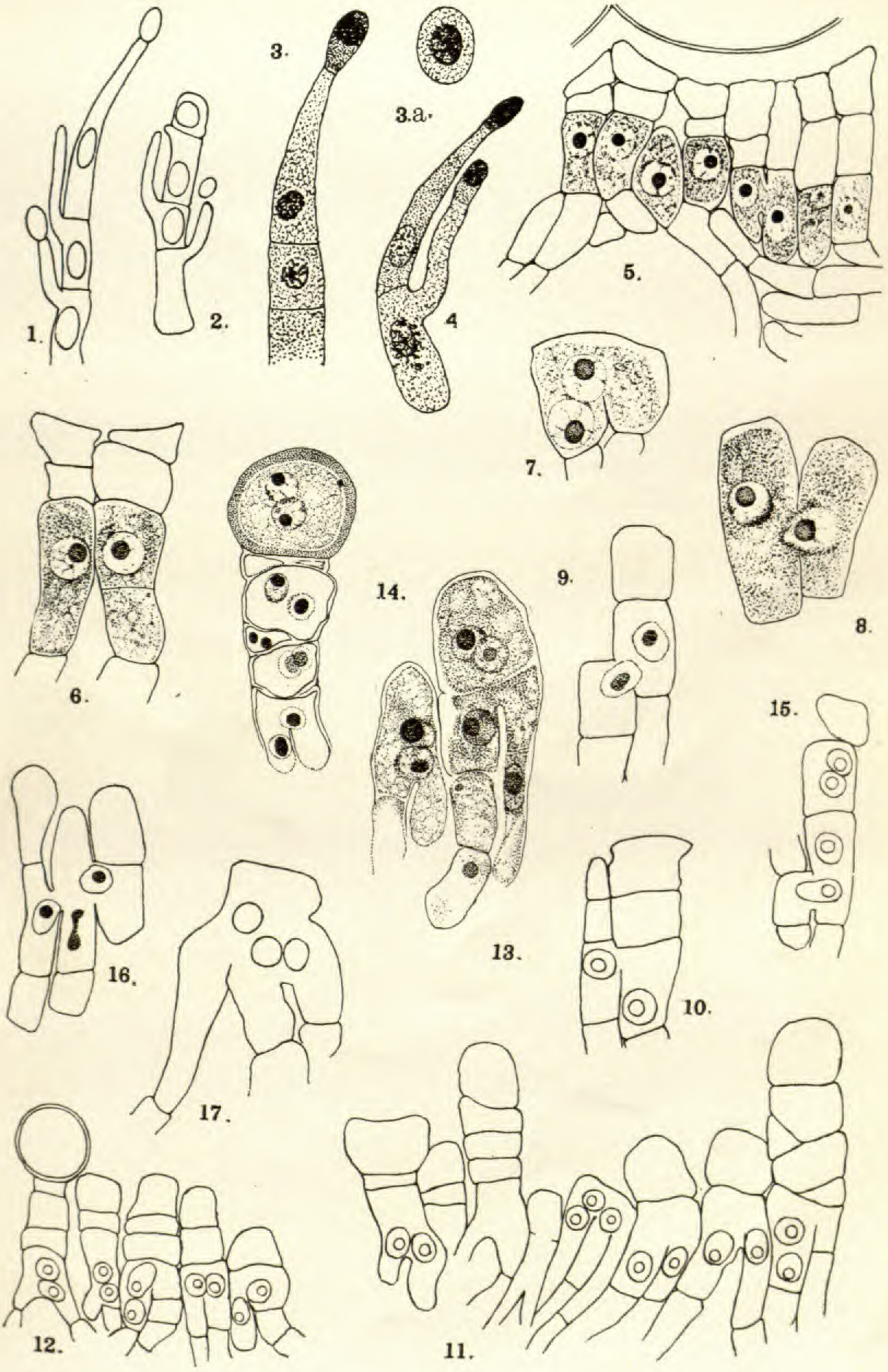

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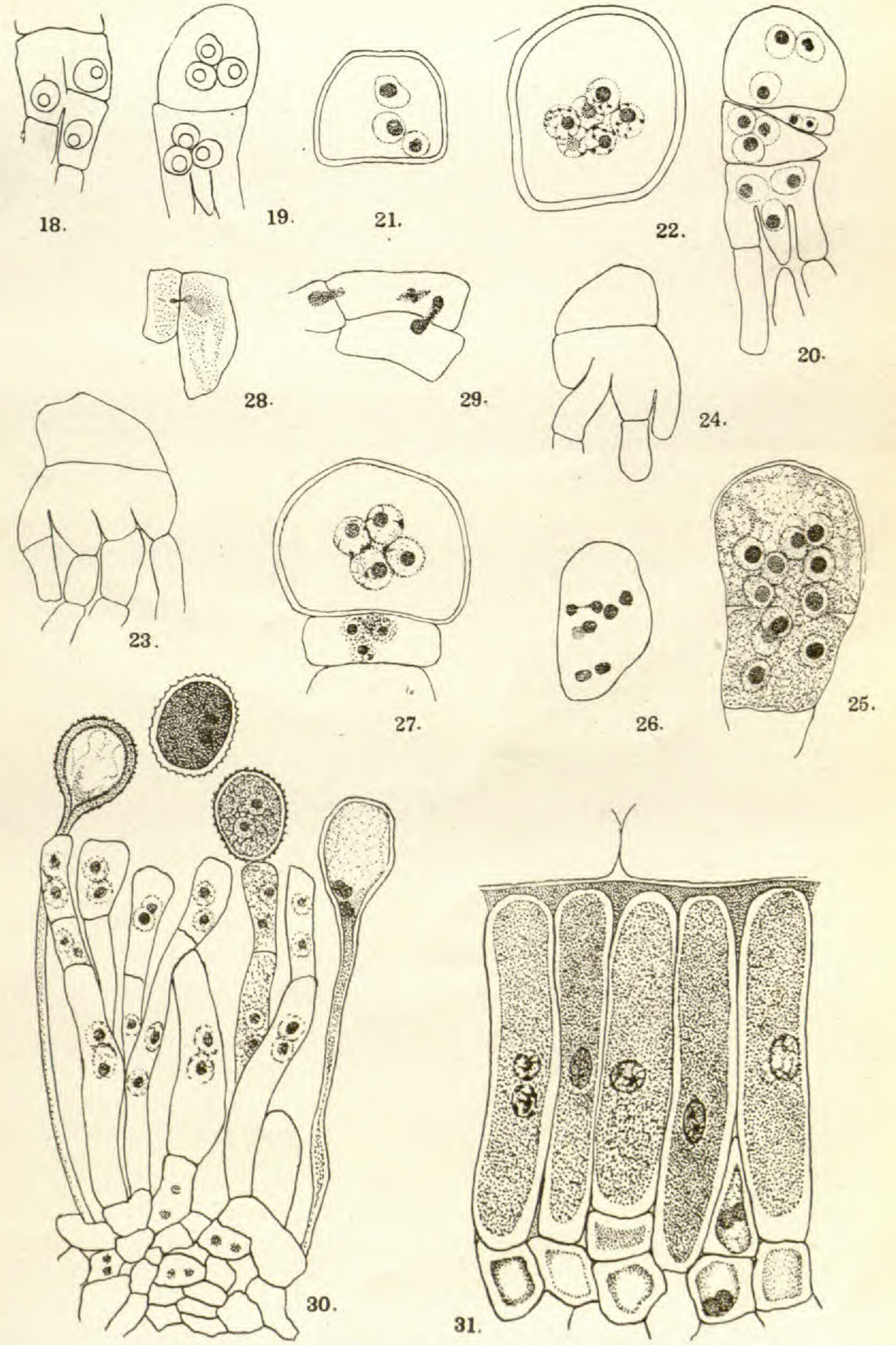

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Methods of culture and the morphology of the archicarp in certain species of the Ascobolaceae

BERNARD O. DODGE

(WITH PLATES 10–15)

INTRODUCTION

The method of origin of the ascocarp in the Ascobolaceae has been an interesting subject of investigation since the days when De Bary and his contemporaries discovered the presence of specially differentiated hyphae, ascogonia, etc., in young fruit bodies of certain Ascomycetes. If the reports of those who have studied the origin of the ascocarp can be accepted, we have in this one family of the Ascobolaceae a wide range of variation. In *Ascodesmis* a cell of the mycelium gives rise to a group of spirally coiled ascogonia (Claussen, 1905). A similar cluster of antheridia arises from the same mycelium and each antheridium becomes twisted about an ascogonium. Fertilization is brought about through the fusion of the one-celled trichogyne with the antheridium. In *Thelebolus*, according to Ramlow (1906), the mycelium gives rise to an ascogonium which is at first one-celled but which later becomes several-celled by the formation of cross walls. The single ascus of the ascocarp arises from the penultimate cell of the ascogonium. Between these two widely different methods of ascocarp formation others have been described which seem to furnish evidence of a gradual loss of sexuality and the assumption of an apogamous or parthenogenetic development.

I have undertaken a general investigation of several species of

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the group, growing them as far as possible in pure cultures, thus making possible a more extended and comparative study of the method of the origin of the ascocarp in the endeavor to furnish further data for an understanding of the relationships existing within and between the various groups of the Ascomycetes.

One obstacle in the way of a more thorough study of the life history of the species of this group has been the great difficulty encountered in all attempts to germinate the ascospores and thus obtain pure cultures in artificial media. I have, therefore, given this phase of the question special attention in my work.

REVIEW OF THE LITERATURE

The literature relating to the question of sexuality in the Ascomycetes has been many times thoroughly reviewed in recent years. I need only refer to the careful and critical papers of Wager (1899), Dangeard (1903, 1907), Vuillemin (1907), Claussen (1907), and Guilliermond (1908, 1910). Data in the literature bearing on the germination of the spores and the comparative morphology of the different forms of ascogonia occurring in the different genera of the Ascobolaceae have not been so thoroughly summarized, and I shall attempt to bring together the available material in this line.

Coemans (1862) claimed that the spores of all species of *Ascobolus* germinate readily on moist slides and produce a mycelium not unlike that of other fungi. He considered remarkable the great facility with which this mycelium produced such quantities of *Penicillium*- or *Torula*-like conidia.

Woronin (1866), who was unable to germinate the spores of *Ascobolus*, questioned the correctness of the account given by Coemans. He described the initial organ of *Lasiobolus pulcherrimus* as a vermiform body consisting of about ten or twelve large cells arising perpendicularly from a vegetative hypha and curving slightly to one side. The cells are rather dark colored, and in addition to the granular contents each cell has one or more vacuoles. As the vermiform body (scolecite) reaches maturity three or four cells at the outer end are surrounded by several hyphae, which send out short sickle-shaped branches cut off from the parent hypha by septa, so that each branch consists of an oblong cell borne on a short stalk. These branches are closely applied to the cells of the scolecite in such a way as to lead Woronin to believe that fertilization occurs at this time.

He further found chlamydospores or resting spores on the mycelium connected with the ascocarp but no conidia or oidia. These thick-walled brownish spores are borne on curved stalks. They germinate after a resting period of several weeks.

Boudier (1869) believed that the spores of the species of *Ascobolus* growing on dung germinate only after passing through the digestive canal of animals, and that the spores of species growing on earth germinate at ordinary temperatures without special treatment. His figure of a germinated spore of *Ascobolus carbonarius* (*A. viridis* Boud.) shows the characteristic mycelium produced by this species. He asserts that in spite of all his work on this group he has never found their mycelia producing anything in the nature of conidia or chlamydospores.

Janczewski (1871) is very positive in his refutation of Coemans' statement (1862) regarding the germination of *Ascobolus* spores without special treatment. He fed the ascocarps of *A. furfuraceus* to an animal, recovering the germinated spores from the faeces. He found that most of the epispore is removed by the digestive processes, and that the spores thus treated germinate, sending out one or more germ tubes at a short distance from each end of the spore. He also investigated the method of the formation of the ascocarp. The material for this purpose was obtained directly from the natural substratum. The ascogonium consists of eight or ten large cells formed as a "worm-like" branch of a vegetative hypha. A slender filament arising from near the base of the ascogonium branches several times and coils closely about the end cells. These filamentous hyphae are the "pollinodia." After the ascogonium is well developed, the third cell from the outer end of the archicarp is seen to be very much enlarged and gives rise to ascogenous hyphae from its upper surface.

Van Tieghem (1876) germinated the spores of *Ascodesmis nigricans* in dung decoctions and beerwort. Following their development in drop cultures he observed the formation of a T-shaped body which branched several times by a false dichotomy. This rosette is the initial organ of the ascocarp. Occasionally a second branch arising near the first and similar to it, takes part in the formation of what he considered a compound or double ascocarp. Claussen (1905) has shown that this second branch is the stalk of a compound antheridium.

Borzi (1878) found a "scolecite" present in the young ascocarps of *Lasiobolus equinus* (*Ascophanus pilosus*), *Ascobolus immersus*, and *Rhyparobius* sp. The mature "scolecite" of *Lasiobolus equinus* consists of eight or ten cells which are differentiated into three distinct regions. The first eight cells form the stalk, which is usually bent a little to one side. The central portion consists of one large spherical cell borne on this stalk. The third region is merely a small projecting cell topping the ascogenous cell. The "pollinodium" is a filamentous hypha which grows up along the stalk of the "scolecite" and branches two or three times as it reaches the terminal portion, the branches coiling tightly about the end cell. Borzi considered the "pollinodia" to be concerned with a process of fertilization and at this time believed sexual reproduction was common among the Ascomycetes. He further finds that *L. equinus* produces two kinds of asexual spores. The first kind is borne on slender, erect, septate stalks. They are thick-walled brownish resting spores which he calls chlamydospores. The second kind appears to be borne on rather thick brushlike branches of erect hyphae. The spores are pinched off from the tips of these branches as small hyaline conidium-like "spermatia." In *Ascobolus immersus* the eight-celled stalk bears a large spherical cell, which is also capped by a small projecting cell. He finds two or three large cells in the young ascocarps of *Rhyparobius* sp. These cells are only the remains of the "scolecite." He figures the asci as arising directly out of the larger cell.

Zukal (1889) cultivated *A. immersus* by a series of transfers on sterilized dung, making the final transfers to a dung decoction where he was able to observe the various stages of growth under the microscope. He found two kinds of asexual spores with heavy brown walls. Branches composed of five or six cells arise from the older mycelial hyphae; the end cell rounds up and becomes surrounded with a thick brown membrane. If the end cell becomes divided by a longitudinal wall in addition to two or three transverse walls, a spore similar to those produced in *Stemphylium* is formed. He describes the ascocarp as originating in a knot of ordinary mycelial hyphae without the appearance of sex organs or an ascogonium. He denies the existence of the large ascogonium which Borzi found in this species. Zukal (l. c.) germinated the spores of *Rhyparobius pachyascus* in dung decoction and followed the development of the ascocarp in drop cultures. He strongly denies the presence of sex organs, but his figure of the initial organs might well be taken to represent oogonia and antheridia. One cell of the mycelium becomes slightly larger than the neighboring cells and sends out a large oval bud which is soon cut off from the parent cell by a septum. Two or three branches arise from the base of this large oval cell, and curving inward, become closely applied to its apex. He states that the mycelium of *Rhyparobius Cookei* gives rise to what he calls "gemmae," by intercalary swellings. He finds that spores of *Ascophanus saccharinus* germinate readily in Liebig's meat extract. The ascocarp originates from a knot of hyphae which he calls a sclerotium. After about six days portions of the mycelial hyphae swell up into knots, which increase in size by a process of budding, forming a compact mass about 40 μ in diameter. These so-called sclerotia may develop directly into ascocarps or they may continue to increase in size up to 80 μ, become reddish in color, and remain in this condition several weeks before developing an ascocarp. A second kind of sclerotium is more parenchymatous than the first and contains a large central cell. Other sclerotia about 200 μ in diameter are covered with hairlike appendages. These sclerotia are said to develop ascocarps if kept in moist chambers about six weeks.

Brefeld (1901) grew *Thelebolus stercoreus* in dung decoctions. He figures a small coiled ascogonium of one or two turns. *Rhyparobius albidus* was the only other species of this family which he was able to cultivate from ascospores. By using portions of the mycelium of *Ascobolus denudatus* he obtained good cultures of the species. The mycelium produced great quantities of oidia. After a time, when the production of oidia had ceased, an abundant crop of apothecia developed. He was able to trace the connection of the apothecia with the mycelium giving rise to the oidia. The oidia were sown on sterilized horse dung, and apothecia were obtained. He does not describe the manner in which the fruit body originates.

Harper (1896) describes the ascogonium of *Ascobolus furfuraceus* as it appears from the time it is completely inclosed with investing hyphae. In this stage the ascogonium consists of a coil of several large cells. Large pores are already formed in the transverse walls, thus bringing the contents of the cells of the row into direct connection. The ascogenous hyphae develop from the entire surface of the ascogenous cell.

Miss Ternetz (1900) finds that ascospores of *Ascophanus carneus* germinate readily in dung decoctions or in dung decoction agar. Cultures kept in a dark room do not develop fruit. The ascogonium arises as a branch of the mycelium. The stalk consists of two to five cells, easily distinguished from the larger and more granular cells of the ascogonium. The coil makes one or two turns, including in this region six or eight cells, and ends in a septate filament which varies considerably in length. It usually contains two or three cells but it may continue to grow out and give rise to another ascogonium. She found no evidence of the existence of an antheridium.

Massee and Salmon (1901, 1902) conducted a series of experiments on spore germination in species of *Ascobolus*. They found that the spores of *Ascobolus albidus* and *A. perplexans* would not germinate at 16° C. in dung decoction but did germinate at 27° C. *A. albidus* grown on dung in a closed tin box, shot the spores on the cover of the box, where they germinated and are said to have produced ascocarps. Spores taken from the ascocarps on the box cover were grown in a nutrient medium, and ascocarps were developed. They found that spores from these ascocarps would not germinate after passing through the alimentary canal of a guinea pig but did germinate at ordinary temperatures in tap water. They drew the very doubtful conclusion from this, that all dung-growing species of *Ascobolus* originally grew on earth where the spores would germinate easily at low temperatures. After one generation on the cover of the box and a second in an artificial medium made of plum jam and gelatin, *Ascobolus albidus* had reverted to its original terrestrial habit.

Molliard (1903) believes that the presence of certain bacteria favors the production of ascocarps by *Ascobolus*. He germinated the spores of *A. furfuraceus* in some way which he does not describe, and obtained pure cultures on sterilized cow dung and on slices of carrot. A dense growth of white flocculose mycelium was produced which gave rise to a great number of what he termed "arthrospores." In rare cases, after several weeks a few ascocarps appeared in some of the cultures. He discovered that the same bacteria that were present on the dung from which he obtained the ascospores for inoculation were also present in these particular cultures. Pure cultures of the *Ascobolus* mycelium and of this bacterium were then made, and he had only to introduce the bacteria into this *Ascobolus* culture in order to obtain an abundant supply of ascocarps. Otherwise he claims the *Ascobolus* remained sterile indefinitely.

Barker (1904) describes the existence of sex organs in *Rhyparobius* sp. but gives no figures. The ascogonium is a spirally coiled branch containing five or six nuclei. An antheridium containing several nuclei arises from the cell next to the one producing the ascogonium. The antheridium grows up and its tip becomes attached to the end of the ascogonium. Septa are now formed in both sex organs, cutting off cells which are uninucleated. The penultimate cell of the ascogonium is, however, binucleated.

Claussen (1905) grew cultures of *Ascobolus furfuraceus*, in which he found chains of oidia produced on the mycelium. He traced a direct connection between the mycelium from a germinated ascospore and the oidia. He sowed these oidia and continued the cultures in this manner for a hundred generations without finding any ascocarps. He has also studied in especial detail the life history of *Ascodesmis nigricans*. This fungus is easily cultivated on artificial media. He finds that the rosette of ascogonia originates as a result of the dichotomous branching of an outgrowth of a vegetative hypha. A short bud is put forth from a cell of the mycelium and immediately becomes T-shaped by division. Branching continues until several pairs of spirally coiled ascogonia are formed. Each ascogonium is now cut off from its stalk by a septum and a one-celled trichogyne is cut off at the apex. The antheridia are produced on a branch which may arise from the next cell to that from which the ascogonial branch originates, or it may come from cells of other hyphae in the vicinity. The antheridial branch divides dichotomously and grows in among the ascogonia, one antheridium coiling spirally about each ascogonium. Fusion takes place between the trichogyne and the antheridium.

According to Ramlow (1906) the mature ascogonium of *Thelebolus stercoreus* is a more or less spirally coiled body composed of five or six cells. Each cell is uninucleated except the penultimate cell, which contains two nuclei. The ascus is formed directly from the penultimate cell of the ascogonium. He was unable to find any organ corresponding to an antheridium. Occasionally two or three asci are found in one apothecium. This results from the inclusion of as many separate ascogonia within one apothecium.

Overton (1906) finds that *Thecotheus Pelletieri* has a compound fruit body containing several ascogonia. Each ascogonium is composed of several multinucleated cells and resembles in form the ascogonium of *Ascobolus*. He is unable to find any opening between the adjacent cells of the ascogonium. The ascogenous hyphae may arise from any or all the cells of the ascogonium.

Dangeard (1907) has described observations on many of the species of Ascobolaceae and related Discomycetes. In what he regards as *Ascophanus ochraceus* he finds that the ascocarp originates from a rosette of eight or ten ascogonia. These ascogonia resemble those of *Pyronema* although they are somewhat smaller. The ascogonium is prolonged into one or two elongated cells and these continue as a slender filament bending back and over the ascogonium. He claims that this outgrowth does not correspond to a trichogyne as no antheridium is present. The mature ascogonium of *Ascobolus furfuraceus* consists of about ten cells. It arises as a lateral branch from the mycelium and as growth proceeds is cut up into multinucleated cells. As it develops it becomes more or less coiled, forming an irregular spiral of one or two turns. He does not find the large pores in the transverse walls reported by Harper (1896), on the contrary he finds that the pores are just such as occur in the septa of the vegetative hyphae, too minute to allow of a bodily transfer of nuclei and cytoplasm. The asci are formed from the binucleated cells of the ascogenous hyphae. The method of forming the ascogonium in a species that he thinks may be *Ascobolus glaber*, differs widely from that of *A. furfuraceus*. The ascogonium has a stalk of twenty or thirty cells of much less diameter than the cells of the parent hypha. The stalk grows along on the medium and forms the spiral coil at its extremity. Dangeard has not been able to follow what takes place in the tangled coil, except to find that its cells are multinucleated and are connected by minute pores. A species which he accidentally found in his cultures of *Pyronema*, did not mature. It showed an exceedingly large ascogonium with the three regions, which I shall discuss later, easily recognizable.

Miss Fraser (1907) developed a method for germinating the spores of *Lachnea stercorea*. She believes that in nature the spores of this species probably pass through the body of the cow. An attempt was made to imitate normal digestion by placing the spores successively in saliva, artificially prepared gastric juice, pancreatic juice, and in a dung decoction. The spores were left in each medium several hours and the temperature maintained at 38° C., the temperature of the cow. Germination occurred after about two days. Further experiments showed that the two factors most essential for germination were heat and the alkalinity of the medium. Five successful experiments on germination by this method are recorded. Her figure of the germinated spore shows a germ tube issuing from each end. She was unable to obtain ascocarps, as all growth ceased soon after the germ tubes were formed. The mature ascogonium of *Lachnea stercorea* consists of a large oval cell at the end of a three- or four-celled stalk. A trichogyne grows out from one side of the ascogonium, and transverse septa are formed in the trichogyne, cutting off several cells. The tip of the trichogyne bends downward and becomes attached to a more or less irregular and indefinite antheridium, the origin of which could not be determined. According to Miss Fraser the septa of the trichogyne are permanent structures, and functional sexuality does not exist.

Miss Fraser's method of spore germination was used by Miss Welsford (1907) in her studies of *Ascobolus furfuraceus* and by Cutting (1909) working with *Ascophanus carneus*. They describe the germination of a few spores but were unable to obtain artificial cultures. Miss Welsford found thick-walled chlamydospores developed on a mycelium supposed to be that of *Ascobolus furfuraceus*, and Cutting observed the "gemmae" and "dense chains

TABLE I

Summary of results obtained by various investigators who have reported germinating the spores of certain species of the Ascobolaceae. Those marked (?) have given no figure of the germinated spores nor a description of the manner in which the spores germinated.

Date	Author	Species	Method	Results
1862	?Coemans	*Ascobolus* sp.	In water	Mycelium producing many conidia
1869	Boudier	*Ascobolus carbonarius* (*A. viridis* Boud.)		No further growth noted
1871	Janczewski	*A. furfuraceus*	Animal digestion	No further growth noted
1876	Van Tieghem	*Ascodesmis nigricans*	In drop culture dung decoction	Produced ascocarps
1889	?Zukal	*Rhyparobius pachyascus*	Dung decoction	Produced ascocarps
1889	?Zukal	*R. Cookei*		Produced "gemmae" and ascocarps
1889	?Zukal	*Ascophanus saccharinus*	Liebig's Beef Extract	Produced 3 kinds of "sclerotia" and ascocarps
1891	Brefeld	*Thelebolus stercoreus*	In dung decoction	Produced ascogonia
1891	Brefeld	*Rhyparobius albidus*	In dung decoction	Produced ascocarps
1900	?Ternetz	*Ascophanus carneus*	In dung decoction agar	Produced "gemmae" and ascocarps
1902	Massee & Salmon	*Ascobolus albidus*	In tap water and plum juice	Produced ascocarps
1902	?Massee & Salmon	*Ascobolus perplexans*	In tap water and plum juice	
1903	?Molliard	*Ascobolus furfuraceus*	On sterilized carrot and dung	Produced ascocarps and arthrospores
1906	?Barker	*Rhyparobius* sp.	In dung decoction	Produced ascocarps
1906	Ramlow	*Thelebolus stercoreus*	In dung decoction	Produced ascocarps
1907	?Claussen	*Ascobolus furfuraceus*		Produced oidia. No ascocarps
1907	?Welsford	*Ascobolus furfuraceus*	Dung decoction + Na_2CO_3 at 38° C.	No further growth
1909	?Cutting	*Ascophanus carneus*	Dung decoction + Na_2CO_3 at 38° C.	No further growth

of chlamydospores" noted by Miss Ternetz (1900) in connection with the mycelium of *Ascophanus carneus*.

TABLE I does not include the names of several who have cultivated *Ascodesmis* from the germinated spores: Zukal (1885), Claussen (1905), Dangeard (1907), Bainier (1907). It is evident that the spores of *Rhyparobius* germinate readily in dung decoction and those of *Thelebolus stercoreus* can be germinated with difficulty in the same medium. The only satisfactory evidence that spores of species of *Ascobolus* have been germinated in artificial media is furnished by Boudier (*A. carbonarius*), Janczewski (*A. furfuraceus*), and Massee & Salmon (*A. albidus*). Janczewski's method involved the process of the digestion of the spores by the animal and is not practicable for artificial culture work. Boudier germinated the spores of *A. carbonarius* but reported no further growth. Massee & Salmon report that they obtained fruits of *Ascobolus* artificially in cultures started by the germination of the ascospores. As previously noted, page 143, Brefeld obtained abundant growths of apothecia of *A. denudatus* from mycelium that also produced oidia. Zukal (1889) grew *Ascobolus immersus* by a series of transfers on sterilized dung. Dangeard (1907) reports growing several species of *Ascobolus* in artificial cultures but he does not describe his methods.

Various terms are now in use to designate the initial organs of the ascocarp. It is difficult to choose a term that shall include such simple fertile hyphae as exist in the Erysiphaceae, *Monascus*, and *Pyronema* and at the same time the complicated structures found in *Aspergillus*, in species of the Ascobolaceae, and in the lichens. The word archicarp will be used in this discussion when referring to the branch consisting wholly or in part of the oogonium or its morphological equivalent, the oogonium being that organ which produces the egg that is fertilized.

In *Sphaerotheca* the oogonium is a uninucleated cell (Harper, 1896), in *Pyronema* it is multinucleated (Harper, 1900). In *Ascophanus carneus*, according to Cutting (1909), there is a fusion of vegetative nuclei in each of four or five cells of the archicarp, but such variations, if they occur, do not necessarily affect the morphological equivalence of the organs in question.

The trichogyne is an outgrowth of the oogonium and functions as an organ to bring together in the oogonium the male and the female nuclei.

The term ascogonium will be used in referring to the oogonium after fertilization. In such cases as *Pyronema* the oogonium after fertilization becomes the ascogonium. Such a use of terms is of course purely morphological and does not prejudge the question as to the existence of apogamy, reduced fertilization, etc.

It is necessary only to mention the antheridium in the lichens, in *Pyronema*, and in *Monascus*, to call to mind the great variation which may occur in this organ, and it would perhaps be premature to attempt to substitute a single term in place of the wide variety of terms that have been proposed.

MATERIAL AND METHODS

The Ascobolaceae form a rather natural group as commonly regarded by systematists. The family as now generally recognized contains about two hundred described species, grouped under ten or twelve genera. The genus *Ascobolus* was established by Persoon (Gmel. Syst. Nat. **2**: 1461. 1791) to include those Discomycetes in which the mature asci protrude from the fruit body.

Several noteworthy monographs dealing with the species of this family have been published in Europe, and all morphological and cytological papers on the group have been based on European material. A few species have been described from America but our knowledge of the group as it exists here is extremely limited. In my preliminary work to obtain suitable material for study I succeeded in growing on the natural substrata in damp chambers thirty-six species and a few additional forms which appear to be varieties.

Cultures were carried on both at the New York Botanical Garden and at Columbia University where most of the artificial culture work was done. I am indebted to Professor C. C. Curtis for his liberality in the provision of apparatus and opportunities to visit other regions for the purpose of collecting these fungi. Professor R. A. Harper's criticisms and timely suggestions deserve an expression of sincere appreciation.

Extensive field studies were carried on and the plants were grown under natural as well as artificial conditions. In the field studies of such species as *Ascobolus viridis*, *A. pusillus*, and *A. carbonarius*, all of which grow on the ground rather than on the excrement of animals, repeated visits to the same spots for three successive years were made and the condition of the species under various weather conditions was noted. Apothecia in all stages of growth were brought into the laboratory and their diagnostic characteristics were worked out in detail. For laboratory cultures on the natural substratum, earth and dung were brought in and placed in damp chambers of glass lined with filter paper.

Some species are very minute, and the apothecia are frequently so few that their detection is a matter of difficulty. The Zeiss binocular with the horizontal arm is a very useful instrument for this work. With the higher powers, and a damp chamber provided with a flat cover, it is possible to study the development of the plants, their heliotropic reactions, and the discharge of the spores under very normal conditions.

The apothecia seem to develop best when the cultures are carried on in a well lighted room having a temperature of about 25°–27° C. In a dimly lighted or cold room there are usually marked changes in the coloration of the spores and fruit bodies. *Ascophanus carneus* when grown in bright sunlight will have a deep pink apothecium, but in a dimly lighted room the fruit body will be nearly colorless. The spores of *A. Winteri* that were allowed to develop in a closed vasculum were perfectly hyaline. When this species is grown in a cold room or is found in nature during cold rainy weather, the spores are much paler than usual.

In order to determine whether certain species were limited in their occurrence to a particular kind of dung, extensive studies were made of the species growing on dung from the New York Zoological Park. So far as could be learned, most of the species are not thus limited.

The following species have been grown on their natural substrata in the laboratory. Their identity has been determined by careful study and comparison with exsiccati at the New York Botanical Garden:

Ascobolus aerugineus Fries
Ascobolus carbonarius Karst.
Ascobolus sp.
Ascobolus furfuraceus Pers.
Ascobolus glaber Pers.
Ascobolus immersus Pers.
Ascobolus Leveillei Boud.

Ascobolus Leveillei var. *americanus* Cooke & Ellis
Ascobolus pusillus Boud.
Ascobolus viridis Currey var. (?)
Ascobolus viridulus Phil. & Plow.
Ascobolus Winteri Rehm
Ascophanus Aurora (Crouan) Boud.
Ascophanus carneus (Pers.) Boud.
Ascophanus sarcobius Boud.
Ascophanus glaucellus Rehm
Ascophanus granuliformis (Crouan) Boud.
Ascophanus Holmskjoldii Hansen
Ascophanus lacteus (Cooke & Phil.) Phil.
Ascophanus microsporus (B. & Br.) Phil.
Ascophanus minutissimus Boud.
Ascophanus ochraceus (Crouan) Boud.
Ascodesmis nigricans v. Tieghem (*Boudiera Claussenii* P. Henn.)
Boudiera sp.
Cubomia sp.
Thecotheus Pelletieri (Crouan) Boud.
Rhyparobius crustaceus (Fuckel) Rehm
Rhyparobius pachyascus Zukal
Rhyparobius niveus (Fuckel) Rehm
Rhyparobius sexdecimsporus (Crouan) Sacc.
Lasiobolus equinus (Müll.) Karst.
Saccobolus depauperatus (B. & Br.) Rehm
Saccobolus Kerverni (Crouan) Boud.
Saccobolus neglectus Boud.
Saccobolus violaceus Boud.
Thelebolus stercoreus Tode

Of this list fourteen species have been grown more extensively and studied from the morphological standpoint as to the characters of their ascogonia, methods and conditions of spore germination, etc. Further studies are in progress, dealing with nuclear phenomena and methods of reproduction. The discussion of the identification of these species forms a part of another paper, which is now being prepared.

I have found aceto-carmin useful for staining young ascogonia, although it is not permanent, and as a temporary stain it can not always be depended upon to differentiate between the nuclei and the granules of the cells. The nuclei are more easily differentiated in the young hyphae. A drop of the aceto-carmin mixture placed on a piece of agar containing the fungus before it is crushed under the cover glass, will stain the hyphae and ascogonia, if the slide is left for some time in a damp chamber where the stain does not dry out. The ascogonia, especially, swell under the action of the stain but this is no disadvantage when it is desired only to locate them.

Material stained in toto with iron-hematoxylin can be crushed on the slide, perfectly dehydrated, and mounted in balsam without shrinkage. Such mounts are useful for showing germinated spores and the young mycelium. A still better method is to allow the spores to be shot upon a slide where they will stick securely enough to be carried through all the processes of heating, germination, fixation, etc.

For the serial sections, Heidenhain's iron-hematoxylin and Flemming's triple stain were used. If longitudinal sections of hyphae were desired the blocks were cut parallel to the original upper surface of the culture medium. The ascogonia could also be located more easily in sections cut in this plane. The coils of the ascogonia do not appear to be oriented in any particular plane, and a section parallel to the upper surface of the agar is as favorable as any for their study.

The nutrient medium most frequently used for artificial cultures was made by soaking 12–14 g. of agar over night in 500 c.c. of tap water and then adding to it 500 c.c. of filtered decoction of goose dung, obtained by allowing about 100 g. of the dung to remain in a liter of warm water for a few minutes. The mixture was heated in an autoclave at 120° C. for 30–40 minutes or in a steam sterilizer for a longer time. It was then filtered with a hot water filter and further sterilized for 30 minutes at 120° C., or intermittently for three days at 100° C. Another nutrient decoction used with good results when a medium with little color was desired, was made by heating about 2 kg. of common garden soil in an oven at 180° C. for an hour. A liter of a filtrate obtained from this soil while still warm was added to 12 g. of agar.

The decoctions of goose dung were always strongly alkaline. During the sterilizing process the ammonia was largely driven off so that the medium was only very slightly alkaline to litmus. After the ascocarps had ripened on the medium, tests made with litmus gave sometimes an acid and sometimes an alkaline reaction, the one occurring as often as the other. The medium made with an extract of heated soil was very slightly acid. Petri dishes 5–10 cm. in diameter and 1–2 cm. high, with as thin bottoms as could be obtained, were preferred as culture dishes on account of the method of observation employed. The plates were poured so that the medium was about 3 mm. deep and left to harden without disturbing.

SPORE GERMINATION

As a preliminary to obtaining artificial cultures of as large a number of species as possible, experiments were made to determine the most favorable conditions for the germination of the spores.

A quantity of goose dung gathered in August 1910, at the Zoological Park, was brought into the laboratory and placed in a tall battery jar completely lined with filter paper, and the jar was left uncovered to facilitate the partial drying of this freshly gathered material. It was left in this condition four or five days. The odor of ammonia, which had been very strong the first few days, became gradually less noticeable, but the bacterial decomposition appeared to be still going on rapidly. Examination showed, however, that the entire surface of the dung was covered with a dense aggregation of young fruits of *Ascobolus Winteri* Rehm.

ASCOBOLUS WINTERI Rehm.

Agar plates were prepared as described above, the nutrient being a decoction of goose dung. The effect of various temperatures, ranging from the body temperature of the birds downward, was first tested. For this purpose a copper germinating trough was used. This trough contained ten compartments covered with glass plates. It was heated by electricity so that the successive compartments were held at temperatures of 42°, 40°, 38°, 35°, 30°, 25°, 25°, and 24° C. respectively. Petri dishes containing the agar inoculated with spores, were placed in these chambers and examined from time to time for 48 hours with negative results in all cases. The plates were then set aside at this time and examined for two or three days or until they became contaminated with bacteria and other fungi. In no case could any germinating spores be found, though the conditions as to degree of heat and time of exposure must have resembled those in the bird. This experiment was tried several times with minor variations. Sometimes a low percentage of sodium carbonate or various combinations of other salts were added to the decoction used in making up the medium. The spores could not be stimulated to growth under any of these conditions.

Some of the damp chambers in which the fungus was growing stood on a laboratory table exposed to direct sunlight. In these cases spores were occasionally found that had germinated in the film of moisture that always gathers on the underside of slides placed over the dung to catch the spores. An attempt was made to transfer these germinated spores to the agar plates. When the spores were removed from the slide the germ tubes were either broken off or injured in some manner, but if the slides themselves were placed on the medium the mycelium would continue to grow and finally produce ascocarps. These cultures invariably became contaminated with foreign fungi.

Small pieces of dung or filter paper upon which young ascocarps were growing, were next placed in the agar medium. Although many attempts were made to obtain cultures in this manner, not the slightest further growth of the mycelium was obtained.

Several plates prepared in this manner were placed in a drying oven and heated slowly for 40 minutes. The temperature of the oven was thus gradually raised to 80° C. The plates were then withdrawn and allowed to stand in the laboratory at room temperatures. After 24 hours it was found that the spores thrown out upon the medium from the mature ascocarps before the cultures had been heated, had germinated and the mycelium was growing vigorously. This experiment was repeated with a number of plates, and unheated controls were maintained at room temperatures. In all the plates that had been heated the spores germinated, while none of the spores in the controls did so.

A series of experiments, some of which are tabulated below, were made to test more fully the effect of heat on germination and to determine the approximate minimum, optimum, and maximum temperatures for spore germination. Controls at room temperatures were maintained in ninety cases. It will be seen from the table that about 80 per cent of the spores heated to 60°–70° C. germinated. In no case were the spores in the controls even swollen. The method as finally worked out may be described as follows: Spores for inoculation were obtained by laying glass slides on corks over pieces of dung bearing ripe ascocarps. With the use of a Zeiss binocular, the spores were removed with a sterilized platinum needle and stabbed into the medium about 1.5 cm. from the edge. If more than one plate was to be inoculated it was found necessary to moisten the spores by blowing the breath on the slide, since they dry out rapidly and adhere to the slide so firmly that their removal is impossible without destroying them.

The species of Sordariaceae and Chaetomiaceae that usually grow in great abundance with species of *Ascobolus*, are for some reason not often present with *A. Winteri* on goose dung in this region. No spores of any other ascomycete were found on these slides. The precautions that are so necessary when pure cultures of other *Ascobolus* species are desired, are of little consequence when working with *A. Winteri.* The molds will be killed off, and the number of bacteria introduced with the spores will be much reduced by the heating process. Two ovens were used at different stages in my studies. One was a sheet-iron drying oven with an asbestos-lined shelf on which the cultures were placed. No oven of this type can be so arranged as to furnish the same degree of heat at all points on the shelf. By regulating a burner so that 20 minutes were required to raise the temperature of the oven to 75° C., as shown by a thermometer placed in one corner of the oven, and then removing the plates, good results were obtained. The plates were often left in the oven to cool, the door being opened, or the gas was turned off at 60° C. and the cultures allowed to cool in the closed oven. When this last method was employed, the spores themselves must have been maintained at temperatures between 50°–60° C. for at least 30 minutes. By substituting a burner that would raise the oven to 80° C. in five minutes, the per cent of germination was greatly reduced.

The second oven was porcelain-lined and was found to be less satisfactory for these experiments, because the temperature of the inclosed air would quickly rise to 100° C. or more while the agar medium would still be cool. To determine the temperature to which this oven must be raised in order to bring about germination, eight cultures were stacked one on the other in three different tiers. It was found that with the oven heated to 100° C. the spores in the lowest plates of the three tiers were the only ones that germinated. The other plates were then reheated to 65° C. in the sheet-iron oven and most of them gave positive results. It is not necessary to mention the great number of variations with which these experiments were performed. The size of the Petri dishes, depth of agar, and the position of the spores, are all factors which make it difficult to determine the exact temperature of the spore in each case where a solid medium is used. By quickly opening the oven and stirring the agar with a thermometer it was found that when this oven had been heated to 75° C. during a period of 20 minutes the agar in the Petri dishes was at about 60° C. When water was substituted in place of the agar the plates in the front row on the asbestos shelf were only at about 55° C. while those on the rear row were at 60°–65° C. The evidence obtained, however, shows conclusively that the application of heat is an effective stimulus to spore germination.

The data for some thirty experiments, in which one hundred and ninety inoculations were made in as many plates, are summarized in TABLE II. The per cent of germination was determined by noting approximately how many spores of given groups failed to grow. 99 per cent means that ungerminated spores could not be found.

The plates in no. 20 and no. 21 were treated exactly alike but only 10 per cent of the spores in the first (no. 20) germinated, while practically all the spores in the second (no. 21) did so. The spores from no. 20 were obtained from dung collected in the field during very cold rainy weather. The apothecia and spores were very much paler than is normally the case. The plates of no. 21 were inoculated with spores from apothecia developed from dung that had been gathered the previous year and stored in the laboratory.

When an artificial culture has produced a number of ripe apothecia the spores may be seen lying all about on the surface and within the medium. These spores do not germinate even though the medium is well supplied with moisture. Three such cultures were heated to 60°, 65°, and 70° C. respectively. None of the spores in the medium germinated. It was not a case where the required nutrient was lacking, since many of the spores on the covers of these same dishes germinated in the film of water after being heated. No second crop of this species ever appears in damp chamber cultures. It may be, however, that certain toxic substances that inhibit germination are given off during the growth of the mycelium and apothecia. Spores from these same dishes were used to inoculate controls containing fresh media, and in these controls germination was abundant.

To determine the effect on germination when hard agar is used, a medium was made up with a much smaller percentage of

TABLE II

Results of experiments to show the effect of heat on the germination of the spores of *Ascobolus Winteri*

No.	Date	No. of plates	Medium, agar +	Minutes to heat oven	Final temp. of oven, C.	Germination observed	Per cent of germination
	(1910)						
1	Nov. 4, 4 P.M.	1	goose dung decoction	7	90°	Nov, 5, 8 P.M.	50
	Control	1	goose dung decoction	0	Room		0 (Nov. 8)
2	Nov. 4, 4 P.M.	1	goose dung decoction	7	90°	Nov, 5, 8 P.M.	20
	Control	1	goose dung decoction	0	Room		0 (Nov. 8)
3	Nov. 5, 9 P.M.	2	goose dung decoction	15	76°	Nov. 6, 3 P.M.	50
	Control	1	goose dung decoction	0	Room		0 (Nov. 8)
4	Nov. 12, 9 P.M.	1	goose dung decoction	15	76°		0 (Nov. 31)
5	Nov. 12, 10 P.M.	1	goose dung decoction	13	77°	Nov. 13, 9 A.M.	5
6	Nov. 12, 10 P.M.	1	goose dung decoction	13	77°	Nov. 13	99
7	Nov. 12, 10 P.M.	1	goose dung decoction	9	64°		0 (Nov. 25)
8	Nov. 12, 10:40 P.M.	1	goose dung decoction	17	82°		0 (Nov. 25)
9	Nov. 13, 12 M.	1	goose dung decoction	5	75°		0 (Nov. 15)
10	Nov. 14, 5 P.M.	1	goose dung decoction	15	77°		0 (Nov. 18)
11	Nov. 15, 5 P.M.	1	goose dung decoction	20	75°	Nov. 17, 1 P.M.	75
12	Nov. 15, 6 P.M.	1	Reheated No. 9	10	82°	Nov. 17	75
13	Nov. 18, 4 P.M.		Reheated No. 10	8	75°		0 (Nov. 30)
	(1911)						
14	May 28, 10 P.M.	18		15	70°	May 29, 8 A.M.	90
15	May 29, 11 P.M.	1	N/100 Na_2CO_3	15	70°	May 30, 9 A.M.	75
16	June 7, 11 P.M.	8	N/100 Na_2CO_3	25	65°	June 9, 8 A.M.	90
17	June 10, 5 P.M.	4	N/100 Na_2CO_3	31	60°	June 11, 8 A.M.	90
18	June 11, 5 P.M.	5	N/100 Na_2CO_3	35	60°	June 12	80
19	May 28, 11 A.M.	28	N/100 Na_2CO_3	30	65°	May 29, 9 A.M.	90
20	Sept. 25, 11 P.M.	30	goose dung decoction	15–20	60–75°	Sept. 26	10
21	Oct. 2, 10 A.M.	30	goose dung agar	15–20	60–75°	Oct. 3	99
22	Nov. 12, 4 P.M.	1	goose dung agar	11	72°		0 (Nov. 15)
23	Nov. 13, 11 A.M.	1	goose dung agar	15	75°	Nov. 14	99
24	Nov. 13, 12 M.	1	goose dung agar	30	90°		0
25	Nov. 15, 5 P.M.	1	goose dung agar	18	75°	Nov. 17, 8 A.M.	99
26	Nov. 19, 10 A.M.	1	goose dung agar	20	65°	Nov. 20	90
27	Dec. 17, 10 P.M.	1	goose dung agar	15	70°	Dec. 18	90
28	Dec. 20, 11 A.M.	20	horse dung decoction	17	70°	Dec. 21, 10 A.M.	90

water. In this case no surface film of moisture was visible on the agar nor on the cover of the dish. Twelve plates were prepared and the spores heated in the usual manner. No spores germinated. Small pieces (about 5 mm. square) of another agar medium containing a good supply of moisture were inserted in the plates of hard agar. Spores were then stabbed into the pieces of soft agar and heated. Practically all of the spores germinated. The mycelium grew out on the hard agar and produced a large number of apothecia in about ten days. This demonstrates the possibility of growth and reproduction under conditions not favorable for spore germination.

ASCOBOLUS CARBONARIUS Karst.

In my first experiments on the effects of heat on the germination of the spores of this species, small pieces of the apothecia were placed in Petri dishes on goose dung agar prepared as above described and placed in the sterilizing oven, which was then slowly heated to a temperature of 65° C., the time required being 30 minutes. They were then removed from the oven and left at room temperature. The following morning, in the cultures that had been heated, hundreds of spores had germinated; not only ripe spores, but half grown, hyaline spores had germinated, sending out fully as long and vigorous germ tubes as the others. In the unheated control plates there was no evidence of germination. A medium was then made up with an extract of heated soil as a nutrient. Twenty plates of this agar medium were poured and inoculated with spores taken from the glass slides. Ten of these plates were heated to 65°–75° C., the other ten were left at room temperatures. About 30 c.c. of the heated soil decoction was poured into each of twenty more Petri dishes and ascospores sowed in these. Ten of the dishes were heated to 65° C., and ten reserved unheated as controls. About 12 hours after, it was found that fully 90 per cent of the spores in both the liquid and the solid media that had been heated had germinated, while there was no germination in the unheated controls. Many small hyaline spores had also germinated. Comparison showed that these were half grown spores of *Ascobolus carbonarius* which had failed to reach maturity before being expelled from the asci. Further attempts to induce the spores of this species to germinate at ordinary temperatures were unsuccessful.

To determine the temperature used in such experiments more exactly, two Petri dishes, each containing about 50 c.c. of a decoction of heated soil, were heated in the oven after having been well inoculated with spores. The temperature of the decoction was determined by stirring with a thermometer. The first reached 65° C. in 25 minutes, the second 60° C. in 19 minutes. So far as I was able to find, every spore in both dishes germinated. Another dish containing a like amount of the decoction without spores was heated in the oven for 30 minutes. At the end of this time the oven temperature was 80° C. The door was then opened and the temperature of the decoction proved to be 72° C. Spores were now put into this dish, the gas was turned off and the oven closed. After five minutes the temperature of the decoction was again determined as before. The temperature had dropped only two degrees. These spores were certainly exposed for five minutes to a temperature of 70°–72° C. Seven hours later all the spores had germinated.

In another experiment a beaker containing a decoction of heated soil was heated in a hot water bath to a temperature of 75°–76° C. Spores were then introduced and the temperature maintained at 75° C. for five minutes. Fully half the spores germinated after six hours and only about one per cent had failed to germinate at the end of 24 hours.

There is no doubt, however, that under certain conditions the spores of *Ascobolus carbonarius* may germinate without being exposed to such high temperatures. This is shown in the following experiment. A damp chamber containing a quantity of carbonaceous earth, upon which several ascocarps were growing, was exposed to direct sunlight for about two hours. Slides were placed above the ascocarps to catch the spores, and a few of these spores germinated in the film of water on the slide. A large number of the spores from these slides were wiped off into a heated soil decoction and kept at room temperatures. The spores that had already germinated continued to grow, and in addition about 5–10 per cent of the others germinated. It was found by further experiments that liquid exposed to the sunlight under these conditions may reach a temperature of 50° C. in 30 minutes. This moderate rise in temperature has evidently a very stimulating effect on the spores, though the per cent of germination so achieved is not high.

In the following table (TABLE III) I have brought together a summary of the results of my experiments on the effect of heat on the germination of the spores of *Ascobolus carbonarius*.

The table shows that in the one hundred and twelve trials over 90 per cent of the spores germinated when heated in an oven for periods of from 15 to 40 minutes, the temperatures running up to but not exceeding 80° C. The highest per cent of germination was obtained by heating the oven up to from 70°–75° C. within the time limits specified. It is clear that the spores of this species very seldom germinate under cultural conditions unless heated to at least 50° C. for several minutes. Germination takes place equally well in such liquid media as tap water, decoctions of carbonaceous earth, decoctions of heated soil, and in dung decoctions; no difference in the percentage of germination is apparent when an agar medium made up with any of the decoctions just mentioned is employed, or when a peptone glucose agar or a malt agar is used. The percentage of germination is 90 per cent or over in all cases where the spores have been heated to 60°–75° C. for a few minutes.

To obtain a more definite idea of the minimum, optimum, and maximum temperatures for the germination of spores of *Ascobolus carbonarius* two series of experiments were made. (*a*) About twenty spores were placed in each of eleven test tubes half filled with a decoction of heated soil. A thermometer was used to stir the contents of the tubes while heating them separately in hot water baths. Each tube was heated for three minutes after its contents had been raised to the desired temperature, and was then cooled quickly by placing it in a cold water bath. After 24 hours the contents of the tubes were poured into watch glasses and the per cent of germinated spores ascertained by actual count. Observations made at the end of three days and again at the end of seven days showed that there was no further germination after the first 24 hours. TABLE IV shows the results of this set of experiments.

(*b*) In the second series the spores were allowed to remain on

TABLE III

The effect of heat on the germination of the spores of *Ascobolus carbonarius*

No.	Date	No. of plates	Medium	Minutes heated	Final temp. of oven, C.	Germination observed	Per cent of germination
1	June 10	3	Goose dung agar	30	65°	June 11	90+
	Control	3	Goose dung agar		Room		0
2	June 11	7	Heated soil agar	31	60°	June 12	99
	Control	7	Heated soil agar		Room		0
3	June 11	3	Goose dung agar	30	69°	June 12	90+
	Control	3	Goose dung agar		Room		0
4	June 12, 11 A.M.	1	Heated soil decoction	20	70°	June 12, 8 P.M.	99
	Control	1	Heated soil decoction		Room		0
*5	June 13	1	Heated soil decoction	20	66°	June 14	90
†6	June 15, 10 A.M.	1	Heated soil decoction	25	65°	June 15, 5 P.M.	99
7	June 15, 10 A.M.	1	Heated soil decoction	19	60°	June 15, 5 P.M.	99
8	June 21	2	Heated soil decoction		70°	June 21, 11 P.M.	90+
	Control	1	Heated soil decoction		Room		0
9	June 22	1	Heated soil decoction	30	80°	June 22, 10 P.M.	99
10	Sept. 4	6	Heated soil agar	15	70°	Sept. 5	99
11	Sept. 4	1	Heated soil agar		Room	Sept. 5	0.5
12	Sept. 27	12	Heated soil agar	40	100°		0
13	Sept. 28	6	Heated soil agar	35	90°	Sept. 29	50
14	Sept. 28	12	Heated soil agar	20	70°	Sept. 29	90+
15	Oct. 7	20	Heated soil agar	15	65°	Oct. 8	90
16	Oct. 7	20	Unheated carbonaceous earth decoction agar	20	70°	Oct. 8	99
17	Oct. 10	2	Peptone glucose agar	15	68°	Oct. 11	99
18	Oct. 10	2	Malt agar	15	68°	Oct. 11	99
19	Oct. 12	15	Decoction carbonaceous earth boiled 5 min. + agar	18	70°	Oct. 13	99

* The slide containing the spores used for no. 4 control was heated to 66° C. in the oven as indicated.

† In no. 6 and 7 the temperature of the decoction was determined by stirring with a thermometer.

The per cent of germination was determined approximately by observing the number of ungerminated spores in given groups.

the glass slides on which they had been caught from the apothecia, and each slide was immersed in a beaker of the decoction of heated soil, which had been raised to the required temperature. In this manner the time of exposure was in every case five minutes. At the end of this time the slide was removed and placed in a Petri dish containing a decoction of heated soil. A fresh decoction and clean beaker were used in each case. As these slides were covered with hundreds of spores, the percentage of germination was determined by counting the spores visible in the field of the microscope and an average taken of ten countings.

TABLE IV

Experiment to show the maximum, optimum, and minimum temperatures for the germination of the spores of *Ascobolus carbonarius* when heated 3 min.

Temperature, C.	No. of spores germinated	No. of spores not germinated	Per cent germinated
95°	0	16	0
93°	1	38	2+
90°	2	27	9+
83°	8	13	40−
80°	9	10	50−
75°	22	0	100
65°	7	0	100
60°	20	5	80
55°	11	10	50+
45°	1	17	5
35°	0	28	0
Room	0	19	0

TABLE V

Experiment to show the maximum, optimum, and minimum temperatures for the germination of spores of *Ascobolus carbonarius* when heated 5 min.

Temperature, C.	Per cent germinated
93°	0
90°	1
85°	30
80°	52
75°	90
70°	99
65°	99
60°	84
50°	60
45°	37
40°	3

Both series of experiments give the same general result. When the spores are heated for three minutes we find that only five per cent of those raised to 45° C. germinated. All spores heated to 65°–75° C. germinated. Between 75° and 80° there was a rapid falling off and at 93° C. only one spore of the thirty-nine germinated. There was also a marked difference in the time required for germination to begin. In the cultures heated to 65°–90° C. the mycelium had already grown several millimeters when examined 24 hours later; the only spore germinated at 45° had just begun to send out the germ tubes at this time. When the time during which the spores were heated was lengthened to five minutes, the maximum temperature was lowered to 90° C. and the optimum was limited to 65°–70° C.

ASCOBOLUS VIRIDIS Curr. var. ?

Liquid decoctions were made from unheated soil gathered in the habitat of the fungus; other decoctions were made from this soil heated to 180° C. for one hour, and from alkaline soil from North Dakota both heated and unheated. Agar media were prepared with each of the above decoctions. At least fifty different plates were inoculated and subjected to various degrees of heat ranging from — 5° C. for 24–48 hours, to 25°–75° C. for much shorter periods. Germination was obtained only in drop cultures made in a decoction of heated soil from the locality where the plants grew. Of the thousands of spores in Petri dishes containing this same liquid, none germinated. The spores germinated in the drop cultures could not be induced to continue their growth on the agar media. FIG. 2 and 3 show the manner in which the epispore breaks up as the spore germinates.

ASCOBOLUS IMMERSUS Pers.

The method by which the spores of *A. immersus* were germinated is the same as was used with the preceding species. The results of my experiments are given in TABLE VI.

THECOTHEUS PELLETIERI (Crouan) Boud.

The methods by which this fungus may be obtained in cultures on the natural substratum have been well described by Overton (1906).

The large size of the spores and the fact that all of the thirty-two usually lie together on the slide arranged to catch them as they are ejected, make it possible to remove them without much danger of introducing the spores of other species. The agar medium was made

TABLE VI

The effect of heat on the germination of the spores of *Ascobolus immersus* Pers.

No.	Date	No. of plates	Medium, agar +	Time of heating oven	Final temp. of oven, C.	Germination observed	Per cent germinated
	(1910)						
1	Nov. 28	1	goose dung decoction	20 min.	75°	Nov. 30	25
2	Dec. 1	3	goose dung decoction	20 min.	75°	Dec. 3	+20
*3	Dec. 1	4	goose dung decoction	17 min.	75°	Dec. 3	100
4	Dec. 3	1	goose dung decoction	30 min.	80°	0	0
5	Dec. 19, 11 A.M.	1	goose dung decoction	30 min.	65°	Dec. 19, 9 P.M.	100
6	Dec. 19, 9:30 P.M.	1	goose dung decoction	30 min.	60°	Dec. 20, 9 A.M.	+
7	Dec. 21	1	heated soil decoction + Na_2CO_3 (N/50)	15 min.	65°	0	0
8	Dec. 21	1	heated soil decoction	15 min.	65°	Dec. 22	75
9	Dec. 21	1	dung decoction	20 min.	80°	Dec. 22	100
†10	Dec. 23	1	heated soil decoction	12 hrs.	−5°	0	0
11	Dec. 23	1	dung decoction	12 hrs.	−5°	0	0
	(1911)						
12	Apr. 19	3	goose dung decoction	20 min.	77°	Apr. 20	80
13	May 5	8	goose dung decoction	25 min.	75°	May 8	15
14	May 8	4	goose dung decoction	20 min.	75°	May 9	50

* Left the plates in the oven to cool. At the end of one hour the temperature of the oven was still 55° C.

† Two inoculated plates set outside the window during freezing weather for 12 hours were then maintained at room temperatures for 10 days without showing any signs of germination. As the table shows, in nearly every case where the plates had been heated for 15–20 minutes a large percentage of the spores germinated.

up with varying strengths of decoctions of dung and of heated soil, and the percentage of agar used was changed to get media of different degrees of hardness. The spores germinated fairly well after being heated 20 minutes, the final temperature of the oven being 70° C. They appear to germinate as well in the heated soil agar medium as in the dung decoction agar. A germ pore is present, as has been shown by Overton (loc. cit. *f. 15*). Germ tubes are usually put out at both ends of the spore at points only slightly to one side of the ends (FIG. 1). Four pure cultures of this species were allowed to grow for six weeks. The mycelium branched profusely in every direction and grew slowly and irregularly. Its appearance was such as to suggest that the nutrient medium was unsuitable for its normal development. After being subjected to daily examinations they became contaminated and were discarded.

The following table shows the results obtained from twenty-six plates inoculated and heated to 65°–75° C., the time ranging from 7 to 25 minutes. The low average per cent of germination (40 per cent) is accounted for by the fact that eight plates were overheated.

TABLE VII

Spore germination in *Thecotheus Pelletieri*

Date 1911	Number of plates	Agar medium + decoction	Time to heat oven	Final temp. of oven, C.	No. of cultures germinated	Positive results, per cent
Apr. 1	1	Goose d.		75°	1	100
*Apr. 4	8	Horse d.	20 min.	65–70°	6	75
Apr. 6	8	Goose d.	20 min.	70°	3	37
Apr. 13	1	Horse d.	7 min.	70°	0	0
†Apr. 19	8	Goose d.	25 min.	75°	1	12

ASCOBOLUS LEVEILLEI Boud.

Damp chamber cultures on horse dung produced such a large number of mature ascocarps that the spores could be caught directly by inverting an uncovered plate over the dung for an instant. In the first experiment three scattered clusters of spores were caught on the medium. The plate was heated to 68° C. in

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* Plates were left to cool in the oven with the door closed. The temperature of the oven one hour after beginning the heating process was 55° C.

† The porcelain-lined oven was used. The eight plates were stacked one above the other. Spores in the bottom plate, the one most heated, germinated.

the oven. Two spores germinated (FIG. 27). The mycelium of this form is more delicate than that of the other species I have studied.

ASCOBOLUS LEVEILLEI var. AMERICANUS Cooke & Ellis. N. A. F. no. 1096.

I was unable to germinate the spores in cultures run parallel with those of *A. Winteri*. Five inoculated plates of horse dung decoction agar heated to 65°–76° C. likewise gave negative results.

ASCOBOLUS XYLOPHILUS Seaver.

This species was collected by F. J. Seaver in Colorado during the summer of 1911. It is one of the few species of *Ascobolus* that are said to grow on wood. An agar medium containing a decoction of heated soil was used. Eight plates were inoculated with small pieces of the dried ascocarps and heated to 55°–70° C. Only two germinated spores were found (FIG. 15). Small amounts of sodium carbonate were added to the medium, previously heated to only 55° C. and then reheated up to 70° C., with negative results. Another medium was made up with a decoction of decayed wood but this did not prove any more effective.

THELEBOLUS STERCOREUS Tode.

After two days, delicate growths of mycelium appeared in two cultures, described above, at several different points where the inoculation with the ascocarps of *A. xylophilus* had been made. No germinated spores of *Ascobolus* could be found at these points, but after eight days an abundant crop of the apothecia of *Thelebolus stercoreus* appeared on this mycelium. The apothecia were arranged in characteristic zones as figured by Ramlow (1906). The material in one plate was killed and imbedded for sectioning. The other plate continued to produce ascocarps for two months, remaining practically a pure culture of *Thelebolus*. Massee & Salmon (1902) and others have already pointed out that this species occasionally produces more than one ascus in an ascocarp. Such abnormalities as the production of the large spherical ascus directly from a cell of the ascogonium at a time before any of the enveloping hyphae had become visible, were also observed. Ramlow (loc. cit.) found that the spores germinated at ordinary temperatures. The circumstances under which the species appeared in my cultures show that the spores will grow after being heated to 55°–60° C. for about 10 minutes.

SACCOBOLUS NEGLECTUS Boud.

The spores germinate readily after being heated to 60°–70° C. during a period of 15 minutes. Commonly one spore of the eight in the spore mass swells to a great size and sends out two or more germ tubes a little to one side of the ends (FIG. 6, 7). In their natural condition the spores are only slightly roughened, but after the swelling which precedes germination the spore wall is cracked in all directions and assumes a roughly warted appearance. In my experiments seldom more than four spores of the group of eight germinated. The mycelium develops in an agar medium containing a decoction of dung or heated soil and fruits well after about 10 days.

ASCOBOLUS FURFURACEUS Pers.

The ascospores which were used in the cultures of this species were secured from an isolated ascocarp of a typically furfuraceous form. A small quantity of sodium carbonate (1:500) was introduced into a plate of heated soil agar and the latter was again sterilized a few minutes at 90°–100° C. The plates were inoculated and the oven heated for 20 minutes, rising to a temperature of 65° C. The spores germinated very readily under these conditions (FIG. 29).

LASIOBOLUS EQUINUS (Müll.) Karst.

Mature ascocarps were crushed out in horse dung decoction agar and heated 15–17 minutes to 65°–68° C. A large number of spores in this plate germinated, but the culture soon became contaminated with bacteria and other fungi and developed no ascocarps.

ASCOBOLUS GLABER Pers.

Several forms of this species have been described. The one used in my work was not colored. The colorless *A. albidus*, which Massee & Salmon (1902) consider a variety of this species, is not, on the evidence of their description and figures of the germinated spores, the same that I have used. The irregular ridges of the epispore are shown in FIG. 26, *a*. I used a horse dung decoction agar in the one experiment tried. The plate was heated for 20 minutes in the oven, and the oven temperature reached 70° C. Many of the spores germinated within 24 hours. The germ tubes were well developed and the hyphae formed later were not distinguishable from the hyphae of *A. immersus*. Two views of a germinated spore are shown in FIG. 16, 26.

TABLE VIII

Species	Date	No. of plates	Medium, agar +	Time to heat oven, minutes	Final temp. of oven, C.	Germination observed
Ascobolus Leveillei var. *americanus*	(1910) Nov. 6	1	horse dung decoction	10	76°	——
Ascobolus Leveillei var. *americanus*	(1911) Oct. 8	4	horse dung decoction	15	65°	——
A. Leveillei	Apr. 7	1	horse dung decoction	17	68°	Apr. 8
A. glaber	May 5	1	horse dung decoction	20	70°	May 6
Lasiobolus equinus	(1910) Nov. 28	2	horse dung decoction	20	80°	——
Lasiobolus equinus	Nov. 29	1	horse dung decoction	11	75°	Nov. 30
Ascophanus carneus	Nov. 15	1	horse dung decoction	15	75°	——
Ascophanus carneus	Nov. 7	1	horse dung decoction	10	70°	——
Ascophanus carneus	Dec. 20	1	horse dung decoction	18	69°	Dec. 21
Ascophanus carneus	(1911) Sept. 29	3	goose dung decoction	15	74°	Sept. 30
Ascophanus sarcobius	Sept. 29	9	goose dung decoction	15	74°	Sept. 30
Ascobolus xylophilus	Dec. 21	3	N/100 Na_2CO_3 + wood decoction	20	60–70°	Dec. 23
Ascobolus xylophilus	Dec. 19	5	heated soil decoction	11	55°	——
A. furfuraceus	Dec. 21	3	heated soil decoction + N/50 Na_2CO_3	17	65°	Dec. 23
Thelebolus stercoreus	Dec. 21	2	heated soil decoction	20	60°	Dec. 23
Saccobolus neglectus	Dec. 24	1	heated soil decoction	16	65°	Dec. 25
Saccobolus neglectus	Dec. 24	1	horse dung decoction	16	65°	Dec. 25
Saccobolus neglectus	Dec. 25	1	horse dung decoction	20	71°	Dec. 26
Saccobolus neglectus	Dec. 30	1	goose dung decoction	16	74°	Dec. 31
Ascodesmis nigricans	Nov. 1	15	goose dung decoction	0	Room	Nov. 2
Ascodesmis nigricans	Nov. 2	2	goose dung decoction	7	50°	Nov. 3

TABLE VIII gives the data obtained in germination experiments with the several species just described. The percentage of germination was not recorded.

ASCODESMIS NIGRICANS Van Tieghem. (*Boudiera Claussenii* P. Henn.)

This species appeared in a damp chamber culture of *Gymnoascus ruber* and *Ascobolus viridulus* on dog dung, April 2, 1910. Several germinated spores were found on the slides used to catch the spores of the *Ascobolus*. The same fungus appeared on human excrement the following September, and a year later still another crop was found growing on goose dung. The spores germinate at room temperatures equally well in dung decoction agar and in a medium made up with decoction of heated soil. Some of the plates were heated to 45°–50° C. for 10 minutes without killing the spores. The mycelium grows rapidly and ascogonia and antheridia appear the second day. As many as ten concentric zones of fruits are formed in some plates. In this condition it resembles the culture of *Thelebolus stercoreus* described by Ramlow (1906), except that the zones of ascocarps are wider than the sterile spaces between adjacent zones. These two species are the only ones of the Ascobolaceae I have grown artificially that show such concentric zones.

The species of Discomycetes, *Detonia trachycarpa*, *Lachnea melaloma*, and *Plicaria violacea* were frequently found on carbonaceous earth along with *Ascobolus carbonarius*. Spores of these species did not germinate when heated to 65° C. in a heated soil decoction agar. *Ascobolus pusillus* (FIG. 8) is another species frequently found on old burned places. I tried two inoculations with spores of this species. The plates were heated to 65° C. None of the spores of *A. pusillus* germinated while practically all of the spores of *A. carbonarius* did.

As is well known, the spores of *Pilobolus* germinate in a dung decoction at normal room temperatures. I found that they would also germinate in a dung decoction agar when heated. This method killed off many of the bacteria and spores of other fungi, making it possible to get a fairly pure culture.

If one considers the evidence which has been given above of the conditions under which the spores of fourteen species have been germinated, it will be seen that the artificial application of heat in certain cases is an effective substitute for whatever stimulus acts under natural conditions to induce germination.

We may now turn to the results obtained by the study of the development of the apothecia in certain of the species named above.

ASCOBOLUS CARBONARIUS Karsten, Fungi Fenniae exs. 463. 1866.

In 1866 Karsten issued as no. 463 of the Fungi Fenniae this species of *Ascobolus*, accompanied by a description which stated that the ascocarp was sessile, greenish, later brownish, and furfuraceous on the exterior. The spores were described as oblong-ellipsoid and purplish black. A formal description was published later (1870). This gave the spore measurements and added that they were reticulately sculptured and violaceous-fuscous in color. The habitat given for the species was on earth among pieces of charcoal. The identity of the species under this name seems to have been entirely lost sight of until the appearance of Seaver's paper on the Iowa Discomycetes (1910). Seaver concludes from a study of no. 463 Fungi Fenniae that the species commonly known as *A. atrofuscus* Phil. & Plow. is the same species. It has long been known that *A. carbonicola* Boud. (1877) and *A. viridis* Boud. (1869) are synonyms of *A. atrofuscus*. Durand (1902) has discussed the synonymy of *A. atrofuscus* and includes *Phaeopeziza Nuttallii* E. & E., N. A. F. no. 2908, among the synonyms. After having examined F. F. exs. no. 463, Phil. Elv. Brit. no. 47, E. & E., N. A. F. no. 2908, Fungi Galliae exs. no. 3935, and compared the spore markings and measurements with Boudier's figures and descriptions of *A. viridis* Boud. (1869, *pl. 5. f. 10*), I am convinced that our common species growing on burned places is identical with Karsten's *A. carbonarius*. Boudier has called our attention to a very characteristic abnormality which occurs in the formation of the outer layer of the spore wall. Such spores as he has figured (loc. cit., *pl. 5, iv, fig. 10*) can be found in all the exsiccati specimens referred to above, and in any collection brought in from this vicinity. FIG. 11 was drawn from a spore taken from Fungi Galliae no. 3935 (*A. atrofuscus*).

One reason for the confusion as to the species is found in Karsten's description of the spore markings. The surface is at first covered with coarse warts and can not well be described as reticulated until the spore walls have dried out and cracked around the borders of the warts. In this condition the spores are reticulated, the reticulations, however, are formed by the cracking of the epispore. The only other species growing on burned places likely to be confused with *A. carbonarius* is *A. pusillus* Boud. (1877). *A. carbonarius* may be found from May until November growing where quantities of wood have been burned. Places burned in the autumn are favorable for the growth of this species during May and June.

As noted above, Boudier (1869) has given us a correct figure of a germinated spore of this species under the name *A. viridis*. Sometimes several germ tubes will arise from the middle of a spore instead of from near the end. The epispore is cracked in all directions, the smaller cracks running in between the warts and two or three larger cracks extending down to the endospore (FIG. 9, *a*).

The germinated spore becomes an integral part of the vegetative mycelium as was noted by De Bary (1884) for many Ascomycetes. FIG. 30 shows that the spore becomes a multinucleated cell, limited by the transverse septa formed beyond the points where the germ tubes emerged. Immature spores which germinated are shown in FIG. 31, *b*.

When the spores are germinated in a decoction of heated soil, and the mycelium is allowed to grow for two or three days in this liquid, there frequently appear at intervals along the course of the hyphae, swellings or sporelike bodies (FIG. 9, *b*, *d*). Such a body is first formed at the end of a hypha but immediately sends out another hypha from the opposite side so that it appears to have been formed as an intercalary swelling. They are probably merely vesicles such as are very commonly found in artificial cultures of all sorts of fungi.

About the third or fourth day one may look for the first appearance of a large number of spherical hyaline bodies arising at the extremities of straight narrow stalks, which are branches of the ordinary hyphae. They are borne singly, and as they are thin-walled and plainly function as spores they may be called conidia. These conidia are perfectly smooth and about 10 μ in diameter. They may be asexual spores designed to spread the species more extensively over the burned area, or they may possibly be blown by the wind and then germinate under suitable conditions in regions far removed from the parent mycelium.

The conidiophore is slightly smaller at the end bearing the conidium (FIG. 9, *c*). One septum cuts off the conidium from its stalk and a second septum usually occurs at about the middle of the stalk. I am unable to state how these conidia are oriented when this species grows under normal conditions on carbonaceous earth. In artificial cultures on agar media and in liquid extract of heated soil they show little tendency to rise above the surface of the medium. They may be formed along the bottom of the Petri dish, within the medium itself, or may extend out above the surface.

A milk-white fluffy mass of mycelium always appears around the edge of the dish in cultures on agar. This mycelium is especially productive of the conidia. The conidia found on the surface of the medium are more or less pear-shaped and are bunched together on rather short threadlike stalks. Very rarely one finds a larger form bluntly pear-shaped and borne on an exceptionally long stalk (FIG. 45). It is not uncommon to see conidia with bladderlike outgrowths at the end or at one side (FIG. 10, 46, 48). In cultures several days old many of the conidia are entirely empty. This may have been due to a lack of sufficient nourishment or to some unknown pathological condition of the culture.

The method of the origin of the ascocarp in this species is unique among the Discomycetes so far studied. The process involves certain perplexing complications which occur at various stages, and we can come to a better understanding of what I believe to be the normal course of events by first describing what I consider a medial well-marked stage of development such as is shown in FIG. 33. The same letters are used throughout the description of earlier and later stages to designate particular parts of the initial apparatus in this species. FIG. 33 shows a spherical conidium (*a*), borne at the end of a rather stout stalk (*b*) which arises from a cell of a mycelial hypha. A septum cuts off the conidium from its stalk. The conidium has sent out a tube (*d*) nearly equal in diameter to that of the conidium itself. There is a slight constriction at the point of emergence. The germ tube grows straight out for a distance of 50–90 μ and then forms a coil (*f*) of two to four turns. The cells of this coil all have the same diameter, each being three or four times as long as it is thick. The entire ascogonium at this stage consists of twenty to forty cells arranged in a loose irregular spiral tapering gradually toward the tip. The distal cell (*g*) of the stalk coil bends sharply and connects with the first cell (*h*) of the ascogonium by a large pore which is distinctly visible. The cell (*h*) is somewhat spherical and its diameter is much greater than that of the stalk cells. The distal cell (*j*) of the ascogonium grows out to form a cell (*k*) whose length is two or three times its diameter. This and the ten to twenty cells next beyond it form an organ (*l*) which it seems to me must be considered as a trichogyne. This trichogyne is more or less irregularly coiled and gradually tapers toward the end, which has coiled itself tightly about the upper part of a somewhat elongated conidium (*m*). The stalk (*n*) of this conidium is much longer and more slender than the stalk of the conidium (*a*). From the conidiophore (*b*) there arises a stout hypha, which sweeps out in an even curve, extending the entire length of the ascogonial coil. It sends out branches at intervals (*p*), which may anastomose with investing hyphae by H-shaped connections (*q*), and some branches come to lie in the region of the end cell (*j*) of the ascogonium. Other investing hyphae arise from the cells of the stalk coil. The stalk coil does not taper in either direction, and the sharp contrast in the shape, size, and contents between the cells *d* and *h* and between the cells *j* and *k* enables us to distinguish with certainty the limits of the three regions of the system, viz., the stalk, ascogonium, and trichogyne. The cells of these regions differ markedly in their behavior in fixing and staining. The cells of the stalk coil are dense and finely granular, are moderately darkened by osmic acid, and deeply and evenly stained by aceto-carmin and safranin. The ascogonial cells have more coarsely granular and vacuolar contents. The cells of the trichogyne are nearly hyaline, are not blackened by osmic acid, and do not stain readily.

The connection between the tip of the trichogyne and the conidium is very close. Whether fusion takes place can not be determined from the preparations as studied in glycerin jelly. There can be no question, however, as to the specific attraction between the trichogyne and the conidium, and I shall call it the antheridial conidium.

We may now note some variations from this type of development. FIG. 36 shows an archicarp in which the stalk is evenly coiled in a sort of snail-shell form. The conidium giving rise to the coil is concealed below but the stalk of the conidium is evidently at *b*. The ascogonium has made only one or two turns before growing far out in the medium. The outer portion has coiled upon itself and either come to an end at *j* or continued as a hyaline filament (*l*) which has come in contact with a mycelial hypha. This figure was drawn from the first fruit of this species that I had seen, and before the existence of the long transparent trichogyne was known. Since investing hyphae were being formed about the ascogonium, fertilization had evidently already taken place and the trichogyne, being dead, would scarcely have been visible without staining.

FIG. 34 shows an archicarp that has failed to develop further, probably owing to some injury received when an adjacent portion of the medium was removed. The first part of the stalk coil could not be found, and the remaining cells are entirely empty. The other regions, however, are very plainly marked, especially the connection between the stalk coil and the first cell of the ascogonium. The end of the trichogyne is plainly coiled around an antheridial conidium.

The young stages of a large number of ascocarps were examined and in every case in these cultures the ascocarp originates from a germinated conidium. This conidium can not be distinguished from the countless other conidia until it has germinated. The stalk is much stouter than in the case of the others. These female conidia may germinate in liquid extract of heated soil and form the stalk coil only. I have never been able to find the complete archicarp in a liquid medium. Occasionally one finds such cases of arrested development in cultures on agar media. FIG. 42 shows that after the stalk coil has been formed, it may take on a vegetative growth.

It is not always possible to trace the connection between the trichogyne and the antheridial conidium. In some cases the end of the trichogyne was quite plainly visible but the connection with the conidium could not be found. FIG. 35 represents a vigorously growing young ascocarp. The trichogyne (*l*) is very close to the long-stalked conidium (*m*). FIG. 40 shows a type in which the whole system is closely twisted into a tangled mass of hyphae, yet the trichogyne (*l*) is plainly seen coiled about a conidium (at *m*).

We have seen that the ascocarp originates as the result of the germination of a female conidium, the formation of a stalk coil, ascogonial coil, and a trichogyne. Whether fertilization regularly takes place by the fusion of the trichogyne with the second conidium is a question that can be determined only after further investigation.

In all the cultures containing ascocarps may be found a structure that at first sight might be taken for the stalk coil of the archicarp. It is, however, quite different in that it originates as a branch from a mycelial hypha, and after making a loose irregular coil of two or three turns sends off branches from various cells. It very frequently produces conidia either on short stalks arising from its cells (FIG. 48) or at the tip end of the coil (FIG. 47). Such coils have not been found in cultures not producing ascocarps, but are very common wherever fruits are being formed. They may be rudimentary archicarps.

One marked feature in connection with the formation of the vegetative portion of the ascocarp, is the presence of the hypha referred to above (FIG. 33, 35, 42) as arising from the stalk of the conidium that produces the archicarp. This hypha may, apparently in some cases, grow out of the conidium itself (FIG. 37, 44) or from the posterior cells of the stalk of the oogonium (FIG. 41). In either case it curves sharply over and extends along the coils of the ascogonium, coming to an end in the region of the trichogyne. This hypha and the stalk coil are still plainly visible in all young ascocarps, even after they have become comparatively well developed. No fusion was observed between this hypha and the trichogyne, although its structure and location might lead one to suspect that its function was not merely vegetative.

The growth of the apothecium proceeds slowly and several days elapse before ascogenous hyphae can be found. In the meantime a fringe of hyphae, the familiar secondary mycelium, grows out from the apothecium and penetrates the substratum in all directions. When this species is cultivated on carbonaceous earth in the laboratory, the base of the apothecium is clothed with a collar of light greenish yellow mycelium.

If the young apothecia are removed from the artificial medium and carefully crushed under the cover glass, the cells giving rise to the ascogenous hyphae may slip out and become exposed to view (FIG. 38). Staining with a drop of aceto-carmin serves to differentiate the paraphyses and the ascogenous system from the other tissues of the ascocarp. About three cells of the ascogonium nearest its stalk coil have become very much enlarged so that they are nearly spherical. The method of the formation of the ascogenous hyphae should be noted. Primary ascogenous hyphae first grow out from the second cell as stout spikelike growths, which are unbranched and consist of four or five cells each. When fullgrown they are somewhat irregularly bent in the region of their tips. This is no doubt due to the obstructions they meet, otherwise they are perfectly straight (FIG. 39). Secondary ascogenous hyphae arise from the ends of each of these primary hyphae and branch a few times to produce the ordinary hook-shaped tips. The ascus arises from the penultimate cell while the ultimate cell may continue its growth and produce another ascus, or if this does not occur it bends sharply downward and becomes closely applied to the antepenultimate cell and possibly fuses with it. At the time when these primary ascogenous hyphae have attained about half their full growth, the next cell of the ascogonium, which is somewhat smaller than the one just described, begins to give rise to similar outgrowths, except that the basal cells may be somewhat swollen (FIG. 39, *r*). It is difficult to obtain both stages at the same time, consequently this cannot be said at present to be a constant feature. The swelling may have been due to the action of the aceto-carmin used in staining. The characteristic staining of the paraphyses and their close connection with these stalklike outgrowths from certain cells of the ascogonium may indicate a closer relationship than is now held to exist.

The ascocarps ripen slowly in the artificial media and reach maturity in 20–30 days after the spores have germinated. The largest ones grown artificially were 4–5 mm. in diameter. Spores from these have been used to obtain a second generation and do not appear to germinate without being heated. Ascocarps grown on the natural substratum in the laboratory require slightly less time to reach maturity and are usually larger than those grown artificially.

ASCOPHANUS CARNEUS Pers.

The cultures used in the studies of the origin of the apothecium of this species were obtained by transplanting small pieces of filter paper bearing the ascocarps to dung agar, where the mycelium grew rapidly and formed ascocarps sufficiently isolated to be transferred. In the first cultures large numbers of Zukal's sclerotia (1889), the gemmae of Ternetz (1900), and the chlamydospores of Cutting (1909) appeared. After several such transfers no such bodies were found. Nine pure cultures of a rough-spored variety, *A. sarcobius* Boud., from Bermuda, have not developed these chlamydospores. The ascospores of this variety are sufficiently large and well marked to enable one to remove them from the slide on which they are caught, with some degree of assurance that the spores of other species are not introduced into the medium at the same time. Three cultures containing the common smooth-spored form, all contain the "chlamydospores." Ternetz's careful investigation would indicate that the production of these bodies is characteristic of this species. Their non-appearance in certain cultures might be due to the nature of the medium used or to light and heat conditions. Or this may be good evidence that *A. sarcobius* is a very distinct species and not a variety of *A. carneus* as I at first assumed. Miss Ternetz's figures of the ascogonium agree with those I found in cultures obtained by transfer. The stalk (FIG. 17, *a*) is composed of about five to eight hyaline cells. The ascogonium is differentiated as a region of five or six larger, granular, and slightly colored cells. The ascogonium forms a loose coil of one or two turns (FIG. 17, *b*) and gives rise to a trichogyne which consists of five to seven narrow, non-granular cells. This organ is usually coiled tightly around over the body of the ascogonium but may sometimes be seen extending straight out into the medium. When this occurs, one frequently finds that it gives rise to a slender branch at about the fourth cell. This side branch (FIG. 17, *d*) may in some cases curve over and come in contact with a hypha arising from the first cell of the stalk of the ascogonium, but I am unable to state at present whether this is a constant feature in the process of development. None of the cultures from the germinated spores has produced ascocarps. Ternetz has proved that *Ascophanus carneus* does not produce fruit when kept in darkness. My cultures were placed in a very dimly lighted room and this may account for their failure to produce ascocarps. Under the same conditions, however, *Ascobolus Winteri* fruited abundantly.

ASCOBOLUS WINTERI Rehm; Rabenhorst, Krypt.-Fl. 1^3: 1124. 1896.

The identification of this species was a matter of some difficulty. In some features it resembles *Ascobolus brunneus* Cooke, *A. stictoideus* Speg., *A. amoenus* Oud., *A. Leveillei* (Cur.) Boud., and *A. Leveillei* var. *americanus* Cooke & Ellis. The spores from apothecia grown in a vasculum are smooth, hyaline, and about 30 μ in length. They appear to be perfectly mature. The asci project from the ascocarp, and the spores are shot upward several centimeters. Such spores might be those of an *Ascophanus*. Spores in the asci from cultures in the light are pale amethyst colored. It is possible to so place this species with reference to the light that hyaline spores will be thrown off from apothecia on one edge of the substratum and well colored spores from the other. The spores are delicately warted; the warts being arranged in short broken lines give it a somewhat reticulated appearance, a characteristic of the spore of *A. brunneus* according to Rehm (1896). A few narrow cleftlike furrows in the epispore are visible (FIG. 12). These apparent clefts resemble those peculiar to the spores of *A. immersus* (FIG. 20). The young apothecia may appear to be either white, greenish, or cinereous, but this color is probably only that of the substratum showing through. The apothecia are rather transparent and colorless. Cf. *A. stictoideus* Speg. The fungus could not be identified with the descriptions of any known species.

In the Massee collection is a specimen accompanied with colored illustrations. The specimen is on goose dung and had been identified by Massee as *A. glaber*. His figure of the spores, and the spores themselves, agree with those in no. 211 Rehm Ascom. exs. (*A. Leveillei*) and with the spores of our species. Massee's specimen can not be *A. glaber*, because the purple spore markings of that species consist of ridges and not cracks. As is well known, Rehm afterwards decided (1896) that his *A. Leveillei* is a new species, which he calls *A. Winteri*. As noted, I was unable to identify this specimen from Rehm's description, but the agreement of my material with no. 211 Rehm Ascom. exs. is perfectly convincing.

Our species has been found on goose dung from several different localities in this vicinity but not on any other substratum. No other species of *Ascobolus* has been found with it, although abundant growths of *Ascophanus carneus* sometimes follow after a week.

An epidemic of cholera destroyed the geese at the Zoological Park in the summer of 1911. There were many other kinds of fowl around the same ponds after the epidemic but the fungus was not found on their dung. It was necessary to obtain material from other localities. It would appear that we have in this case one species, at least, that is closely confined to a particular kind of substratum.

The time that intervenes between spore germination and the formation of the initial organs of the apothecium, seems to depend mainly on two factors, viz., the nature of the medium and the point at which the inoculation has been made. If a weak decoction of dung or of heated soil is used in making up the agar medium a correspondingly longer time must elapse. If the inoculation is made at about 2 cm. from the edge of a Petri dish 10 cm. in diameter, the first apothecia will be found at a point between the germinated spores and the nearest edge of the dish. They have often appeared in this region in less than 48 hours after the spores germinated. On the other side, the mycelium will spread out fanlike and reach the edge in 4–6 days. Curiously enough, as a usual thing, no apothecia are formed until the growth of the mycelium is interrupted by the edge of the Petri dish; then they begin to appear in patches around the border. Later on, dense clusters may spring up at any point in the medium. Other regions may remain entirely free from apothecia. When spores are sown at two points on opposite sides of the plate rather close to its edge, the hyphae from either region will not cross over into the territory of the other, but the apothecia are formed in an irregular line just back of the tips of the hyphae, parallel to a neutral zone between the two mycelia. (TEXT FIG. 1.)

FIG. 1. Shows the growth of the mycelium and formation of the apothecia of *Ascobolus Winteri* in a culture inoculated at two points on opposite sides of the plate.

FIG. 2. A large number of apothecia are formed in the region at *c*, where a colony of bacteria has developed.

The behavior of the vegetative hyphae with reference to bacterial colonies present in the cultures, also shows some interesting peculiarities. In some cases the mycelial hyphae would run through and over the bacterial colonies and mingle with them. In other cases the growth of the hyphae was checked at some distance from the bacterial colony, apparently owing to the emanation of toxic substances from it. A sterile zone one centimeter wide was sometimes left between the hyphae and the bacteria. Bordering this zone a dense aggregation of apothecia would form. (TEXT FIG. 2.)

No circular concentric zones of fruit bodies were formed in this species. Any factor tending to limit the vegetative growth of the mycelium serves to bring about the formation of apothecia.

The manner in which the mycelium made its way in a hard medium deserves notice. Ordinarily the mycelium grows along the bottom, within the medium itself or on the surface. When a very hard agar is used, as described under spore germination, the mycelium from the germinated spores divides into two portions, one growing on the surface, the other along the very bottom. On focusing down through the medium the two planes of growth are seen to be very sharply defined. The older mycelium does not show the planes of separation as does the mycelium formed during the first few days. Another interesting feature in this connection is the vertical distribution of the ascocarps. In some cases all of the ascogonia were formed deep down in the medium and in direct contact with the bottom of the dish. Again they would form on the very surface of the medium or be distributed irregularly as regards depth. The amount of light and its direction, the temperature of the room, and the depth of the medium in the dish are apparently the determining factors in this respect.

The apothecium takes its origin in a well marked archicarp, which arises as a branch of a mycelial hypha and immediately bends sharply on itself. As growth proceeds its diameter increases to such an extent that it can be readily distinguished from ordinary vegetative branches (FIG. 50). A septum is formed a few microns from the parent hypha, and the distal part (FIG. 51) begins to curve at the tip and to form a spiral (FIG. 52) which ultimately consists of two or three complete turns (FIG. 53). This spiral may be formed on the same side of the hypha where it originated, or the branch may curve over or under the hypha and form the spiral on the opposite side. The coil continues to grow and thicken and soon becomes septate. Its tip becomes somewhat long and tapering, and on analogy with the carpogonia of the lichens may be regarded as a trichogyne. We can distinguish three regions in this initial organ (FIG. 54): the stalk (*a*) consisting of two or three cells; these, however, are not sharply distinguished from (*b*) one of the two or three larger central cells, which later becomes the ascogenous cells. The remaining outer portion of the spiral (*c*), which I shall call the trichogyne, is made up of three or four cells which gradually decrease in diameter and end rather abruptly (FIG. 53). At this time the cells of the coil are not inclosed by investing hyphae. A great many archicarps can be found in the stage of development shown in FIG. 53, and this may indicate that a short resting period occurs at this time. I have not found that the archicarps are produced more abundantly during any particular hour of the day. From the first stalk cell a hypha (*d*) now arises which apparently grows very rapidly, keeping close to the coil (FIG. 54). Similar branches (*e*) then emerge from the second or even the third cell and these appear to be the first enveloping hyphae. At this stage the tip of the trichogyne may sometimes be seen to be entirely free but lying close to the next adjacent turn of the coil. Development from this stage on takes place so rapidly that it is difficult to follow the process. By crushing small portions of agar containing ascogonia under the cover glass and staining with acetocarmin or methylene blue, stages were found in which the tip of the trichogyne had actually applied itself to the branch from the lowest cell and perhaps fused with it. In several cases observed the point of contact is some distance back of the tip of this branch. It is quite possible that there is a fertilization at this stage and that the branch arising from one of the stalk cells is an antheridium. FIG. 55 shows the point of contact still farther from the tip than is ordinarily the case. When this cell was first examined no indication of a fusion could be made out, but when the cover glass was pressed down on the agar the spiral was partly untwisted and the apparently fused cells were exposed to view. FIG. 54 shows another similar fusion.

Many archicarps fail to produce apothecia. In these the spiral is more open and makes only one or two complete turns before a long tapering trichogyne is formed. The central cells are fewer in number, and the stout hyphae arising from the two or three stalk cells appear very early and extend straight out into the medium instead of up over the coil towards the trichogyne. The trichogyne tapers gradually into a slender tip (FIG. 57, *c*), or it may be set off sharply from the larger cells by a very sudden narrowing (FIG. 56). Such forms as these are very conspicuous and should be favorable for study. Although many attempts have been made to follow their development, no case was found in which the trichogyne came in contact with a hypha from the basal cells. As noted, none of these cases observed developed apothecia or continued their growth to any great extent. In one case the trichogyne was seen to be apparently fused with branches from neighboring hyphae, and the branches from the basal cells were observed to fuse with similar vegetative hyphae. FIG. 57 shows such a fusion which resulted in no further development. Their failure to develop normally may possibly have been due to the treatment to which the plants were subjected in studying the cultures, which may have resulted in slight drying or even mechanical injury. Still in some cases archicarps were observed at about two-hour intervals continuously for two or three days, which showed but little further growth, while all about in the same cultures other coils were continuing their development and apothecia were being ripened. It seems quite possible that the failure of these archicarps to develop was due to failure of the trichogyne to effect a fusion with an antheridium, though the explanation of this failure is not clear.

ASCOBOLUS IMMERSUS Pers.

This species is widely distributed and very well known. The spores, which are about 60 × 30 μ, are entirely smooth with the exception of a few narrow clefts in the epispore (FIG. 20). FIG. 21 represents a spore germinating at four different points. The germ pores are distinctly visible at this stage. FIG. 22 and 23 show two germinated spores from the same group of eight. The hyphae shown in FIG. 23 were well fixed with a weak Flemming's fluid. The cytoplasm has a finely granular structure. The cytoplasm of the large hyphae (FIG. 22) is very coarsely reticulated and vacuolar. As the germ tube issues from the pore, it enlarges suddenly, giving rise to a hypha slightly thicker than the hyphae produced by some spores. These coarse hyphae can readily be distinguished in cultures on agar media. I have not learned that they differ functionally from the smaller and more common sort.

The mycelium grows vigorously in heated soil agar but produces very few fruits. The most abundant crops were obtained on a goose dung decoction to which sodium carbonate (1:500) had been added. It will be seen by referring to FIG. 24 that the archicarp is larger and contains more cells that the archicarp of *A. Winteri*. The structures shown in this figure are somewhat disproportionally swollen by the aceto-carmin stain, especially the parent vegetative hyphae. The archicarp consists of about twenty cells, of which we may say four to six belong to the stalk, about eight to the ascogonial region, and the remaining cells to the trichogyne. A large number of archicarps were stained in toto with aceto-carmin and iron-hematoxylin. In a majority of these preparations there were three or four cells of the archicarp that took but little stain. All the other cells contained several nuclei while only an occasional nucleus could be found in the region of these hyaline cells (FIG. 25). I have seen no cultures that appear to be more vigorous that this one, and as there were many apothecia in all stages of development present, I can not believe this was a pathological condition. If such were the case it was pretty generally distributed in the culture.

In this species as in all others I have studied, the spiral nature of the coil is much altered as the ascocarp is developed. The investing hyphae push in between the turns and straighten out the coil so that sections of the apothecium show a wormlike body.

The young apothecia are covered with a secondary mycelium which spreads out in all directions, even directly upward to the surface of the medium when the apothecium is completely imbedded. The time required for the production of the mature fruit seems to be much longer in these artificial cultures than is the case with plants developing on the natural substratum.

ASCOBOLUS FURFURACEUS Pers.

The manner in which the spores germinate (FIG. 29) does not differ materially from that described for other species. Nine days after the germination, the cultures contained hundreds of archicarps and young ascocarps. The light greenish color was present at a very early stage. Molliard (1903) and Claussen (1905) found great numbers of oidia were produced on the mycelium. As has been noted above, the former was unable to obtain ascocarps without the introduction of bacteria. Claussen grew the mycelium from oidia for one hundred generations without obtaining fruits. I am very certain that no oidia were produced in these cultures, nor were there any chlamydospores such as Welsford (1907) has described. These asexual spores may possibly be produced under different cultural conditions from those maintained in my experiments.*

The archicarp is very similar to that of *A. Winteri* and *A. immersus*. The three regions, stalk, ascogonium, and trichogyne, are not as distinctly differentiated as in the archicarp of *Ascophanus carneus*. The archicarp arises from the mycelium and forms a spiral coil of three or four complete turns. FIG. 28 is reconstructed from stained microtome sections. The few investing hyphae arising from the stalk cells and growing up near the trichogyne, are not included in the drawing. The stalk is quite well marked, consisting of about four short cells. The complete archicarp consists of about twenty cells.

GENERAL DISCUSSION

It is probably true that many species of the Ascobolaceae are distributed by animals that have eaten food upon which the spores have been ejected. It has been shown by Janczewski, Massee, and others, that animal digestion may be an effective stimulus to germination, or at least that the spores are not killed by this treatment. It is well known that the spores of *Thelebolus*, *Ascodesmis*, and species of *Rhyparobius* will germinate in dung decoctions or even in tap water without special treatment. Coprophilous fungi such as *Pilobolus*, *Gymnoascus*, and *Coprinus* germinate at ordinary temperatures; and it has not been proved that the species of *Ascobolus*, which have been thought to germinate only after being digested by animals, may not germinate readily at ordinary temperatures after a sufficient resting period. During a resting period of several weeks or months the possibly necessary chemical changes leading up to germination might be effected by natural agencies, such as the products of bacterial decomposition in the substratum, alternation of heat and cold, changes in condition of moisture, etc. My experiments show that occasionally the spores of a species will grow under conditions that are not, however, favorable for a general germination. These exceptional cases may account for the many contradictory statements that have been made

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* Oidia have been found in several later cultures, presumably of *A. furfuraceus*, though they remained sterile and I have been unable to determine their identity with certainty.

regarding the germination of the spores of certain species of the Ascobolaceae, and any experiments on germination should take into account this apparent variability in the tendency of the spores to germinate under given conditions. None the less it is clear from my experiments that the spores of *Ascobolus* in general will not germinate in culture media at ordinary temperatures.

It has been recognized by many investigators that exposure to rather high temperatures favors the germination of spores as well as the germination of seeds. It is also well known that temperatures of 50°–60° C. do not kill the spores of certain species of fungi. I have been unable to find any account of germination effected at temperatures of 50°–60° C. when much lower temperatures would not have proved even more satisfactory. As the experiments here described have shown, the spores of certain species of *Ascobolus*, *Ascophanus*, *Thecotheus*, and *Lasiobolus* could be made to germinate abundantly by heating them to 50°–70° C. for a short time. The method of artificial culture that I have employed differs from others mainly in this fact, that I have subjected the spores to high temperatures for short periods as a means of inducing germination when longer exposures at lower temperatures were not effective. It may be that high temperatures bring about chemical changes analogous to the changes that might be produced at low temperatures during longer periods. It is a striking fact that half-grown spores of *Ascobolus carbonarius* germinated readily after being heated to 60°–70° C.

I have made a few experiments on non-coprophilous Discomycetes, which, however, were too limited to show whether the heating process was especially effective in connection with dung-growing fungi only. My experiments with *Ascobolus* suggest that rather unusual treatments may be effective in stimulating germination in the case of forms that have hitherto proved entirely resistant. It is especially interesting to note that heating not only favors germination but at the same time kills off other fungi which naturally grow along with the *Ascobolus* on the dung. Still certain species of the Sordariaceae germinate at ordinary temperatures in dung decoctions and many of these are not killed at these higher temperatures; in fact, some of them appear also to be stimulated by the process.

It will be of interest to determine whether there are temperature optima for spore germination in different groups of fungi, and also whether these optima correspond to those for enzyme action on fats and other reserve materials found in spores and seeds.

Melhus (1911), working with the spores of certain Oomycetes, has shown that the optimum temperature for the germination of spores of *Cystopus* is below that of the ordinary room and that the spores can be germinated abundantly and after being exposed to temperatures of 1°–5° C. for 24 hours. It is not easy to understand, why low temperatures should be effective in the case of the Oomycetes and high temperatures in the Ascobolaceae. The teleutospores of the rusts can be made to germinate much earlier if artificially subjected to low temperatures. Experiments which I have tried with *Ascobolus*, however, seem to indicate that freezing temperatures are not generally effective.

I have been able to germinate spores of several species of the Ascobolaceae in an extract of heated soil made slightly acid, and have noted a few spores germinating in a film of water on the cover of the Petri dish containing the apothecia. My experiments show that the acidity or alkalinity of a medium, within certain limits, or the amount of nutrient present, are entirely secondary factors and of minor importance in connection with spore germination, though, of course, these factors are highly important for the growth of the mycelium and the production of fruit bodies. As I have described above, the growth of the mycelium and the apothecia is apparently accompanied by the formation of certain toxins in the medium, which have an inhibitory effect on spore germination and on the growth of the mycelium from another region of the culture. This might seem to be opposed to Ferguson's observation (1902) that the spores of *Agaricus* can be made to germinate by placing small portions of the mycelium in the medium with the spores. The statements are, however, not necessarily antagonistic. The presence of an actively growing mycelium of the mushroom might hinder germination.

Janczewski (1871) has pointed out the weakness of a characterization of the Ascobolaceae on the basis of the projection of the asci above the surface of the hymenium. He finds that the asci of many species of the Pezizaceae likewise project above the surface and that such a character is quantitative rather than qualitative. He suggests that it is only by a more thorough knowledge of the initial organs of the ascocarp that a satisfactory classification of the Ascomycetes can be obtained. Such a basis for classification would require a vast amount of investigation, since it is known that forms now widely separated have quite similar initial organs, and that in species now placed in the same genus these organs may be quite unlike.

The archicarp of *Ascobolus carbonarius*, with its long trichogyne conjugating with a conidium, is very suggestive of the conditions in the lichens. The trichogyne of the lichens, however, grows upwards through the tissues of the thallus until its tip becomes slightly protruded above the surface. The spermatia which are extruded from the spermogonia, are then in some way brought into contact with the tip of the trichogyne. It is probably true that many of the conidia arising from the mycelium of *Ascobolus carbonarius* are asexual spores, but it is quite as clear that some of them are functionally equivalent to the spermatia of the lichens. The presence of only a limited number of male cells, and these permanently attached to their stalks, would favor the development of a trichogyne with a tendency to grow outward in a very irregular fashion, thereby increasing their chances of reaching a male cell. In this similarity of the male cells to the ordinary vegetative reproductive cells we may have a step toward such a condition as is present in the rusts, where the sexual fusions occur between equal hyphal cells, and the spermatia have become functionless.

On the basis of these facts I am inclined to favor the view that the Ascomycetes have originated from the red algae through forms like the lichens, perhaps forms that have given rise to the lichens. Trichogynes and spermatia are found only in red algae and Ascomycetes, and the fungal element of the lichens represents closely the essential features of each group. This would not necessitate accepting the view that the apothecium is the most primitive type of the ascocarp. The differences between the cleistocarp and the apothecium are not very fundamental; the transition from the one to the other is easily conceived, and is indicated in the species of the lichens in which the fruit body is a pyrenocarp.

There are also forms in which the thallus is very poorly developed. Some species resemble quite closely species of *Humaria* and *Ascobolus* which grow on the ground among mosses and algae. An investigation of these forms may lead to the discovery of initial organs, which will even more convincingly establish the relationship between the Discomycetes and the discomycetous lichens.

I have shown that *Ascobolus carbonarius*, with its long trichogyne coming to wind about an antheridial conidium, is suggestive of a relationship between this species and the lichens. The development of the archicarp directly from a female conidium may be an adaptive feature correlated with the commonly occurring failure of the rudimentary coils (described p. 175) to develop ascocarps. No other ascomycete is known in which the archicarp originates directly from the germination of a conidium. I believe, however, that further investigation will show that this habit is not confined to this one species alone. When it is considered that only a few species of the Discomycetes have been cultivated artificially in such a way as to enable the investigator to follow the development of the apothecium directly from the mycelium, it is not surprising that our knowledge in this connection is very limited.

The multicellular trichogyne of *Lachnea stercorea* indicates a phylogenetic relationship between this species and *Ascobolus carbonarius*. Miss Fraser was unable to trace the origin of the antheridium with which this trichogyne fuses.

There is an undoubted tendency to the disappearance of the trichogyne in the Ascomycetes, though this does not necessarily mean a disappearance of sexual reproduction. We can trace the reduction of a trichogyne through well graded stages. Well developed septate trichogynes are also found in *Ascophanus carneus*, *A. ochraceus*, *Ascobolus immersus*, and *A. Winteri*. In the last two species the trichogyne is not always distinctly differentiated from the ascogonium. Spirally coiled archicarps tapering gradually toward the tip, are known in such forms as *Aspergillus*, *Sordaria*, *Hypocopra*, and *Saccobolus*.

In *Pyronema* the archicarp has become reduced to such an extent that septa are no longer found in the trichogyne. The antheridium has come to be developed sufficiently near the oogonium to enable a one-celled trichogyne to bring the sexual nuclei together. The reduction of the trichogyne has gone on still further in *Ascodesmis*. *Humaria granulata* is one of the best known forms in which a trichogyne is no longer developed.

I am inclined to believe that Dangeard's species *Ascobolus mirabilis* is really *A. viridis* Boud., as he suggests it may be. I have given my reasons for considering this latter species as identical with *A. carbonarius* Karst. Dangeard found his species in one of his old cultures of *Pyronema* and assumed that it was introduced along with some carbonaceous earth upon which the *Pyronema* was growing. This habitat on carbonaceous earth is very characteristic of *A. carbonarius*. Dangeard found few apothecia in his cultures, a feature I have noted in my cultures of *A. carbonarius*. The structure of the archicarp, or as much of it as he saw, agrees in general with the central portion of that organ as I find it in *A. carbonarius*. The stalk cells are very similar, and the three or four enormous cells concerned in the production of the ascogenous hyphae are essentially like the same cells as I have described them. In a few cases he saw a few hyaline cells extending out beyond these larger cells, as do the empty cells of the distal end of the ascogonium in my forms. Dangeard noted how easily the ascogenous cells can be squeezed out of a young apothecium, and the appearance of the ascogenous hyphae growing out of the ascogenous cell was such as to attract his attention. He has also noted that septa are formed in these ascogenous hyphae as they grow out from the ascogenous cell, so that when they are mature they are straight, club-shaped structures consisting of three or four cells. These are plainly the organs that I have called primary ascogenous hyphae. His figure of a young apothecium, as seen from above, agrees also with my observations. What he has taken to be the remains of the stalk of the archicarp lying outside of the main fruit body, is in my opinion, however, the distal end of the archicarp from which the trichogyne grows. I find as above described, that this long winding end of the ascogonium becomes invested with hyphae quite independently of the portion that is to give rise to the main fruit body. It is only in the older stages that the whole system is uniformly inclosed to form an oval mass. The very transparent trichogyne might easily escape his attention. He shows the archicarp arising directly from the mycelium as a branch of an ordinary hypha and found no cases in which it arises from a conidium. Both methods of origin occur beyond question. He makes no mention of asexual spores and describes the vegetative hyphae as being rather coarse and larger than the hyphae of *A. furfuraceus*. This is not always true for the hyphae of *A. carbonarius*. His description of the pores between the cells of the ascogonium does not agree with my observations on *A. carbonarius*, but he has not correctly described the pores as they exist in *A. furfuraceus*. If his species is not really *A. carbonarius* it is certainly interesting that there is another species so similar in many respects, growing on carbonaceous earth.

SUMMARY

1. The ascospores of many coprophilous species of the Ascobolaceae, which rarely germinate in artificial media under ordinary conditions, can readily be made to germinate by subjecting them to high temperatures, 50°–70° C., for five to ten minutes. In the case of *Ascobolus carbonarius*, which is terrestrial, many spores will still germinate when heated to 80° C. for five minutes. The heating process favors pure cultures, since the spores of many fungi are killed at these high temperatures.

2. Heating the spores appears to hasten the ripening processes; half-grown spores of *A. carbonarius* can be germinated in this manner.

3. Germination occurs about eight hours after the spores have been heated. The epispore becomes cracked in all directions, and two or more germ tubes are put out at short distances from the ends of the spore.

4. The acidity or alkalinity of a medium is not an important factor in determining germination. The number of apothecia produced may depend upon the reaction of the nutrient medium.

5. The mycelium of *A. carbonarius* produces a large number of conidia, some of which give rise directly to the archicarp. The archicarp consists of three distinct parts: the preliminary or stalk coil, the ascogonium, and the trichogyne. The tip of the trichogyne sometimes becomes coiled about an antheridial conidium. Archicarps may also arise from the mycelium.

6. The archicarps of *Ascophanus carneus*, *Ascobolus immersus*, *A. furfuraceus*, and *A. Winteri* arise directly from the mycelium; they are spirally coiled organs of which the peripheral cells represent a more or less strongly developed trichogyne. The trichogyne frequently becomes attached to a hypha growing out at the base of the archicarp.

7. The general character of the archicarps described and the presence of septate trichogynes, support the view that the lichens represent primitive forms of the Ascomycetes.

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Explanation of plates 10-15

The magnifications are given in connection with each figure. In some cases the surface markings of the spores are not shown in the figure.

PLATE 10

Fig. 1. *a*, germinated spore of *Thecotheus Pelletieri*, unstained. ×275. *b*, germinated spore of *Thecotheus Pelletieri*, showing germination from only one germ pore, stained in toto. ×425.

FIG. 2, 3. germinated spores of *Ascobolus viridis* var. ×450.

FIG. 4. *a*, immature spore of *A. viridis* var. ×800. *b*, mature spore of *A. viridis* var. ×800.

FIG. 5. Very large spore of *A. viridis* Curr. from *no. 196* Phil. Elv. Brit. ×800.

FIG. 6. Germinated spore of *Saccobolus neglectus*, showing the manner in which the epispore has been broken away during germination. ×450.

FIG. 7. Group of eight spores of *Saccobolus neglectus*, in which one spore has germinated and a second spore (*a*) has swollen preparatory to germination. ×450.

FIG. 8. Spores of *Ascobolus pusillus* Boud. ×800.

FIG. 9. *Ascobolus carbonarius: a*, germinated spore; *b*, swollen vesicle on the hypha; *c*, conidium; ×275; *d*, another vesicle stained with aceto-carmin; ×450.

FIG. 10. Conidium of *A. carbonarius*, showing swollen protuberance. ×250.

FIG. 11. Spore of *A. carbonarius*, showing the ends capped with a thickening of the epispore. ×800.

FIG. 12. Spores of *Ascobolus Winteri*. ×700.

FIG. 13. Germinated spores of *A. Winteri*. ×250.

FIG. 14. Mycelium and germinated spore of *A. Winteri*. ×725.

FIG. 15. Two spores of *Ascobolus xylophilus*, one spore germinated. ×450.

FIG. 16. Germinated spore of *Ascobolus glaber*, showing the manner in which the epispore becomes cracked due to swelling. ×400.

PLATE 11

FIG. 17. Ascogonia of *Ascophanus carneus: a*, stalk cells; *b*, ascogonium; *c*, trichogyne; *d*, hypha in contact with the trichogyne. ×250.

FIG. 18. Germinated spore of *A. carneus*. ×380.

FIG. 19. Germinated spores of *Ascophanus sarcobius*. ×380.

FIG. 20. Spore of *Ascobolus immersus*. ×400.

FIG. 21. Germinated spore of *A. immersus*. ×250.

FIG. 22, 23. Germinated spores and mycelium of *A. immersus*. ×650.

FIG. 24. Archicarp of *A. immersus*, stained in toto with aceto-carmin: *a*, stalk cells; *b*, ascogonium; *c*, trichogyne torn from the hypha (*d*). ×630.

FIG. 25. Archicarp of *A. immersus* stained with aceto-carmin, showing four apparently empty cells. ×630.

FIG. 26. Spores of *Ascobolus glaber*: *a* shows the characteristic markings of a mature spore; *b*, germinated spore. ×900.

FIG. 27. Germinated spores of *Ascobolus Leveillei*. ×650.

FIG. 28. Archicarp of *Ascobolus furfuraceus*: *a*, stalk cells; *b*, ascogonium; *c*, trichogyne. ×650.

FIG. 29. Spores of *A. furfuraceus*: *a*, *b*, ungerminated spores; *c*, *d*, germinated spores. ×360.

PLATE 12

Ascobolus carbonarius

The lettering for each figure is the same as given for FIG. 33.

FIG. 30. Section of a germinated spore of *A. carbonarius*. ×650.

FIG. 31. Germinated spore of *A. carbonarius*: *a*, optical section of a mature spore; *b*, immature spores which germinated. ×380.

FIG. 32. *a*, section of a conidium of *A. carbonarius*; *b*, sections of germinated female conidia. ×650.

FIG. 33. Mature archicarp: *a*, conidium giving rise to the stalk coil; *b*, conidiophore; *c*, hypha arising from conidiophore; *d*, first cell of stalk coil (*f*); *g*, last cell of stalk coil giving rise to the ascogonium (*h*); *j*, last cell of ascogonium; *k*, first cell of trichogyne (*l*); *m*, male conidium or antheridium (?); *n*, stalk of antheridial conidium. ×400.

FIG. 34. Archicarp in a pathological condition. ×400.

FIG. 35. Archicarp in which the trichogyne (*l*) does not coil about the conidium (*m*), which is entirely empty. ×135.

FIG. 36. Archicarp in which the characteristic trichogyne was not seen; *l* may be the trichogyne. ×270.

FIG. 37. Archicarp in which the trichogyne lies beneath; *m*, a conidium near by. ×135.

FIG. 38. Cells of the ascogonium giving rise to primary ascogenous hyphae. ×400.

FIG. 39. Two adjacent cells of the ascogonium with primary ascogenous hyphae (*o*, *r*). ×400.

PLATE 13

Ascobolus carbonarius

Lettering as in FIG. 33.

FIG. 40. Mature archicarp showing the trichogyne (*l*) coiled twice about the conidium (*m*). ×300.

FIG. 41. Archicarp becoming invested with hyphae: a trichogyne is visible at *l*, the remaining portion being concealed beneath the ascogonium. ×300.

FIG. 42. The conidium (*a*) has germinated, giving rise to the stalk coil which has begun vegetative growth; *b*, the conidiophore; *c*, hypha arising from the conidiophore. ×300.

FIG. 43. *a*, germinated conidium with short thick stalk (*b*). ×300.

FIG. 44. Archicarp showing hyphae arising from the conidium (*a*) and from cells of the stalk coil (*d*); *j*, the last cell of the ascogonium giving rise to the trichogyne not shown in the figure. ×300.

PLATE 14

Ascobolus carbonarius

FIG. 45. Large pear-shaped conidium giving rise to slender hyphae. ×265.

FIG. 46. Conidium with a swollen tip. ×265.

FIG. 47. Coiled hyphae arising from the mycelium: *s*, the stalk of the coil; *t*, a conidium on the end of the coil. ×200.

FIG. 48. Two coils arising from the same mycelial hypha: *s*, the stalks of the coils; *t*, conidia arising from the coils; *u*, inflated conidia not connected with the coils. ×200.

FIG. 49. Coil arising from the mycelial hypha at *s*. ×200.

PLATE 15

Ascobolus Winteri

FIG. 50. Archicarp arising from the mycelium; the septum has not yet formed. ×675.

FIG. 51. One-celled stage of the archicarp. ×675.

FIG. 52. Archicarp composed of four cells, immature. ×675.

FIG. 53. Young archicarp showing hyphae (*e*) arising from the stalk cells. ×675.

FIG. 54. Mature archicarp: *a*, stalk cells; *b*, ascogonium; *c*, trichogyne; *d*, antheridium (?). ×765.

FIG. 55. Mature archicarp showing the trichogyne (*c*) and hypha (*d*) somewhat distorted by the pressure of the cover glass; connection distinctly visible. ×900.

FIG. 56, 57. Archicarps which have taken on a vegetative growth, the trichogyne (*c*) of FIG. 57 fusing with a mycelial hypha, and the hypha (*d*) from the stalk cell fusing with a branch from another hypha. ×675.

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The lichens of the Linnean Herbarium with remarks on Acharian material

R. HEBER HOWE, JR.

Through the kindness of Dr. B. Daydon Jackson, general secretary of the Linnean Society of London, I had the opportunity from February 12 to 20, 1912, to study the lichens (314 sheets, *fide* Jackson) of the Linnean Herbarium now preserved in Burlington House, London, England.

I have made a critical study only of those species which now fall under the family Usneaceae (plus p. Filamentosi of Linn.), but am listing here all species that can in any sense be considered represented by types. In 1886 Dr. E. Wainio examined the herbarium and published a list of the species (Revisio Lich. in herb. Linn. asservatorum. Meddel. Soc. pro Fauna et Flora Fenn. 14: 1–10. 1886). He made no attempt, however, to select types, and I have found a number of important sheets he failed to record, e. g., *L. nivalis*: 3 specimens. Moreover, he did not have the great advantage of Dr. Jackson's* exhaustive study of the Linnean Herbarium, Linneana, and the handwritings of contemporaneous botanists. Dr. Wainio's determinations and mine (in the Usneaceae) agree in the main, and where we differ I have had the kind aid and collaboration of Miss Annie Lorrain Smith, of the British Museum of Natural History, e. g., "1 folio . . . *A. chalybeiformis* Wain." = *A. jubata*.

The sheets referring to Species Plantarum (1753) fall naturally into four classes. First, those that have the Sp. Plant. number; the equivalent name in Linnaeus' handwriting; plus the number of his Fl. Suec. (1745). These specimens (in the Usneaceae) represent reliable types, based evidently on Dillenius' Historia Muscorum† (1741) and diagnostically described by Linnaeus in Sp. Plant., with correct references to Dillenius' figures, e. g., *L. floridus*.

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* Jackson. MS. list Linn. Herb. 1755?, 1–39 [1907]; e Proc. Linn. Soc. 89–126. 1906–1907.

† Crombie. Jour. Linn. 17: 554–556. 1880.

Second, those that have the Sp. Plant. number; the equivalent name in Linnaeus' handwriting; but without a Fl. Suec. number, e. g., *L. vulpinus*. These are for the most part authentic types, yet in some cases they do not agree entirely with Dillenius,* Linnaeus' own descriptions, nor the conception of early post-Linnean authors, e. g., *L. barbatus*. Third, those without Sp. Plant. number; with names in Linnaeus' handwriting; and no Fl. Suec. number, e. g., *L. chalybeiformis*. Fourth, those that have a seemingly erroneous Sp. Plant. number and name but an evidently authentic Fl. Suec. number correctly referring to Dillenius and diagnostically described by Linnaeus, e. g., *L. plicatus*. The remaining sheets, of which there are a large number (95), again fall into three classes. First, those that are named in Linneus' handwriting and are types of later species, which he described in Fl. Suec. 2 ed., 1755; Sp. Plant. 2 ed., 1763; Syst. Nat., 12 ed., 1767; and Mantissae 1 and 2, 1767 and 1771, e. g., *L. chrysophthalmus*. Second, those that were named by Linnaeus' son (Linn. fil.) in the latter's handwriting and represent types of his, published in Suppl. Pl. 1781, e. g., *L. capensis*. Third, those that were evidently added by the purchaser of the Linnean Herbarium, J. E. Smith, including species of J. Dickson, Swartz, Ehrhart, and other later workers, few if any of which constitute types.

The figure accompanying this article is of the two leaves of the MS. catalogue of the Linnean Herbarium giving the lichens in his handwriting "presumably compiled in the year 1755." The dot in front of the name indicated "such [plants] as were in the Herbarium." These accord well with the plants at present preserved in the herbarium, as a comparison will show. (I have placed dots in the printed list.) In a future paper on the Usneaceae I shall publish photographs of all the Usneaceae types.

Below is given the list of specimens that can be considered as authentic types printed in heavier types. In italics are placed those having less verifying data, which, however, can be properly considered types. All these are listed because they bear published Linnean names. Numbers in brackets were not given on the sheets, and the numbers following the names refer to Fl. Suec. Names underlined appear in Linn. fil. handwriting. The modern

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* Through the kindness of Dr. S. H. Vines, of the Botanic Gardens, Oxford, Eng., I have seen the Dillenian types, a reference to which will be made in a later paper.

species conception in the family Usneaceae is given after each species.

SPECIES PLANTARUM 1753

[1.] scriptus

● 4. *sanguinarium*

[9.] ventosus

● *11. carpineus*

● **12. ericetorum** 936

[13.] candelarius

[14.] tartareus

●[15.] pallescens

[16.] subfuscus

● *17. upsaliensis*

● **18. centrifugus** 945

● **19. saxatilis** 946

●[20.] omphalodes

● **21. olivaceus** 948

●[22.] fahlunensis

[23.] stygius

● *25. parietinus*

● **26. physod[es]*** 951

27. stellaris

● **28. ciliaris** 952

● **30. islandicus** 959 = *Cetraria islandica* (L.) Ach.

30y. islandicus (*tenuissimus*) = **Coelocaulon aculeatum** (Schreb.) comb. nov.

● **31. nivalis** 958 = *Cetraria nivalis* (L.) Ach.

● **32. pulmonarius** 960

● **33. furfuraceus** 953

● **35. farinaceus** 957 = *Ramalina farinacea* (L.) Ach.

● **36. calicaris** 956 = *Ramalina scopulorum* (Retz.) Ach.

● **37. fraxineus** 955 = *Ramalina fraxinea* (L.) Ach.

39. prunastri 954

● *40. juniperinus* [967]†

[41.] caperatus

● **42. glaucus** 966

● *44. resupinatus*

● *45. venosus* (composite) 964.

● **46. aphtosus** 963‡

● **47. arcticus** 962

● *48. caninus*

● **49. croceus** 965§

51. velleus 968

● **52. pustulatus** 969

● *53. proboscideus*

● **54. deustus** 970

[55.] polyphyllus

[62.] digitatus

[64.] deformis

● **65. rangiferinus** 980

● **66. uncialis** 979

[67.] subulatus

● **68. paschalis** 982

● **69. fragilis** 983

● *70. Roccella*

72. barbatus = *Usnea articulata* (L.) Hoffmg.

● **73. jubatus** 986 = *Alectoria jubata* (L.) Ach.

● *74. lanatus*

[75.] pubescens = *Alectoria pubescens* (L.) R. H. Howe, Jr.

● *76. chalybeiformis* = *Alectoria chalybeiformis* (L.) S. F. Gray

● *77. hirtus* [984]¶ (a composite)

● *78. vulpinus* = *Letharia vulpina* (L.) Wain.

● **80. floridus** = *Usnea florida* (L.) Web.

2 ED. FLORA SUECICA 1755

[1102.] *saccatus*

2 ED. SPECIES PLANTARUM 1763

[34.] *leucomelos*

12 ED. SYSTEMA NATURAE 1767

[—.] *divaricatus* = *Letharia divaricata* (L.) Hue.

1ST MANTISSA 1767

[82.] *pertusa*

[84.] *Usnea* = *Ramalina usneoides* (Ach.) Fr.

[88.] *horizontalis*

[92.] *globifer[us]**

[93.] *fascicularis*

2ND MANTISSA 1771

[—.] *crocata*

[—.] *chrysophthalmus* 32 Koeg. = *Teloschistes chrysophthalmus* (L.) Th. Fr.

SYSTEMA VEGETABILIUM—Murray 1774

[—.] Burgessii

SUPPLEMENTUM PLANTARUM 1781

[—.] capensis = *Teloschistes flavicans capensis* Nyl.

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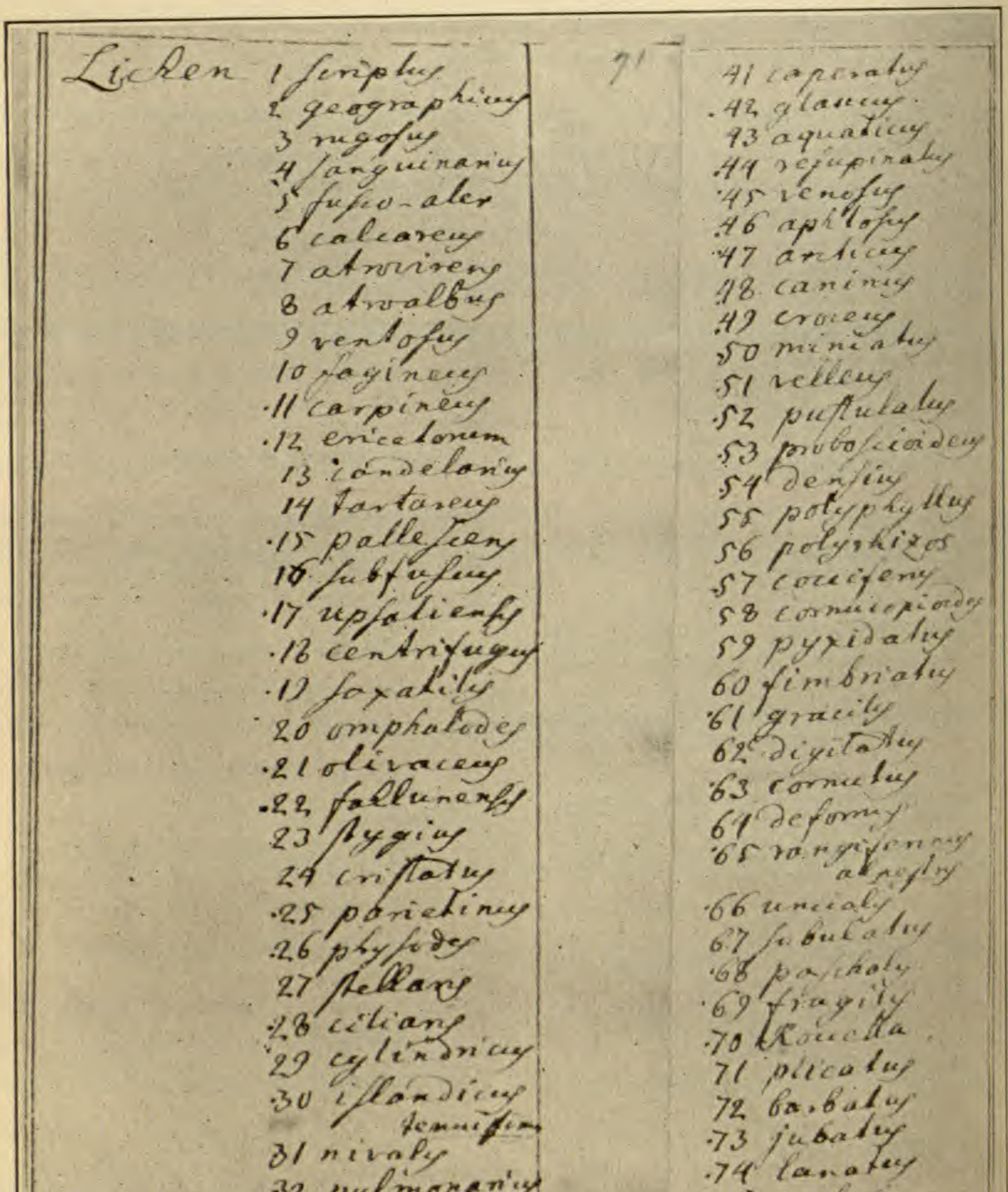
* Two final letters not on label.

† This number is on a duplicate sheet no. 40, also, but the specimen is *Physcia parietina.*

‡ In Linn. personal note-correction an *h* is inserted = *aphthosus.*

§ Fl. Suec. no. on an attached sheet.

¶ Number *L. plicatus* in Fl. Suec.



Lichen 1 ſcriptus
2 geographicus
3 rugoſus
4 ſanguinarius
5 fuſco-ater
6 calcareus
7 atrovirens
8 atroalbus
9 ventoſus
10 fagineus
11 carpineus
12 ericetorum
13 candelarius
14 tartareus
15 palleſcens
16 ſubfuſcus
17 upſaliensis
18 centrifugus
19 ſaxatilis
20 omphalodes
21 olivaceus
22 fahlunensis
23 ſtygius
24 criſtatus
25 parietinus
26 phyſodes
27 ſtellaris
28 ciliaris
29 cylindricus
30 iſlandicus
tenuiſſimus
31 nivalis
32 pulmonarius
33 furfuraceus
34 ampullaceus
35 farinaceus
36 calicaris
37 fraxineus
38 fuciformis
39 prunaſtri
40 juniperinus

71

41 caperatus
42 glaucus
43 aquaticus
44 reſupinatus
45 venoſus
46 aphthoſus
47 arcticus
48 caninus
49 croceus
50 miniatus
51 velleus
52 puſtulatus
53 proboſcideus
54 deustus
55 polyphyllus
56 polyrhizos
57 cocciferus
58 cornucopioides
59 pyxidatus
60 fimbriatus
61 gracilis
62 digitatus
63 cornutus
64 deformis
65 rangiferinus
alpeſtris
66 uncialis
67 ſubulatus
68 paſchalis
69 fragilis
70 Roccella
71 plicatus
72 barbatus
73 jubatus
74 lanatus
75 pubeſcens
76 chalybeiformis
77 hirtus
78 vulpinus
79 articulatus
80 floridus.

Linnean manuscript copy of lichens in Species Plantarum

At Burlington House I had also the opportunity to study a set of specimens which though probably not cotypes (perhaps in some cases topotypes) represent authentic Acharian material. These were mentioned by Dr. Asa Gray (Sill. Amer. Jour. Sci. and Arts 40: 8. 1841) as follows: "Here we find the cryptogamic collections of Acharius, containing the authentic specimens described in his works on the Lichens, ..." On examining these I find them named by Acharius but without localities, and I therefore conclude that the specimens at Helsingfors (Universitetets Botaniska Institution, *fide* Dr. Fred. Elfving *in litt.*) where the localities (type) are given must constitute the true types. In De Candolle's work (La Phytographie 391. 1880) we find the following: "Acharius, Herb. de l'Univ. d'Helsingfors (Lasèque, Mus. Deless. 344 [1845]). Une série authent. de ses esp. dans l'herb. de la Soc. Linn. de Londres (A. Gray, Amer. Journ., Oct. 1840)." Through the kindness of Dr. Jackson, and with the permission of the Council of the Linnean Society I am able to throw the following light on the acquisition of this material by the society.

"Copy of Minutes of Linnean Society of London relating to the Lichens presented by E. Acharius

"Council Minute, 21st May 1806

"Order'd, That a copy of the Transactions of this Society be presented to Dr. Acharius, F.M.L.S., upon his sending to the Society a Collection of specimens of lichens describ^{d} by him.

"13th June 1809

"Order'd that a Cabinet be provided to contain the Collection of Lichens presented to the Society by Professor Acharius: but that no greater expence be incurr'd on this Account than Five Pounds.

"General Minutes, 7th March 1809.

"A collection of Lichens from Sweden, describ'd in the Methodus Lichenum were presented from Dr. Acharius, F.M.L.S.

"Council Minutes, 17th November 1812

"Order'd that a copy of the Society's Transactions be presented to Dr. Acharius."

THOREAU MUSEUM OF NATURAL HISTORY,
CONCORD, MASS.

INDEX TO AMERICAN BOTANICAL LITERATURE
(1911-1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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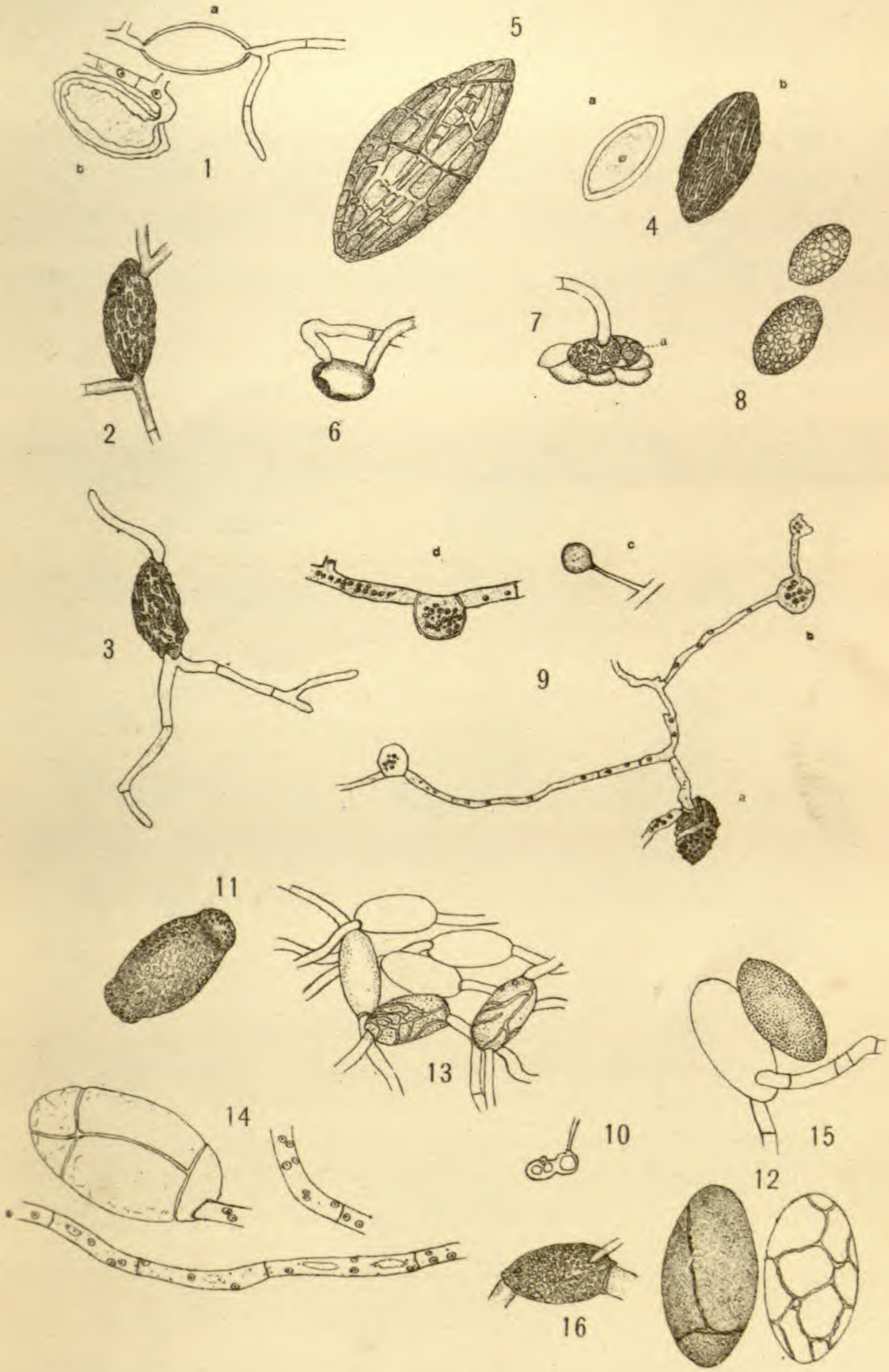

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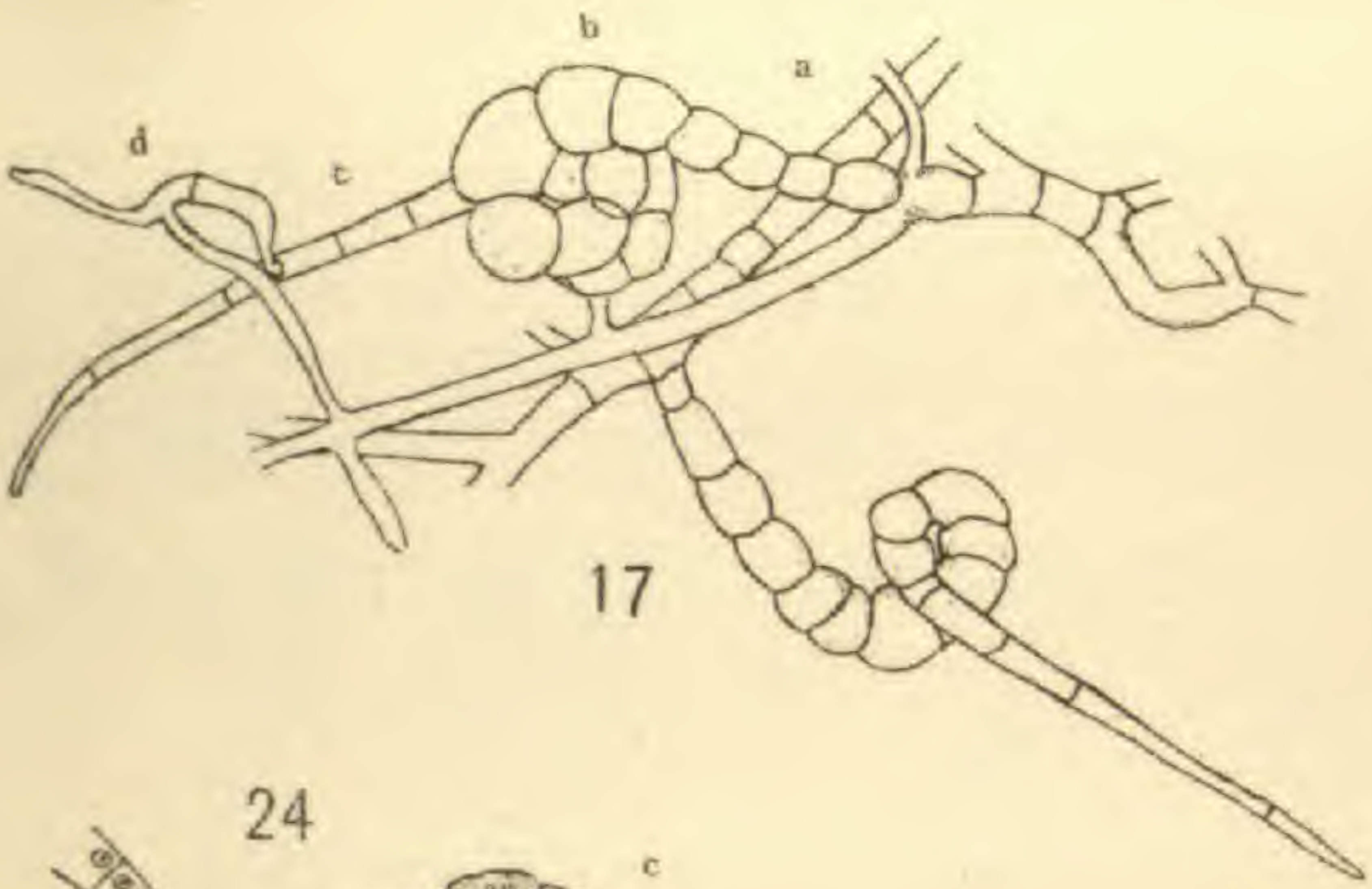

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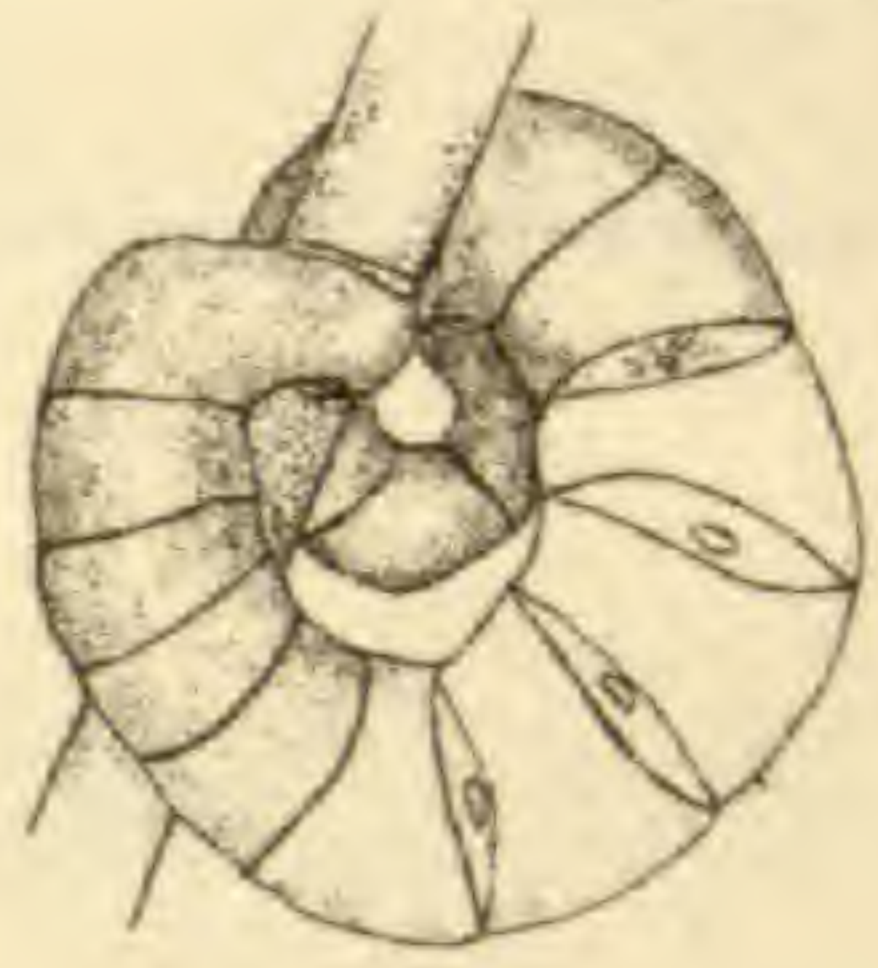

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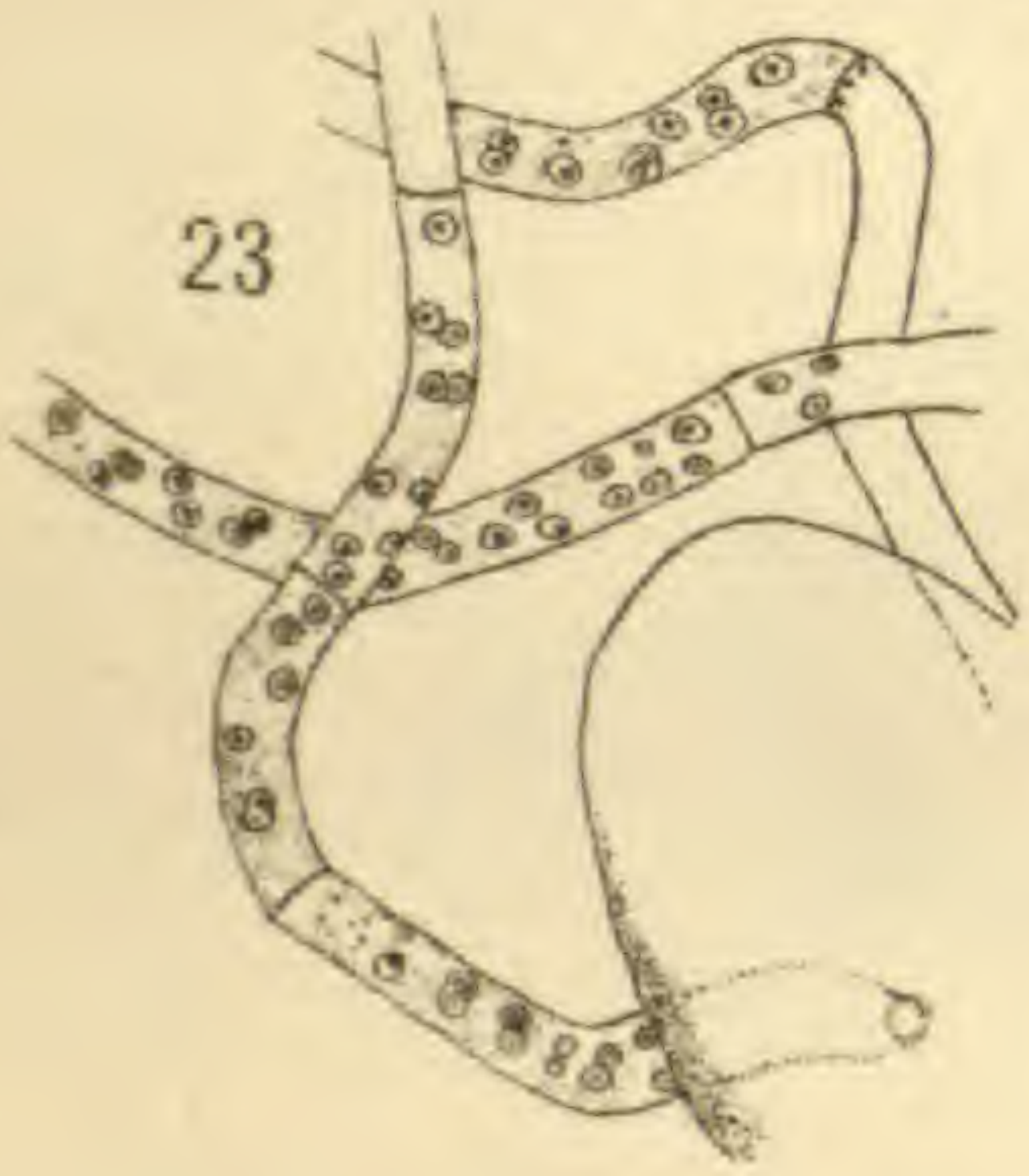

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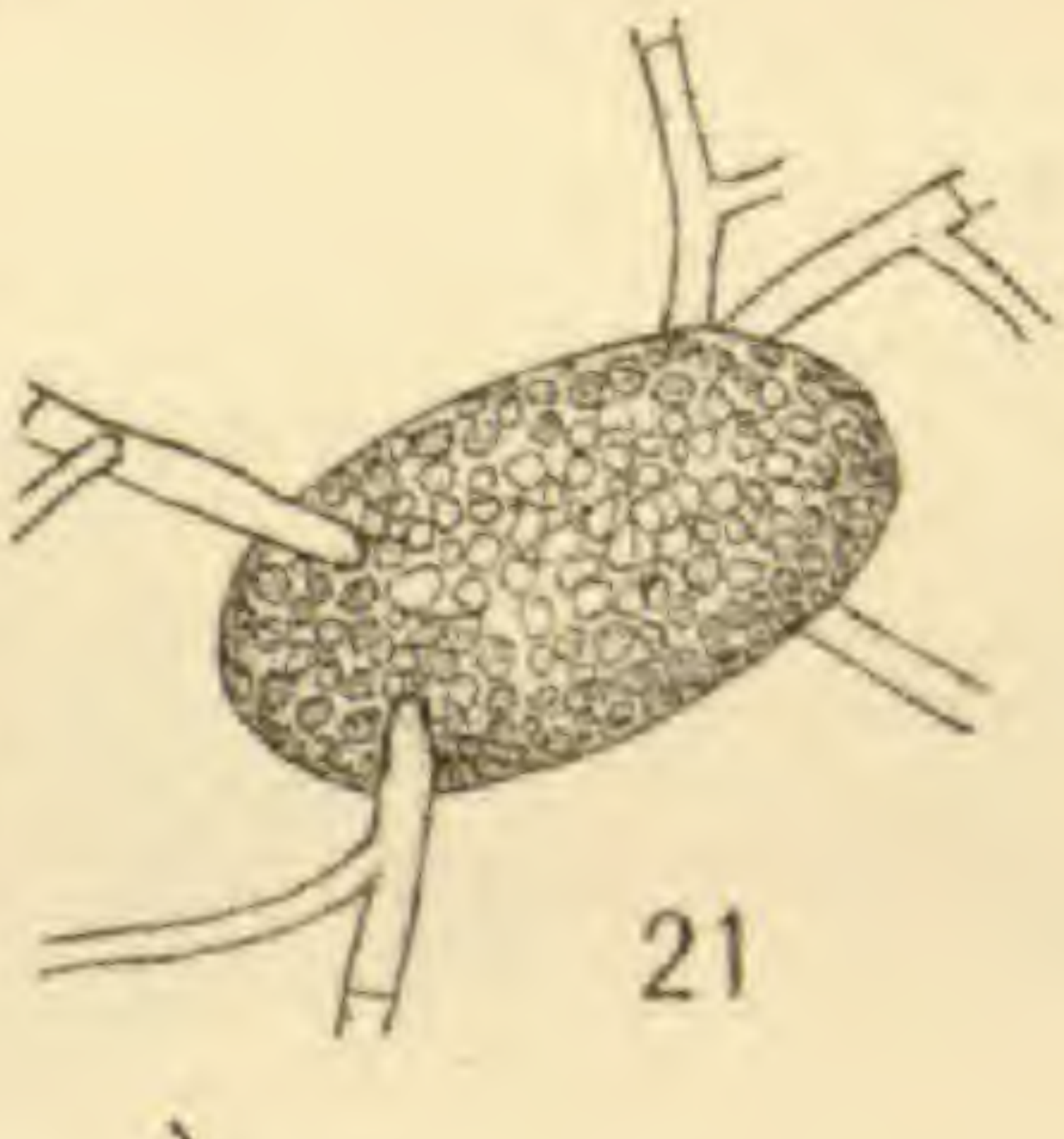

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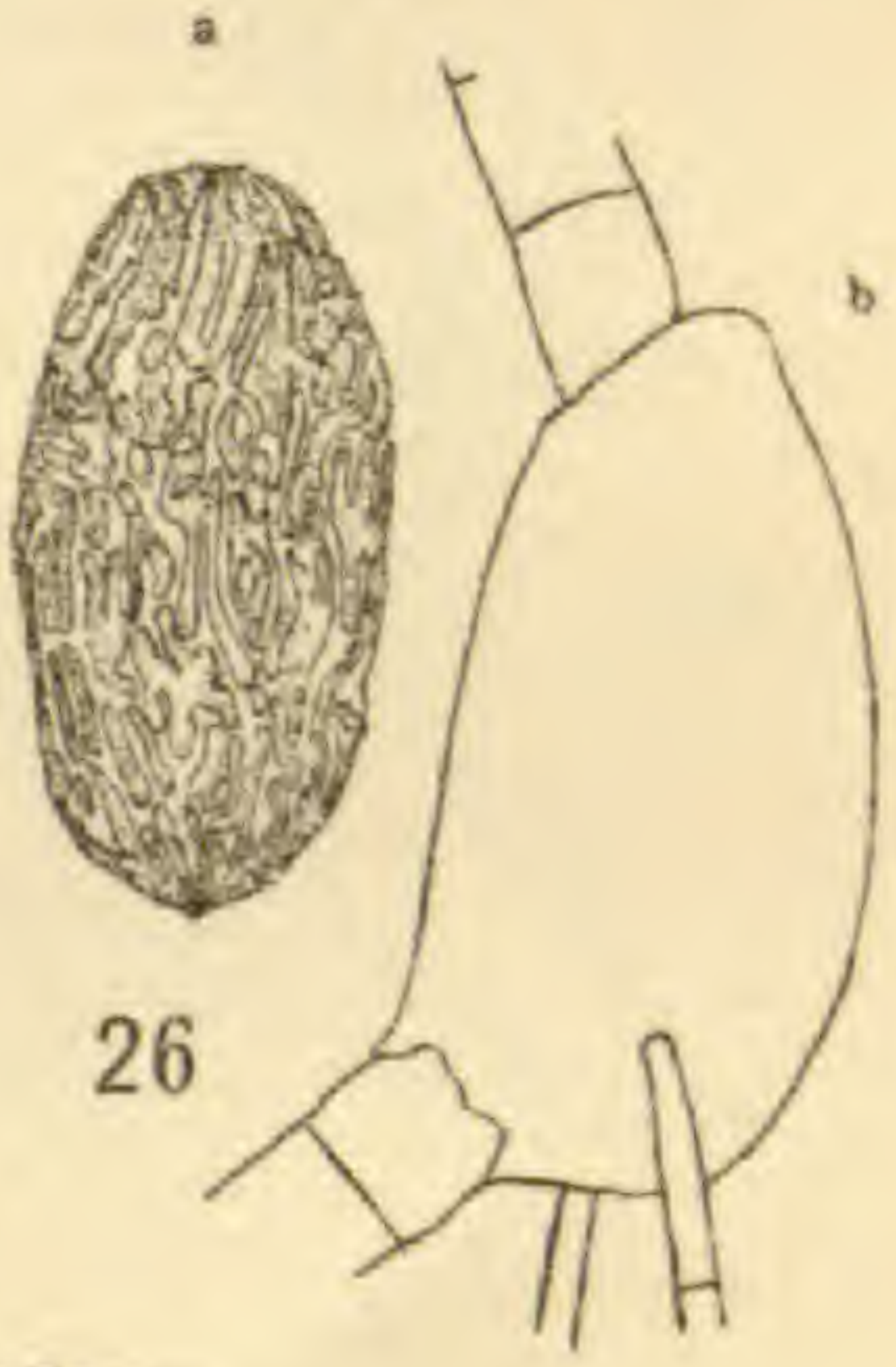

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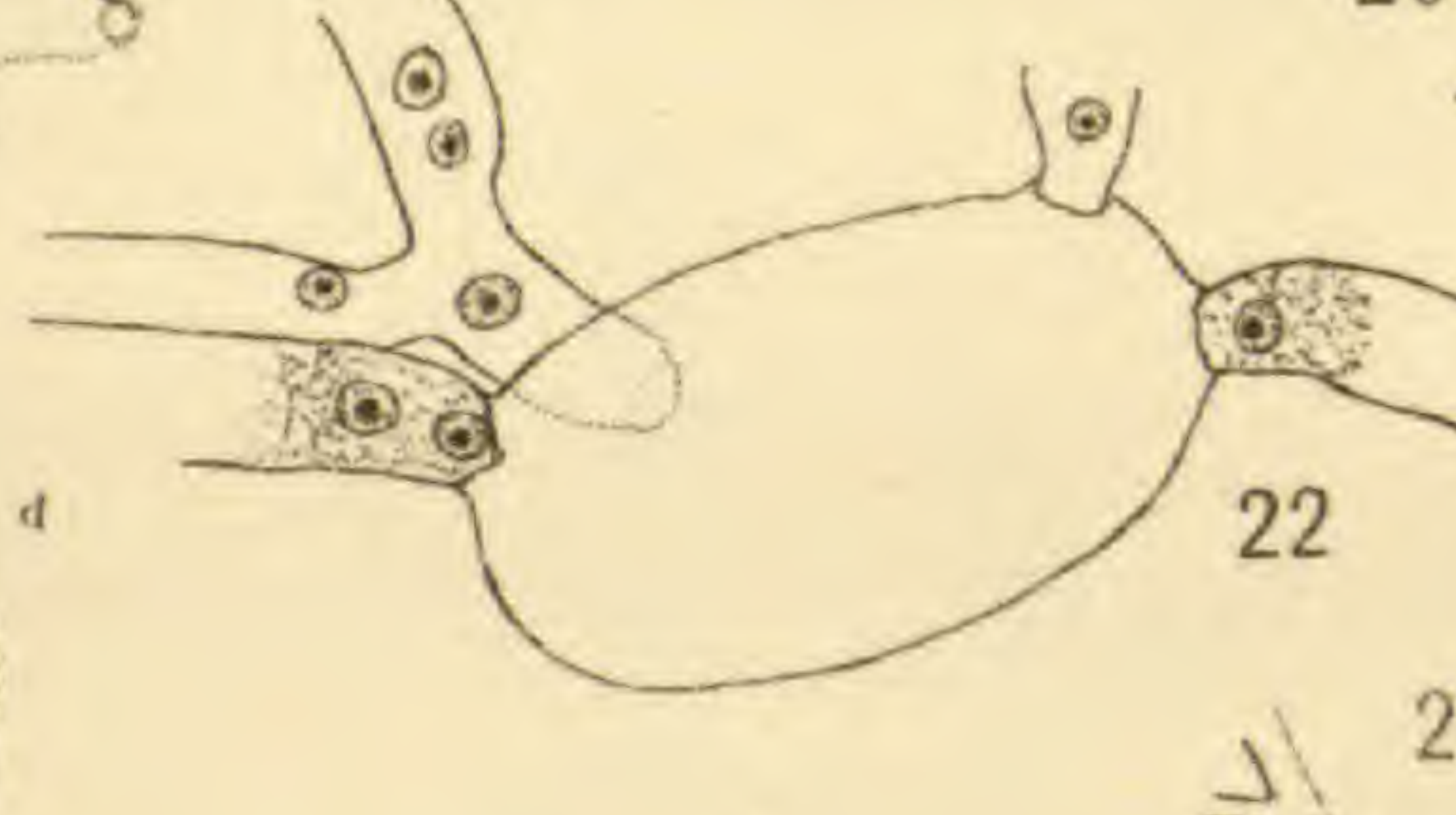

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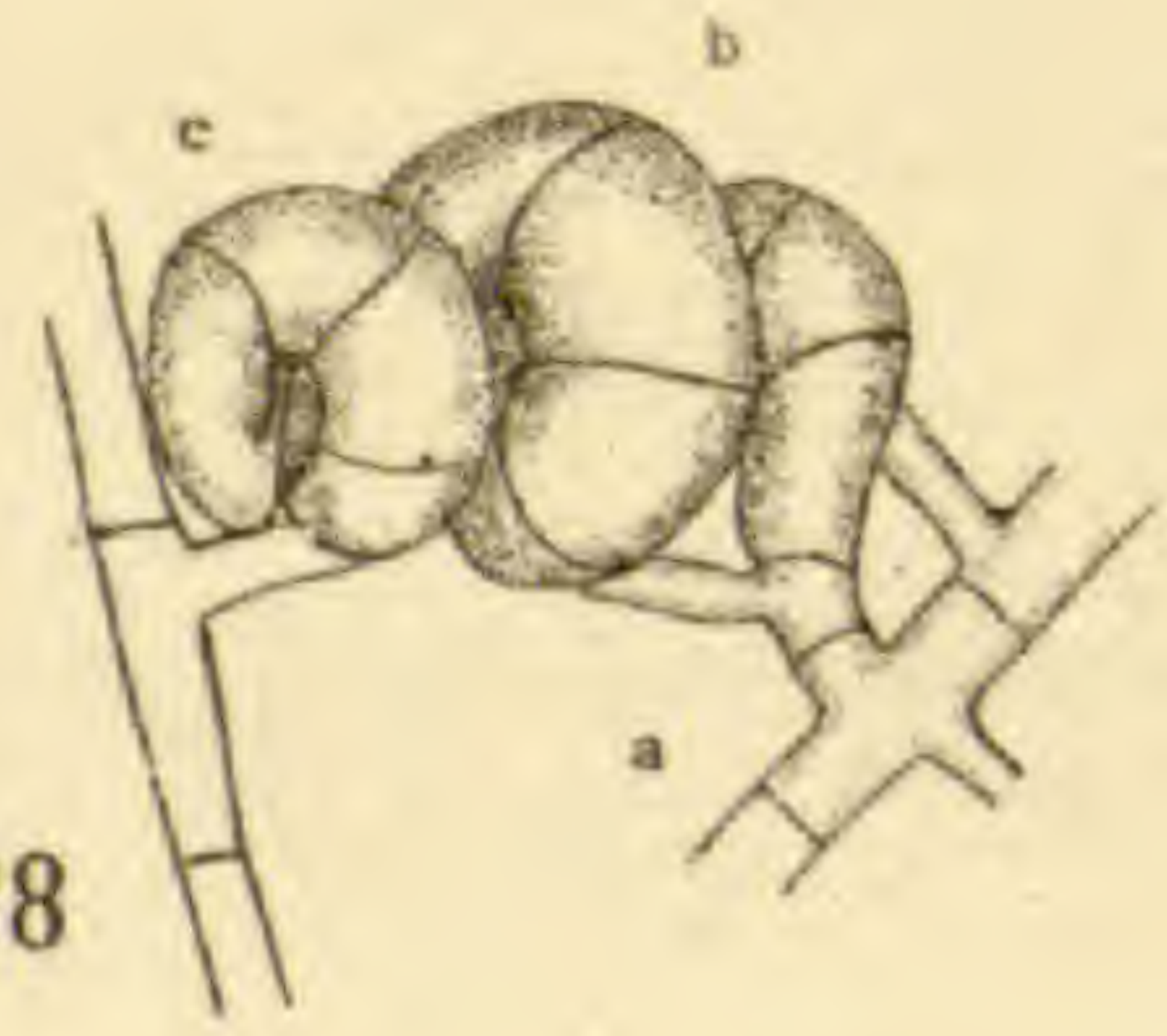

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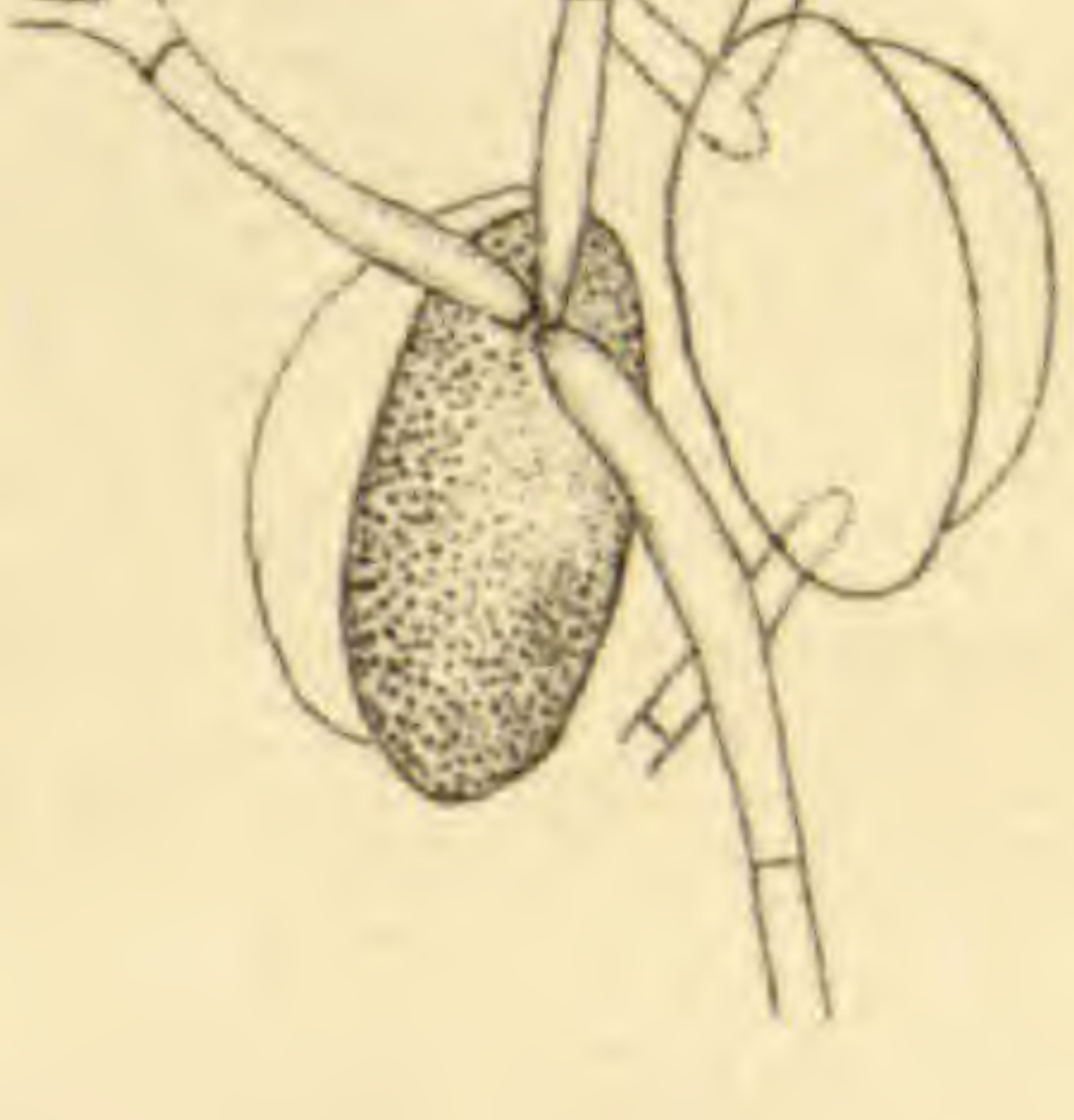

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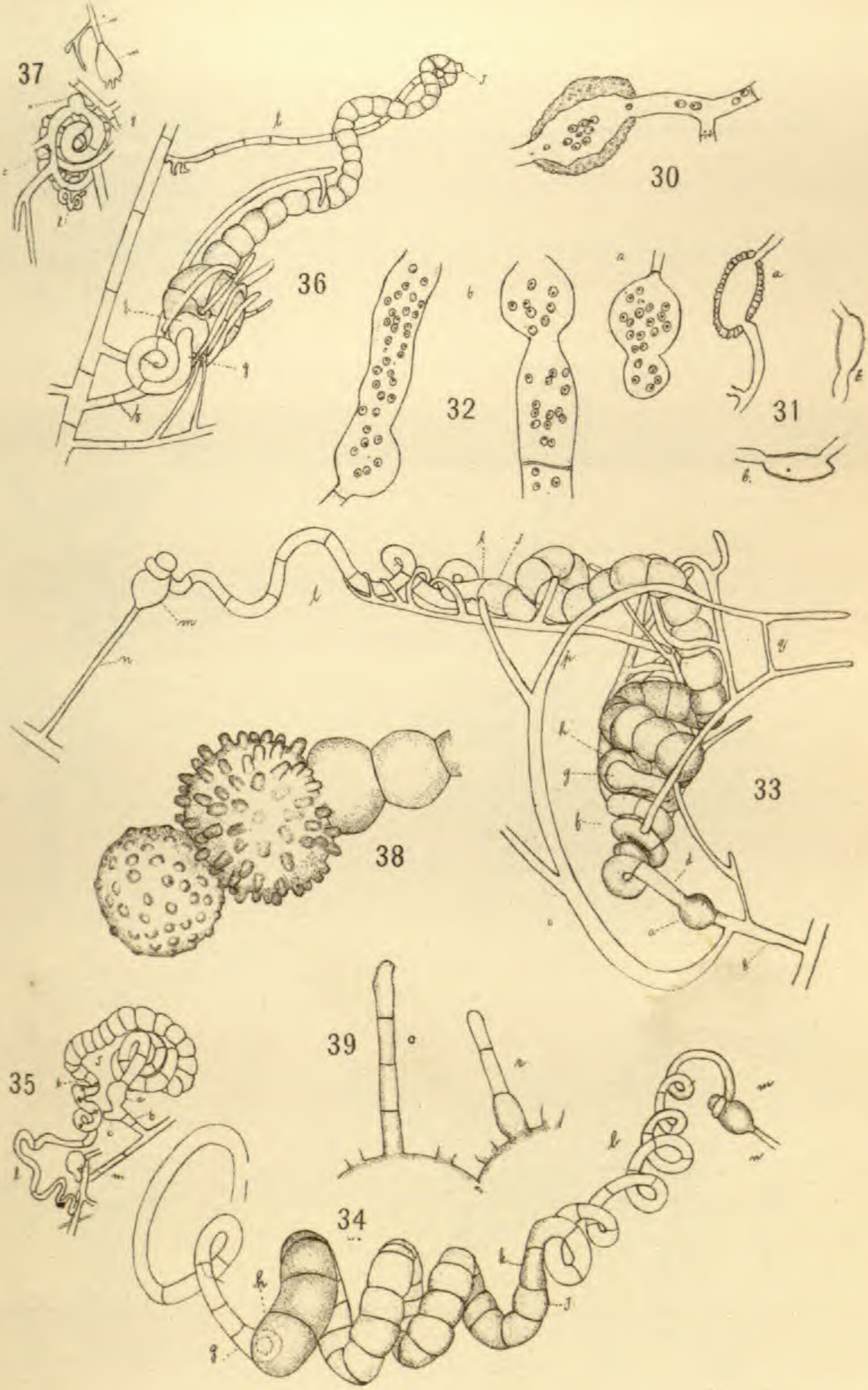

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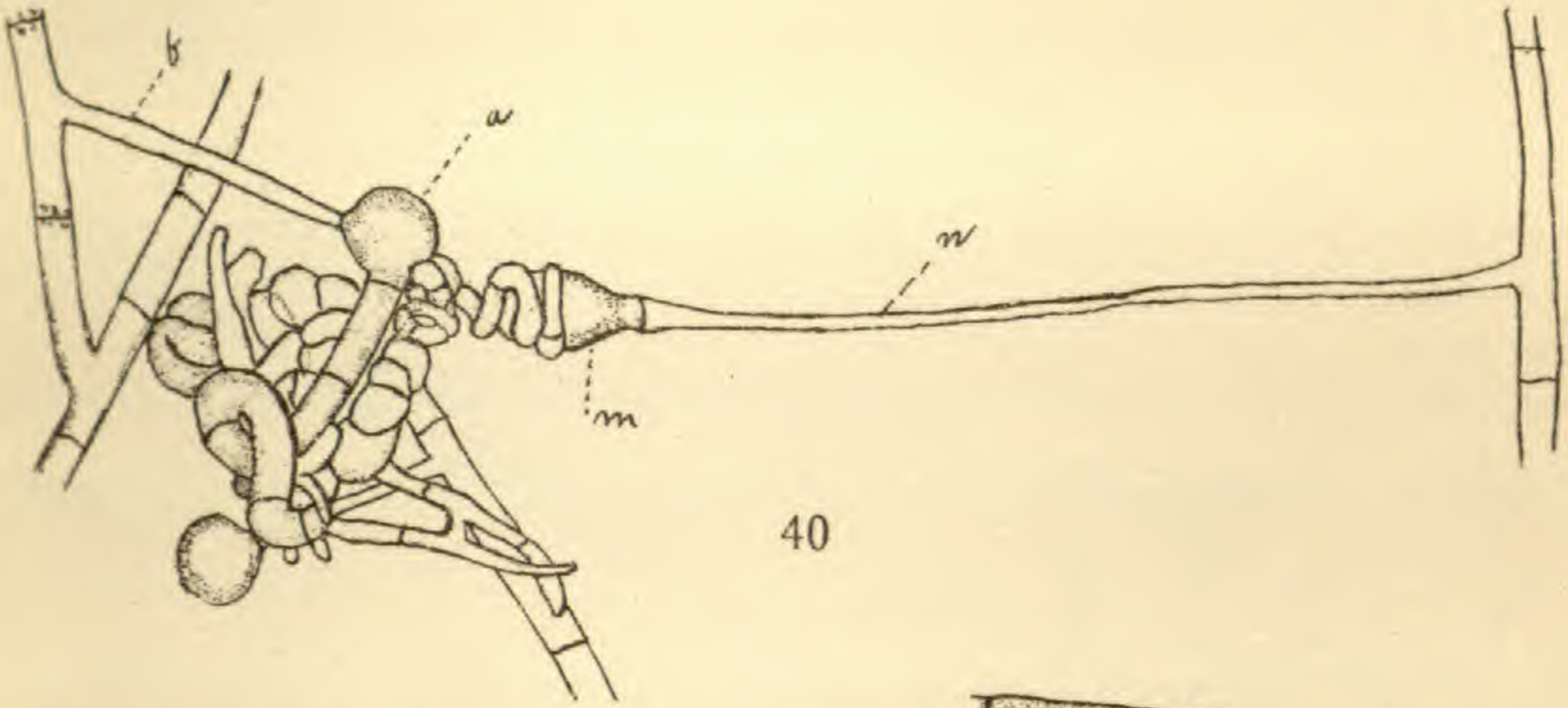

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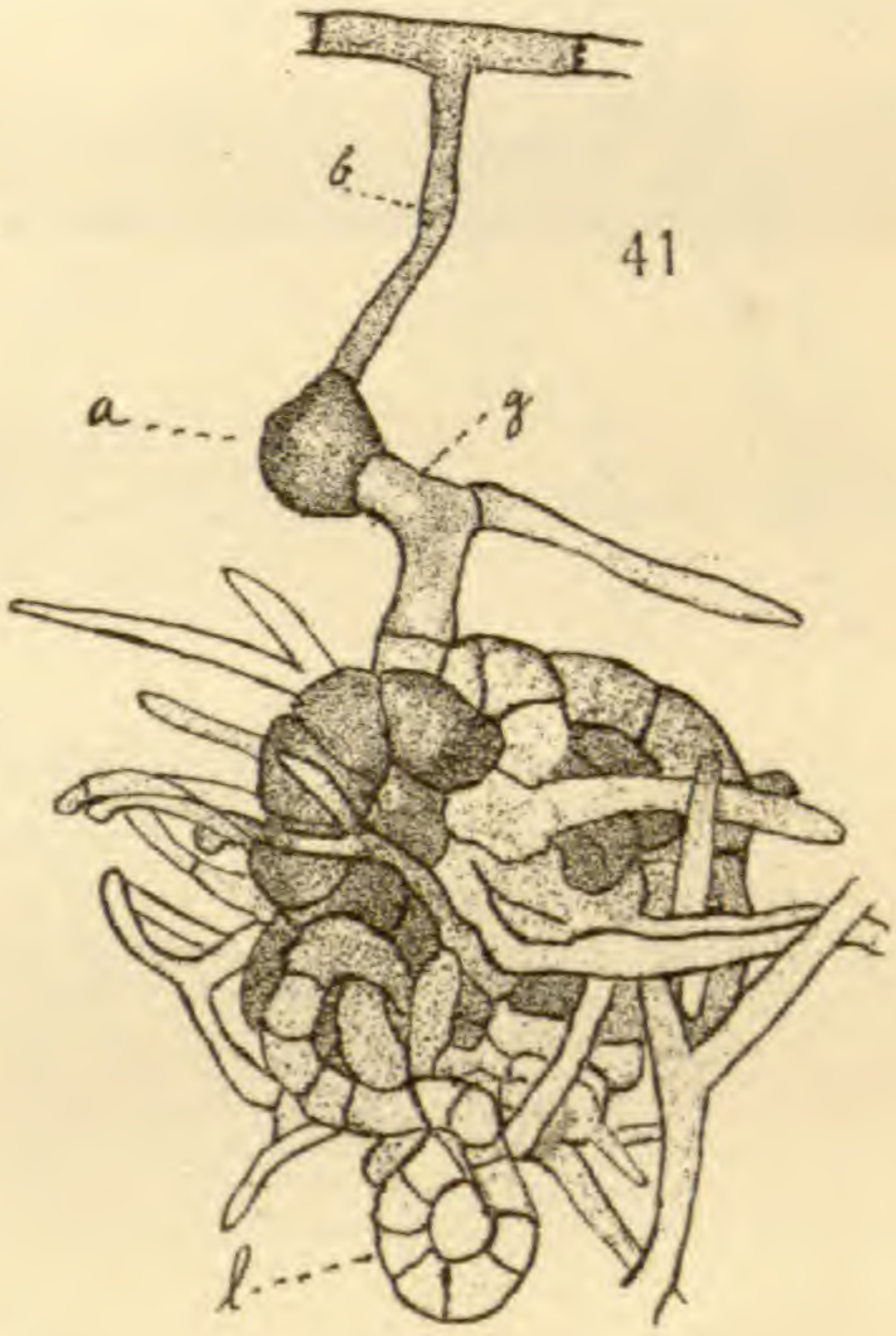

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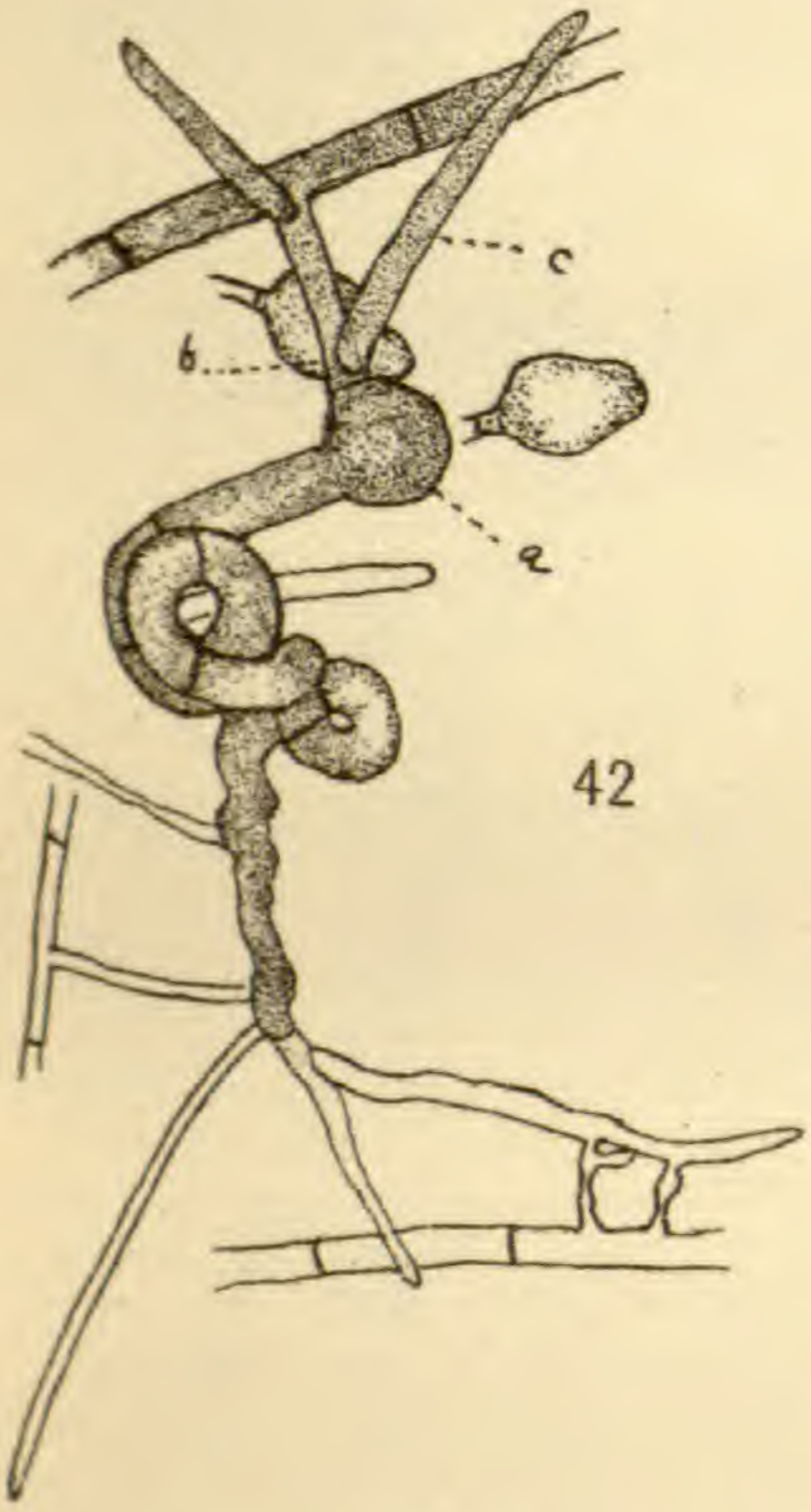

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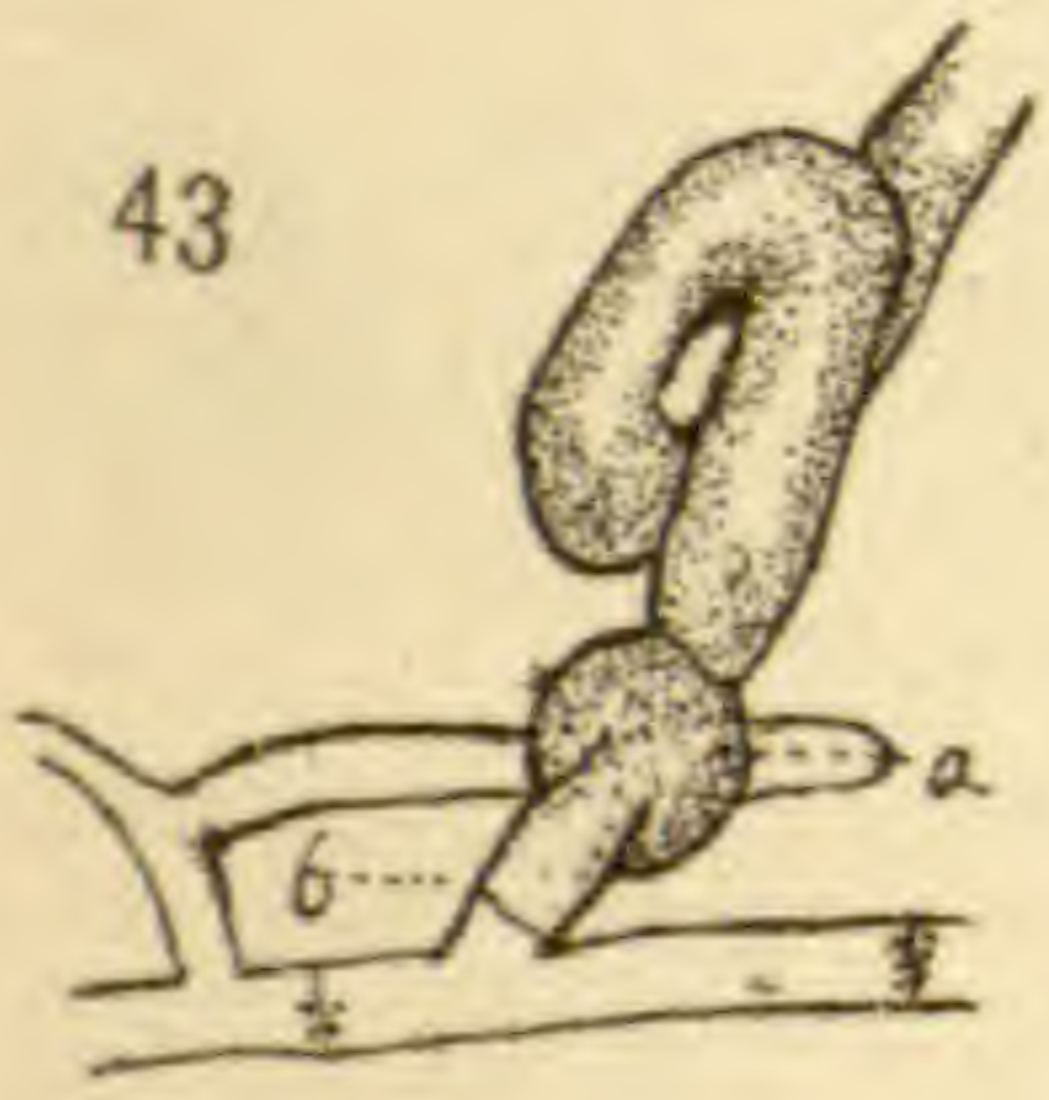

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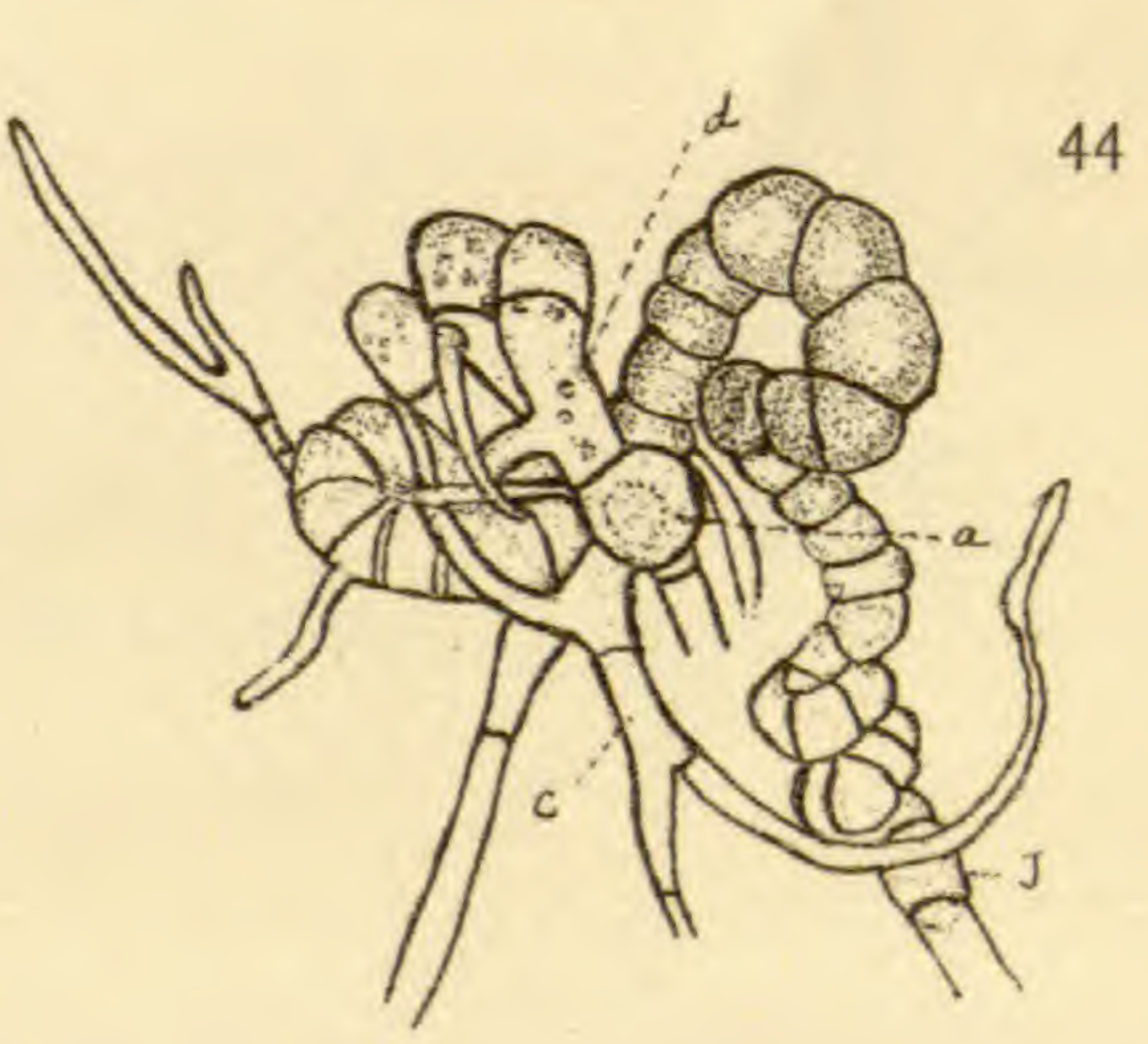

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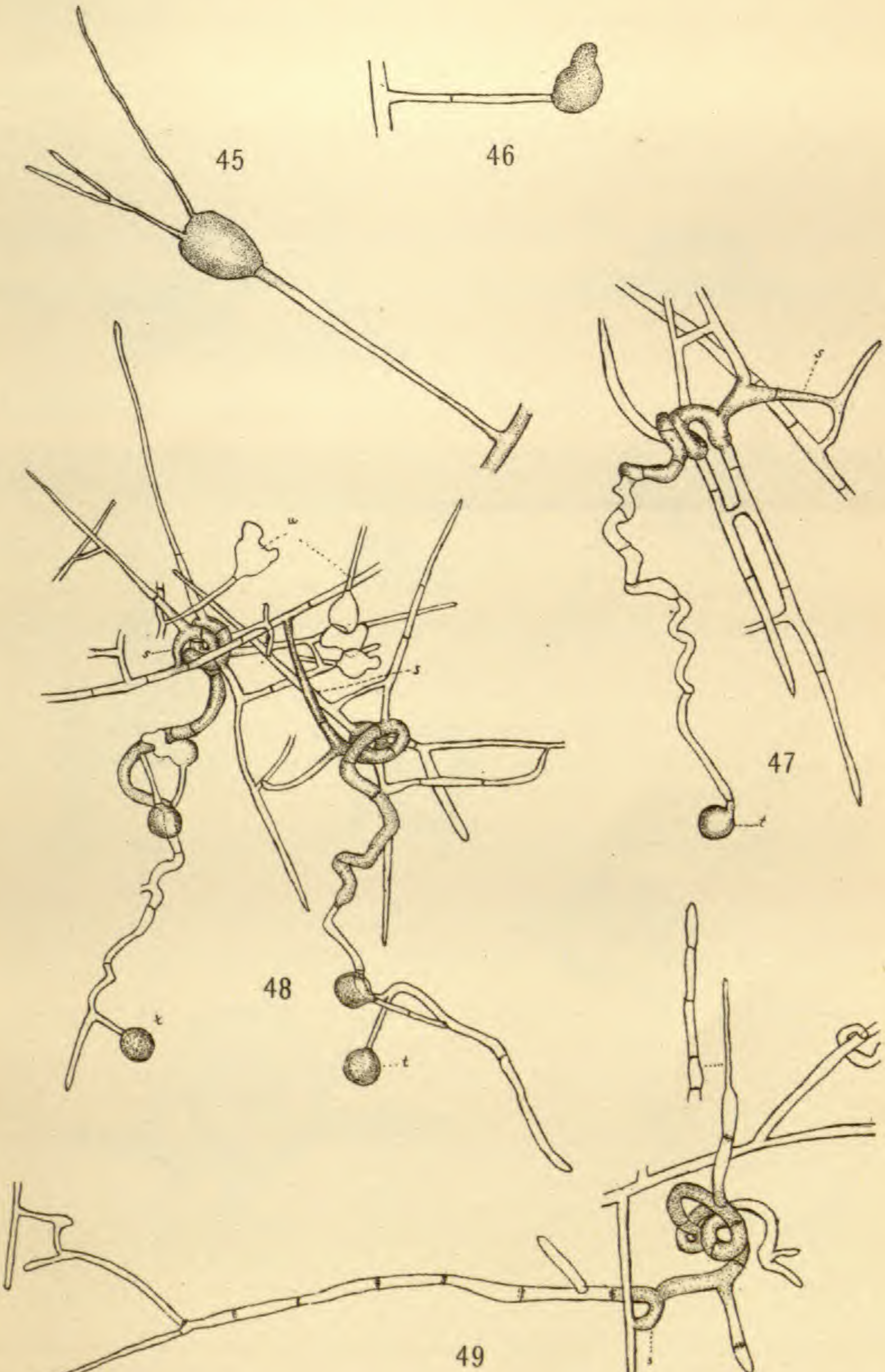

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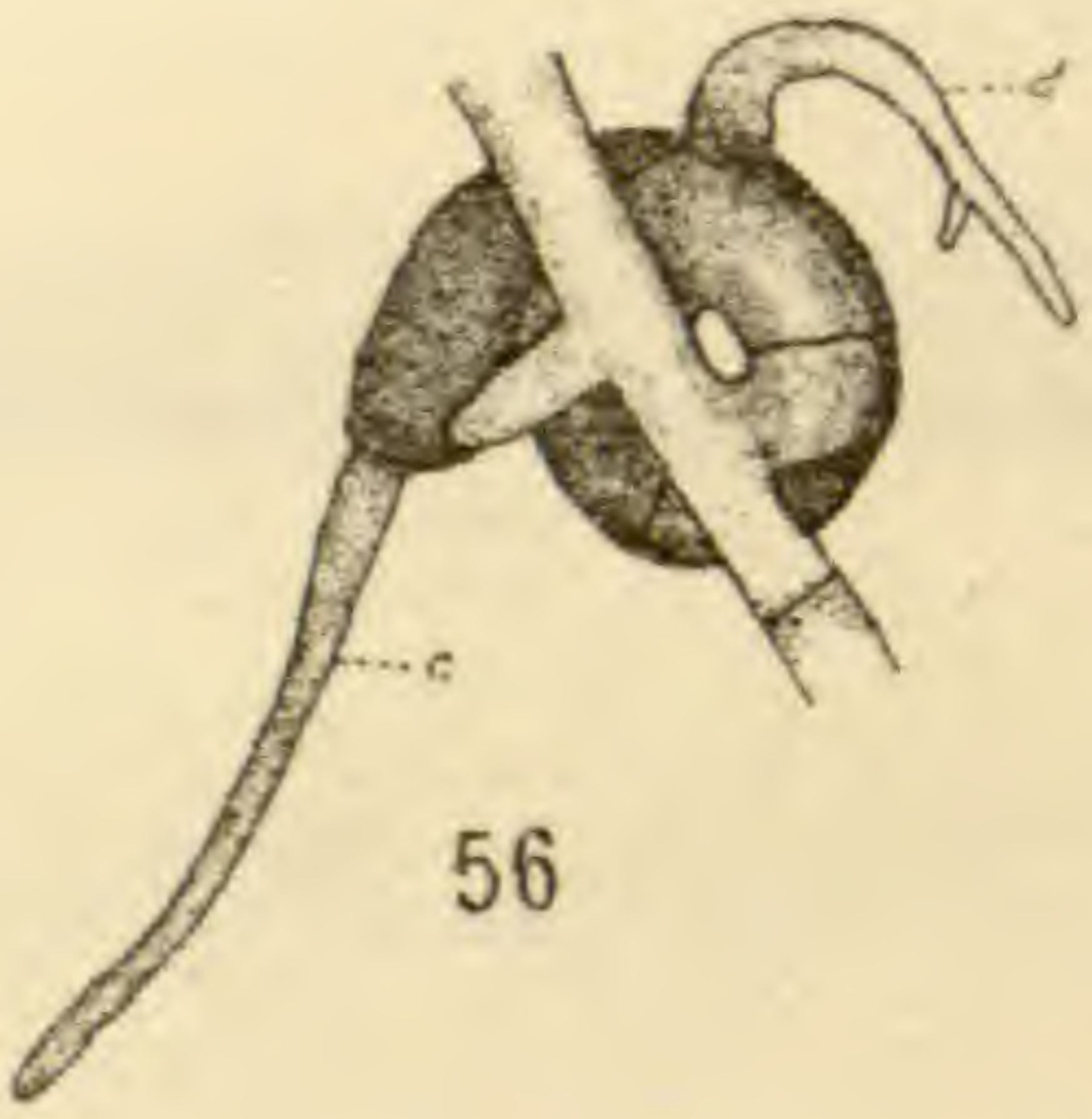

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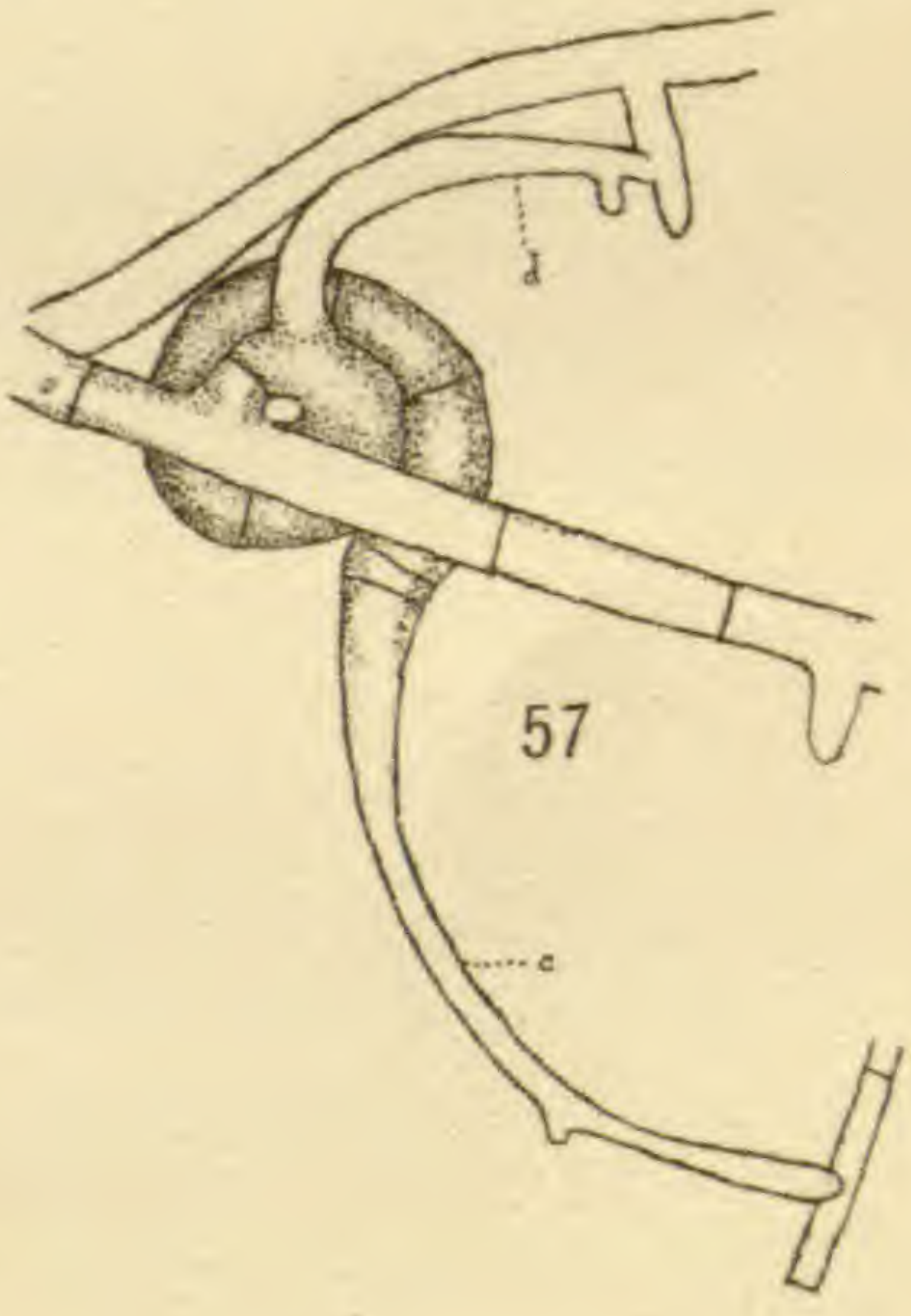

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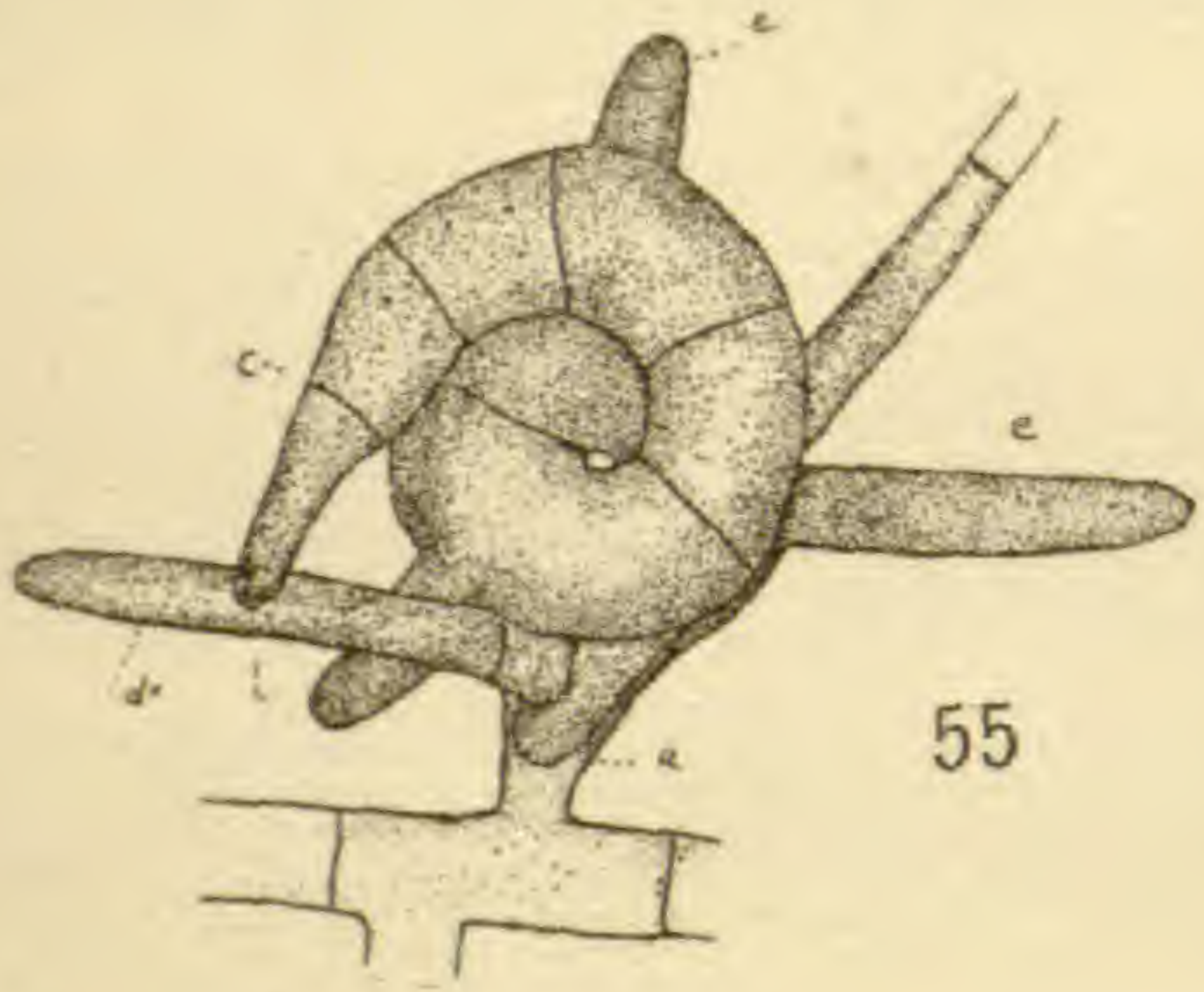

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Alexander W. Evans

(with plates 16 and 17)

In the tenth paper of this series* three genera of the Lejeuneae are discussed in which underleaves are entirely absent. In the genus *Diplasiolejeunea* the underleaves are duplicated; in other words an underleaf is developed for every lateral leaf, instead of for every pair of lateral leaves (plate 16, figures 1 and 10). The only other genus in which this peculiar condition is found is *Colura*, which contains some of the most remarkable species of the Lejeuneae. To explain the doubling of the underleaves in *Colura*, Goebel† advanced the theory that the leaves are not arranged in a three-ranked spiral, as is usual in the leafy Hepaticae, but that a postical segment is cut off from the apical cell after each lateral segment. This being the case the leaves would be arranged in a zigzag, and the imaginary line connecting their successive bases would not cross the antical surface of the stem at all. The examination of growing points in *Diplasiolejeunea* brought out the fact that Goebel's explanation would apply to this genus as well as to *Colura*. It should be noted, however, that the duplication of the underleaves is not an absolutely constant feature. The base of a branch, for example (figure 10), shows the ordinary spiral arrangement, and the same thing is true of an antheridial spike throughout its entire length (plate 17, figure 2). In the

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* Bull. Torrey Club 38: 251–286. *pl. 11, 12.* 1911.

† Organographie der Pflanzen 286 (footnote). 1898.

involucre, also, a single bracteole is present for the pair of bracts (PLATE 16, FIGURE 1), just as in other genera of the Lejeuneae. It is evident, therefore, that the spiral arrangement of the leaves is the primitive one and that the zigzag arrangement represents a later development.

In spite of its duplicated underleaves *Diplasiolejeunea* has many characters in common with *Cololejeunea* and *Leptocolea*, in which no underleaves whatever are developed. In fact, the authors of the Synopsis Hepaticarum included in their subsection Duplicatae, which is one of the groups into which they divided their § Typicae of the genus *Lejeunea*, two species of *Leptocolea* as well as several species of *Diplasiolejeunea*. Gottsche afterwards grouped together all the Lejeuneae known to him in which the underleaves were duplicated, some of which naturally belong to the genus *Colura*.* Spruce, however, was the first to define *Diplasiolejeunea* in its present sense. He included it among the subgenera of *Lejeunea*,† but it was soon raised to generic rank by Schiffner.‡

The genus is widely distributed in tropical regions and contains about twelve species. The type species, *D. pellucida* (Meissn.) Schiffn., is abundant in America and is known also from Africa, the East Indies, and New Caledonia. Three of the other species are African, one is known from Tasmania only, and the others are American. Although the plants attain a fairly large size for members of the Lejeuneae they are delicate in texture and show little or no pigmentation. They grow on bark and on living leaves, and at least some of the species seem to be constant in their choice of a substratum.

The stems cling closely to the substratum and branch irregularly according to the usual *Lejeunea* or *Radula* type. The stems are at first scattered, but with the appearance of branches compact mats are gradually formed, the branches lying subparallel or diverging in a more or less radiate manner. The leaves are large and usually loosely imbricated (PLATE 16, FIGURES 1, 10, and 11). The lobes are attached by an exceedingly short and almost transverse

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* Ann. Sci. Nat. Bot. V. 1: 164. 1864.

† Hep. Amaz. et And. 301. 1884.

‡ Engler & Prantl, Nat. Pflanzenfam. 1^3: 121. 1895.

line, very much as in *Cololejeunea* and its immediate allies. They spread widely from the axis and lie more or less appressed to the substratum, although in some species they are distinctly convex. They vary in outline from ovate to suborbicular, their apices are broad and rounded, their margins are entire or nearly so, and they tend to arch across the axis at the antical base. The cells of the lobes are plane or nearly so, and their walls are more or less thickened. In some species the thickening appears to be uniform, while in others trigones and intermediate thickenings are clearly visible. In all the Puerto Rico species ocelli are numerous and scattered throughout the lobe, very much as in the genus *Stictolejeunea*. They are found also in the perianths but seem to be constantly absent from the lobules and underleaves. In *D. pellucida* the lobes are often margined by a band of hyaline cells, but these have not been observed in the other species.

The lobule agrees in many respects with that of *Cololejeunea*. It is of a fairly large size, from one third to one half the length of the lobe, and is inflated throughout more or less of its extent. It broadens out abruptly from a narrow base and forms a distinctly arched keel with the lobe. The free margin is involute in its basal portion and sometimes for about half its length, the outer part being frequently appressed to the lobe. At some little distance beyond the middle the apical tooth is situated and is separated from the end of the keel by a shallow sinus. The tooth is remarkably well developed and shows considerable variation in form. It may, for example, be subulate and acuminate (FIGURES 1 and 5) or it may broaden out from a stalklike base into a t-shaped structure (FIGURES 10 and 13). The hyaline papilla is situated at the base of the tooth on the inner surface of the lobule. When the base of the tooth is three cells wide the papilla is on the median cell; when the tooth is two or four cells wide it is situated on one side of the median wall, sometimes on the distal side and sometimes on the proximal. In addition to the apical tooth the free margin bears a second tooth, proximal to the apex; this tooth is shorter than the apical tooth and also different in form. Between the proximal tooth and the base of the lobule one or more minute denticulations may be distinguished in certain species.

The underleaves are sometimes distant and sometimes overlap more or less closely. They are deeply bifid with long and spreading divisions, which taper gradually to sharp or blunt apices (PLATE 16, FIGURE 1; PLATE 17, FIGURES 1 and 2). Sometimes the divisions spread so widely that the upper margin of the underleaf is bounded by an approximately straight line. At the base a distinct radicelliferous disc is usually developed (PLATE 16, FIGURE 6) and affords a firm anchorage to the substratum. The margin is practically entire although the cells in some species often project as indistinct crenulations.

So far as known the inflorescence is either autoicous or dioicous and seems to be fairly constant for a given species. The archegonium is sometimes borne on a leading branch (FIGURE 1) and sometimes on a very short branch, in many cases a single leaf and a single underleaf being the only appendages present except the involucral leaves and the perianth (FIGURE 2). The female flower seems to be invariably subtended by a single innovation. The bracts are much smaller than the ordinary leaves and are subequally bifid (FIGURE 7), the lobule sometimes slightly exceeding the lobe in length (PLATE 16, FIGURE 17, on left). The single bracteole is free and more or less bifid, the divisions sometimes spreading widely and sometimes being suberect or connivent (PLATE 16, FIGURES 1 and 11). The perianth is sharply five-keeled, although more or less compressed, and becomes suddenly contracted at the apex into a short beak. The surface is apparently never roughened by teeth or projecting cells even along the keels. The antheridial spikes (PLATE 17, FIGURE 2) are much as in other Lejeuneae. They either occupy short branches or are terminal on longer branches and rarely show signs of proliferation. The bracts, which are rarely numerous, are usually diandrous. The sporophyte is essentially the same as in *Cololejeunea* and the other genera of the Lejeuneae.

The only species of *Diplasiolejeunea* that has been recorded from Puerto Rico is the type species, *D. pellucida*. The material collected by the writer includes this species and also three others, one of which seems to be undescribed. In distinguishing the species the lobules, the underleaves, the inflorescence, and the perichaetial bracts yield the best differential characters. The gemmiparous branches and the gemmae, which will be described at the close of the paper, may likewise be of service.

DIPLASIOLEJEUNEA PELLUCIDA (Meissn.) Schiffn.

Jungermannia pellucida Meissn.; Sprengel in Linnaeus, Syst. Veg. ed. 16. 4^2: 325. 1827.

Lejeunea ocellulata Mont. & Nees, Ann. Sci. Nat. Bot. II. **19**: 264. 1843.

Lejeunea pellucida Meissn. in G. L. & N. Syn. Hep. 393. 1845.

Lejeunea albifolia Tayl. Lond. Jour. Bot. **5**: 399. 1846.

Lejeunea (*Diplasio-Lejeunea*) *pellucida* Spruce, Hep. Amaz. et And. 302. 1884.

Diplasiolejeunea pellucida Schiffn. in Engler & Prantl, Nat. Pflanzenfam. 1^3: 121. 1895.

Pale green or whitish, growing scattered or in depressed mats: stems 0.07 mm. in diameter, sparingly and irregularly pinnate, the branches (except the subfloral innovations) widely spreading, similar to the stems but usually with smaller leaves: leaves loosely imbricated, the lobe obliquely to widely spreading, closely appressed to the substratum, broadly ovate, 0.85–1 mm. long, 0.7–0.85 mm. wide, antical margin rounded at the base and extending across the axis, outwardly curved to the apex, postical margin also curved, sometimes forming a vague angle at the junction with the keel, antical and apical regions often bordered by from one to four rows of hyaline cells; lobule ovate, 0.4–0.5 mm. long, 0.25–0.35 mm. wide, abruptly broadening from a narrow base, inflated throughout, keel arched, free margin more or less involute, often involving the proximal tooth, apical tooth obliquely spreading, acute, mostly three to five cells long and three or four cells wide at the base, usually tipped with a row of two or three cells, the terminal cell sometimes rounded or truncate, proximal tooth smaller than the apical tooth and usually tipped with an acute cell, hyaline papilla mostly on the distal side of the apical tooth, sinus about four cells long; cells of lobe averaging about 12μ at the margin, 23 × 20μ in the middle, and 35 × 20μ at the base, the walls more or less thickened but with vague trigones and occasional intermediate thickenings, hyaline marginal cells (when present) thin-walled: underleaves distant, rounded to cordate at the base, broadly cuneate, about 0.085 mm. long and 0.4 mm. wide, deeply bifid with widely spreading acuminate divisions, the apical sinus being very shallow or even obsolete, margin entire or subcrenulate from projecting cells: inflorescence dioicous: ♀ inflorescence borne either on a leading branch or on a very short branch, the innovation apparently continuing the floral axis and often bearing another inflorescence; bracts obliquely spreading, sharply complicate but not winged along the keel, shortly bifid (about one third), the lobe oblong, rounded, entire, 0.5 mm. long and 0.15 mm. wide, lobule nearly as large as the lobe, acute to acuminate, sparingly and irregularly denticulate; bracteole ovate, 0.35 mm. long, 0.15 mm. wide, bifid almost to the base with suberect or often connivent or overlapping acuminate divisions and a narrow sinus; perianth obovate, 0.95 mm. long, 0.5 mm. wide, rounded at the apex and with a very short beak: ♂ inflorescence terminal on a leading branch or occupying a short branch, not proliferating; bracts imbricated, mostly in from three to ten pairs, diandrous, strongly inflated, shortly and subequally bifid with rounded divisions, the postical sometimes bluntly pointed, keel strongly arched; bracteoles similar to the underleaves but much smaller and less deeply bifid with obliquely spreading acute divisions: capsule about 0.35 mm. in diameter; spores yellowish green, minutely verruculose, about 20μ in short diameter; elaters about 12μ wide, the wall irregularly thickened. (PLATE 16, FIGURES 1–9.)

On living leaves. Puerto Rico, without definite localities, *Schwanecke*, *Sintenis* (*27*). Sprengel describes the type locality of *Jungermannia pellucida* in the following words, "ad filices Ind. Occid." The writer has not been able to study any of the original material but bases his conception of the plant upon a series of specimens determined by various authorities. The species occurs in two fairly distinct modifications, the second of which is described below as a new variety. The typical form may be recorded from the following additional localities in the American tropics: Cuba, *Wright;* Jamaica, *Underwood*, *C. E. Cummings*, *N. L. Britton*, *Evans;* Costa Rica, *Pittier;* French Guiana, *Leprieur*, *Perrottet;* Brazil, *Endlicher*, *Pabst*, *Spruce*, *Glaziou*. Material from the various collections mentioned, much of which is in the British Museum, has been examined by the writer. The specimen collected by Leprieur, however, which represents the type of *Lejeunea ocellulata*, is in the Montagne herbarium at Paris. Of African specimens two have been studied, one collected in 1814 by Beauvais at "Oware," and the other by Rodriguez on the island of Mauritius. Both agree with the American plant, so far as can be determined by the fragmentary material. The Beauvais specimens, one of which is in the Kew herbarium, represent the type of *L. albifolia*, and show a certain approach to the variety described below. As has already been noted, *D. pellucida* has been reported also from the East Indies and from New Caledonia, but no material from these regions has been available for study.

Diplasiolejeunea pellucida malleiformis var. nov.

Apical tooth of lobule variable, sometimes as in the typical form of the species but usually t-shaped, the terminal portion consisting of from two to four cells placed at right angles to a short stalk, the latter one cell or rarely two cells wide: in other respects agreeing closely with the type. (TEXT FIGURE I.)

On leaves, rarely on bark. El Yunque, *Evans* (*10*, *120* in part, *127* in part). The variety may also be recorded from the following stations: John Crow Peak, Jamaica, *Evans* (*135* in part); Grande Soufrière Hill, Dominica, *Elliott* (*1815*, *1816*); Laudat, Dominica, *Lloyd* (*324a* in part); St. Vincent, *Elliott* (*9*, *22*, *356*).

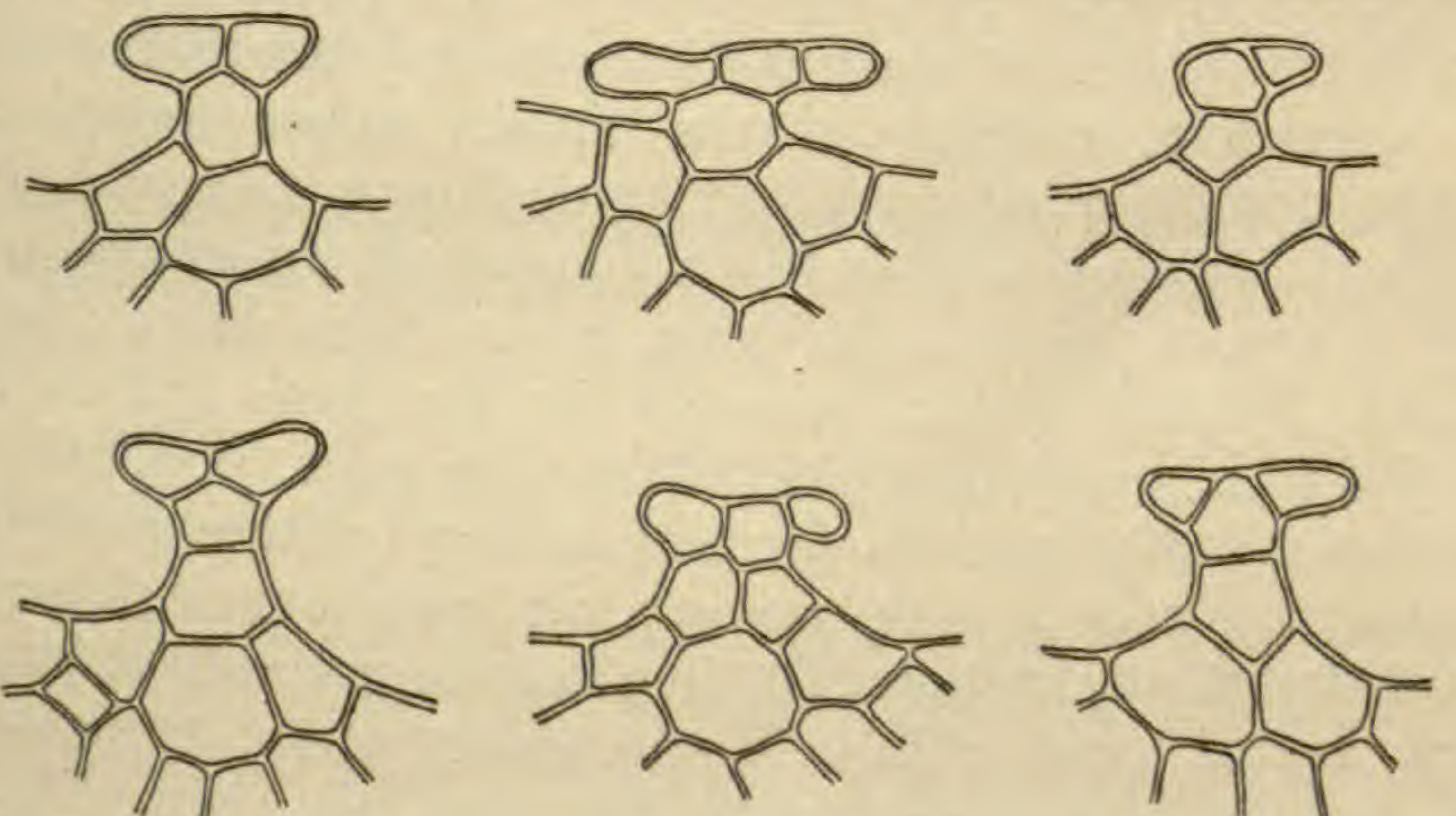

FIGURE I. *Diplasiolejeunea pellucida malleiformis;* El Yunque, Puerto Rico, *Evans* (*10*). Apical teeth of lobules, × 300.

The t-shaped apical tooth of the lobule in this curious variety is so different from the pointed tooth in typical *D. pellucida* that a specific separation seemed at first to be indicated. Unfortunately further study soon showed that this single difference was quite unsupported by others, and also that the t-shaped tooth formed an inconstant feature, some of the specimens showing both t-shaped and ordinary pointed teeth. In the Beauvais specimens noted above, none of the teeth are distinctly t-shaped, although some are tipped by two cells placed side by side at right angles to the stalk, and the latter is occasionally two cells wide. The material from the Grande Soufrière, Dominica, is in the herbarium of the

British Museum and was referred by Stephani to his *D. armatiloba*,* a species that requires further study. It was based on sterile specimens from Guadeloupe and was regarded by Gottsche as a variety of *D. pellucida*. Unfortunately the type has not been accessible, but a specimen in the British Museum, collected by Elliott at Trois Pitons, Dominica (*1754*), and determined by Stephani, coincides closely with the original description. This plant has a dioicous inflorescence and is very much like the variety *malleiformis*, the apical tooth of the lobule being even more definitely t-shaped. The underleaves, however, have rounded or obtuse divisions, which spread obliquely.

Diplasiolejeunea brachyclada sp. nov.

Pale green or yellowish, scattered or in depressed mats: stems 0.1 mm. in diameter, sparingly and irregularly pinnate, the branches widely spreading, similar to the stem: leaves loosely imbricated, the lobe obliquely to widely spreading, not appressed to the substratum, plane or more or less squarrose in the antical portion, broadly ovate, 1.25–1.5 mm. long, 1–1.1 mm. wide, when well developed, antical margin rounded at the base and extending across the axis, outwardly curved to the apex, postical margin straight or slightly curved, forming a very obtuse angle at the junction with the keel; lobule ovate, 0.7 mm. long, 0.3 mm. wide, inflated throughout, keel arched, free margin involute at least near the base, apical tooth obliquely spreading, acute, truncate or t-shaped, mostly three or four cells long and two cells wide at the base, proximal tooth sometimes inflexed, shorter than the apical tooth and acute, hyaline papilla distal in position; cells of lobe averaging about 12μ at the margin, $27 \times 18\mu$ in the middle, and $38 \times 20\mu$ at the base, the walls thickened uniformly: underleaves distant, rounded to subcordate at the base, broadly cuneate, averaging about 0.17 mm. in length and 0.6 mm. in width, deeply bifid with obliquely spreading acute divisions and a very obtuse sinus, margin entire: inflorescence autoicous: ♀ inflorescence borne on a very short branch, a single leaf and a single underleaf being present in addition to the involucral leaves and perianth, the innovation usually simple and sterile, rarely bearing a second female flower; bracts obliquely spreading, sharply complicate but not winged along the keel, bifid about one fourth, the lobule often a little longer than the lobe, the latter oblong, 0.5 mm. long, 0.17 mm. wide, rounded at the apex, entire or vaguely and sparingly

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* Hedwigia **35**: 80. 1896.

denticulate along the margin, lobule obtuse, sparingly denticulate; bracteole oblong-obovate, 0.5 mm. long, 0.3 mm. wide, bifid about one half with acute suberect divisions, entire or irregularly crenulate from projecting cells; perianth oblong or oblong-ovate, 1.2 mm. long, 0.5 mm. wide, rounded to truncate at the apex and with a very short beak: ♂ inflorescence occupying a short branch, very rarely proliferating; bracts imbricated, in from two to four pairs, similar to those of *D. pellucida;* bracteoles also similar: mature sporophyte not seen. (PLATE 16, FIGURES 10–18.)

On bark of trees. Puerto Rico: El Yunque, *Evans* (*24, 127* in part). Jamaica: Cinchona, *Evans* (*138, 250* in part). No. 24 may be designated the type.

This new species is closely related to *D. pellucida* but is at once distinguished by its larger size and by its autoicous inflorescence. The leaves, furthermore, always lack the hyaline border, which is so frequent in *D. pellucida*, and are never closely appressed to the substratum; in fact, they are oftentimes distinctly squarrose in the antical region. In other respects they are much alike in the two species. The underleaves yield a few additional points of distinction. In *D. pellucida* the divisions are acuminate and spread so widely that the upper margin of the underleaf is often scarcely indented in the middle. In *D. brachyclada* the divisions spread obliquely and form a distinct angle where they come together. Their apices are acute, rather than acuminate, and are usually tipped with a single cell; even when tipped with two superimposed cells they taper more abruptly than in *D. pellucida.* Apparently the female inflorescence in *D. brachyclada* is invariably borne on an abbreviated branch, but the involucral leaves and perianths show no very striking peculiarities. The antheridial spikes, also, show little tendency to vary in length. In *D. pellucida* both male and female branches are subject to marked variation in this respect.

DIPLASIOLEJEUNEA UNIDENTATA (Lehm. & Lindenb.) Schiffn.

Jungermannia unidentata Lehm. & Lindenb. in Lehmann, Pug. Plant. **6**: 48. 1834.

Lejeunea unidentata Lehm. & Lindenb. in G. L. & N. Syn. Hep. 392. 1845.

Lejeunea (*Diplasio-Lejeunea*) *unidentata* Steph. Hedwigia **29**: 90. 1890.

Diplasiolejeunea unidentata Schiffn. Bot. Jahrb. **23**: 583. 1897.

Pale green or whitish, growing in compact depressed tufts: stems 0.14 mm. in diameter, prostrate, irregularly pinnate, the branches obliquely to widely spreading, similar to the stem but usually with smaller leaves: leaves imbricated, the lobe widely spreading, somewhat convex, broadly ovate to suborbicular, 1.2–1.4 mm. long, 1–1.2 mm. wide, antical margin straight to rounded at the base, usually arching across the axis, strongly outwardly curved to the apex, postical margin also curved, forming a very obtuse or rounded indentation at the junction with the keel; lobule obovate, 0.7 mm. long, 0.4 mm wide, inflated along the arched keel, more or less appressed to the lobe in the outer portion, free margin involute near the base but usually plane otherwise, apical tooth acute, obliquely spreading, mostly three to five cells long and two or three cells wide at the base, usually tipped with two superimposed cells, proximal tooth much shorter and often inconspicuous, acute to rounded, hyaline papilla mostly distal, sinus shallow, forming a distinct angle with the apical tooth; cells of lobe averaging 18μ at the margin, 28 × 18μ in the middle and 32 × 18μ at the base, more or less thickened and usually with distinct trigones and occasional intermediate thickenings: underleaves distant to subimbricated, broadly cuneate, 0.2 mm. long in the middle, 0.5–0.6 mm. wide, bifid about one half with obliquely spreading divisions, obtuse to rounded at the apex, sinus mostly acute, margin entire: inflorescence dioicous: ♀ inflorescence borne on a leading branch or on a more or less abbreviated branch, the innovation mostly simple and sterile; bracts obliquely spreading, sharply complicate and sometimes very narrowly winged along the keel, bifid one third to one half, the lobe oblong, 0.6 mm. long, 0.25 mm. wide, rounded at the apex, entire, lobule similar in form, 0.5 mm. long, 0.22 mm. wide, rounded to very obtuse at the apex, margin entire; bracteole ovate, 0.45 mm. long, 0.35 mm. wide, bifid about one third with acute suberect divisions and an entire margin; perianth as in *D. pellucida*, 1.3 mm. long, 0.75 mm. wide: ♂ inflorescence occupying a short branch, not proliferating; bracts mostly in from three to six pairs, similar to those of *D. pellucida;* bracteoles also similar: mature sporophyte not seen. (PLATE 17, FIGURES 1–12.)

On bark, rarely on leaves. El Yunque, *Evans* (*2, 120* in part, *145*). The species is known to the writer from the following additional localities: Mansfield, Jamaica, *Evans* (*336*); Sharford Estate, Dominica, *Elliott* (*1601*); Martinique, *Duss;* St. Vincent, Herb. Hooker, the type station.

The present species and the following, *D. Rudolphiana*, have been so much confused that a brief account of their history may not be out of place. *Jungermannia unidentata* was originally described from a specimen in the Hooker herbarium, collected on the island of St. Vincent. A portion of this original material is preserved at Kew, and although it is perfectly sterile it agrees so closely with the other plants cited above that there can be but little doubt that they represent the same species. A similar specimen from the Lehmann herbarium is in the Montagne herbarium at Paris. In 1845 Montagne reported *D. unidentata* from Cuba, his record being based on specimens collected by Ramon de la Sagra.* He also published figures of these specimens, and since his time *D. unidentata* has been listed from a number of localities in tropical and subtropical America, many of the determinations being apparently based on these figures. A careful study of Montagne's specimens, however, has shown that the Cuban plant is not the same as the type specimen in the Hooker herbarium, and that some of the published records for the species are therefore incorrect, a fact which the writer has already noted elsewhere.† The Cuban plant, however, does not represent an undescribed species. It agrees closely with *D. Rudolphiana*, and the same thing is true of some of the other specimens that have been referred to *D. unidentata*.

In the opinion of Spruce,‡ *D. unidentata* ought to be considered as a variety of *D. pellucida*, but there are many reasons for regarding them as distinct species, in spite of the fact that both are dioicous. *D. unidentata* is a more robust plant than *D. pellucida*, it grows normally on bark and not on leaves, it is much less closely appressed to the substratum, its leaves always lack hyaline borders, and the leaf cells usually show distinct local thickenings in their walls. The underleaves, too, present a very different appearance. The divisions spread obliquely, forming a distinct sinus, and their apices vary from obtuse to rounded instead of being acuminate. In the involucre the bracteole is much less deeply bifid than in *D. pellucida*, and the lobes are consequently broader

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* In Ramon de la Sagra, Hist. Fis. Pol. y Natur. Cuba 9: 478. *pl. 19. f. 2.* 1845.

† Bull. Torrey Club 38: 207. 1911.

‡ Hep. Amaz. et And. 302. 1884.

and less sharply pointed; the perianth, however, is essentially the same. When compared with *D. brachyclada*, the dioicous inflorescence, the absence of t-shaped apical teeth on the lobules, the distinct local thickenings in the cell walls, and the blunter divisions of the underleaves will serve as distinguishing characteristics.

DIPLASIOLEJEUNEA RUDOLPHIANA Steph.

Lejeunea unidentata Mont. in Ramon de la Sagra, Hist. Fis. Pol. y Natur. Cuba **9**: 478. *pl. 19. f. 2.* 1845. Not Lehm. & Lindenb.
Diplasiolejeunea Rudolphiana Steph. Hedwigia **35**: 79. 1896.

Yellowish or brownish green, growing in compact depressed tufts: stems 0.12 mm. in diameter, sparingly and irregularly pinnate, the branches widely spreading, similar to the stem but usually with smaller leaves: leaves imbricated, more or less convex, the lobe widely spreading, broadly ovate, 1.2–1.4 mm. long, 1–1.2 mm. wide, antical margin rounded at the base, arching across the axis, strongly outwardly curved to the apex, postical margin likewise curved, forming a rounded indentation at the junction with the keel, margin entire or vaguely and sparingly crenulate from projecting cells; lobule obovate, 0.7 mm. long, 0.35 mm. wide, inflated in carinal region or throughout, keel arched, free margin involute near the base but usually plane elsewhere, apical tooth long and slender, subparallel with the axis or obliquely spreading, usually from six to eleven cells long and two cells wide at the base, proximal tooth shorter but sharp and distinct, often inflexed, usually tipped with a row of two or three cells, hyaline papilla distal; cells of lobe averaging 15μ at the margin, 28 × 22μ in the middle, and 37 × 25μ at the base, walls slightly thickened showing small trigones and very rare intermediate thickenings: underleaves distant to subimbricated, broadly cuneate, 0.17–0.2 mm. long in the middle, 0.4–0.6 mm. wide, bifid about one half with a rounded sinus and obliquely spreading divisions, mostly rounded at the apex but occasionally obtuse or subacute, margin as in the leaves: inflorescence autoicous: ♀ inflorescence borne on an elongated branch or on a very short branch, the innovation usually simple and sterile; bracts obliquely spreading, strongly complicate and very narrowly winged along the keel, bifid two thirds to three fourths, the lobe oblong-obovate, 0.4 mm. long, 0.17 mm. wide, rounded, margin vaguely crenulate from projecting cells, lobule oblong, 0.35 mm. long, 0.12 mm. wide, obtuse to subacute, margin as in the lobe; bracteole ovate, 0.35 mm. long, 0.25 mm. wide, bifid one fifth to one third with acute to obtuse suberect divisions, margin as in the bracts; perianth much as in *D. pellucida*, 1.3 mm. long, 0.5 mm. wide: ♂ inflorescence occupying a short branch, not proliferating; bracts mostly in from three to six pairs, similar to those of *D. pellucida;* bracteoles also similar: mature sporophyte not seen. (PLATE 17, FIGURES 13–17.)

On bark of trees. Near Cayey, 1900, *Evans* (*96* in part, *102*). The writer has examined specimens from the following additional localities: near Camp Longview, Florida, *Small & Wilson* (mixed with *2058*); various stations on New Providence, Bahama Islands, *Coker, E. G. Britton;** Cuba, *Ramon de la Sagra, Wright;* near Port Margot, Hayti, *Nash* (*165*); Troy, Jamaica, *Evans* (*658*); Paramaribo, Dutch Guiana, *Kegel;* Petropolis, Brazil, *Rudolph*, the type locality. The portion of the type that was studied is in the herbarium of the British Museum and agrees closely with the other specimens cited.

Although the geographical distribution of *D. Rudolphiana* is by no means thoroughly known, it seems to be the dominant representative of the genus in the lowlands of tropical America. It is often associated with the presence of man and occasionally occurs at higher altitudes along roadsides and in plantations. In this respect it resembles the common *Frullania squarrosa* (R., Bl. & N.) Dumort. It is closely related to *D. unidentata* but differs from it in two important particulars, its autoicous inflorescence and the remarkable development of the apical teeth of its lobules. The teeth form a very characteristic feature of the plant, even if poorly developed branches sometimes fail to show them in a typical condition. When well developed the apical tooth attains a length of about ten cells and is two cells wide for at least half its extent. It occupies a position parallel with the axis, and this is due, sometimes at least, to a curve at the base. The portion of the lobule from which the tooth arises shows an almost straight edge, the tooth forming a distinct angle on each side. The base is usually four cells across and the hyaline papilla is borne on the outer of the two median cells. The proximal tooth, also, is unusually long and distinct but is sometimes strongly inflexed and difficult to demonstrate. Between the proximal tooth and the

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* Bull. Torrey Club **38**: 207. 1911.

base one or two minute teeth, each consisting of a single projecting cell, can sometimes be distinguished. In cases where the apical tooth spreads obliquely, as in *D. unidentata*, it shows the same complexity as when parallel with the axis. Aside from the peculiarities just noted *D. Rudolphiana* is much like *D. unidentata*, and almost the same differential characters will serve to separate it from *D. pellucida* and *D. brachyclada*.

VEGETATIVE REPRODUCTION IN DIPLASIOLEJEUNEA

The vegetative reproduction in *Diplasiolejeunea* is carried on by means of discoid gemmae, which bear a marked resemblance to those found in the genera *Cololejeunea*, *Leptocolea*, and *Aphanolejeunea*. These gemmae have been demonstrated in *D. pellucida* (including the variety *malleiformis*), in *D. unidentata*, and in *D. Rudolphiana*. They have not yet been observed in *D. brachyclada*, however, and it is therefore possible that they are associated with certain species and never produced by others.

In *D. pellucida* the gemmae are borne on the lower surface of ordinary leaf lobes (TEXT FIGURE 2, *A*) and seem to be entirely absent from bracts and perianths. They occur on plants of either sex but tend to be more frequent on male individuals. In some cases the leaves on one side of a gemmiparous axis will develop gemmae much more abundantly than the leaves on the other side. Apparently the production of gemmae has no marked effect on the growth of the shoot, and the leaves upon which the gemmae are borne show no modifications. In *D. unidentata* and *D. Rudolphiana* the gemmiparous branches are very different from those of *D. pellucida* and much more highly specialized. They show a definite limitation in growth, and the gemmae are restricted to the youngest leaves that reach maturity, in most cases to the terminal pair of leaves (PLATE 17, FIGURES 1 and 3). These leaves differ considerably from normal leaves. Instead of being plane or convex, when examined from above, they are distinctly concave in the apical portion; and instead of spreading widely from the axis they spread very slightly. They are also relatively narrower than normal leaves, although sometimes larger. The modifications in the lobule affect chiefly the apical tooth, which is distinctly shorter than on normal leaves (FIGURE 6) and tends to be nearer the outer extremity of the free margin. The hyaline papilla occupies the usual position but no proximal tooth is developed. The gemmae, which are produced in great abundance, are confined to the apical portion of the lobe, but are situated on the lower surface as in *D. pellucida.*

The development of the gemmae is essentially the same as in *Cololejeunea* and its allies, so that only the most important features of the process need be mentioned. The establishment of the mother cell of the gemma, the division into quadrants, and the greater growth of the apical quadrants take place as described by Stevens for *Cololejeunea Biddlecomiae* (Aust.) Evans.* In the same way each apical quadrant proceeds to divide as a two-sided apical cell and cuts off two series of segments, the first division wall being parallel with the median wall of the gemma. The segmentation, however, is carried considerably further, the number of segments being usually from seven to ten. It will be remembered that five is the highest number of segments observed in *Leptocolea.* The gemma shown in TEXT FIGURE 2, *B* has ten segments on the left-hand side and nine on the right-hand side. The subsequent divisions in the segments are largely by periclinal walls, as many as three such walls appearing in some of the older

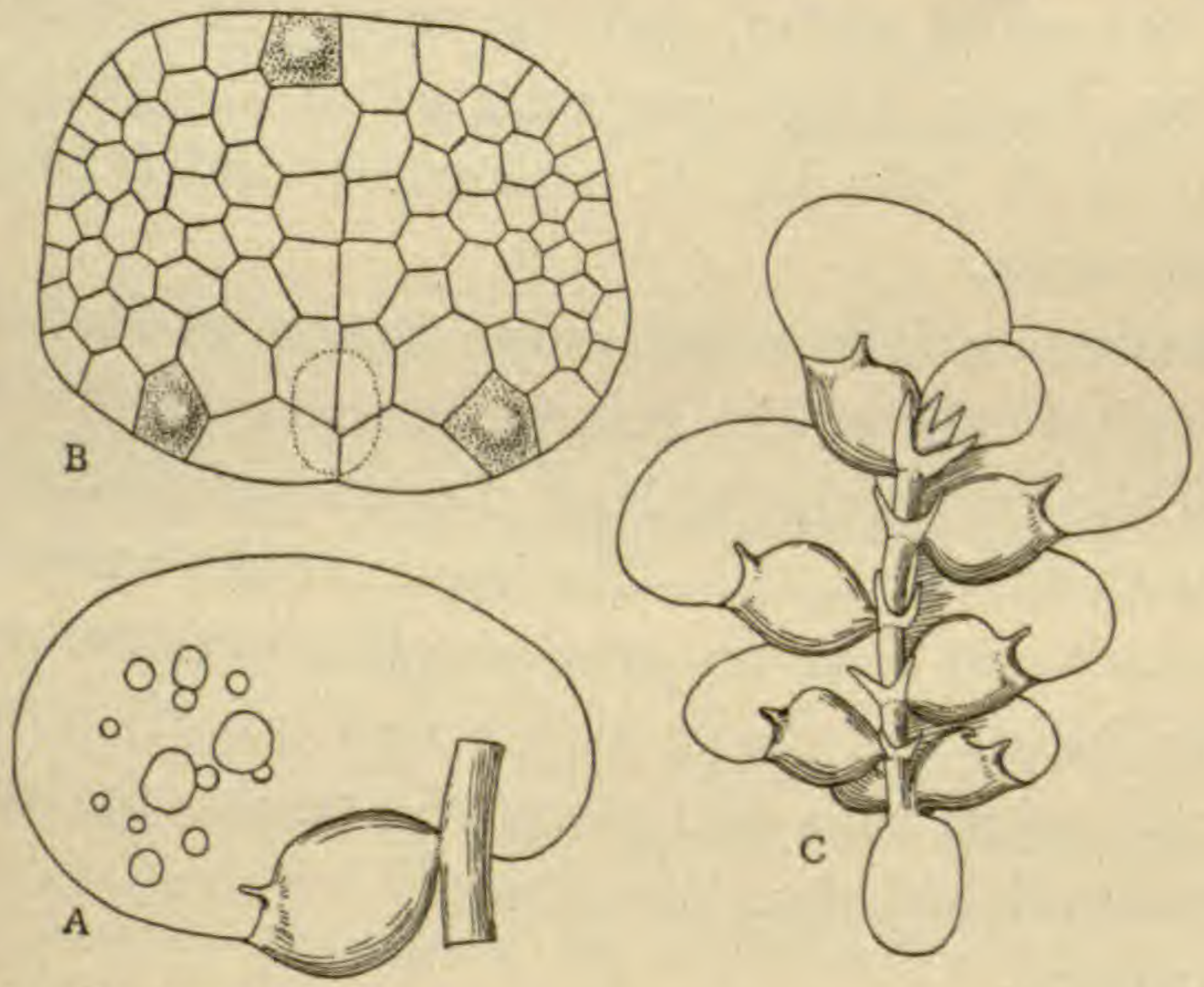

FIGURE 2. *Diplasiolejeunea pellucida;* Morce's Gap, Jamaica, *Evans* (*55*). *A.* Gemmiparous leaf, postical view, × 40. *B.* Gemma, × 300. *C.* Germinating gemma, postical view, × 40.

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* Bull. Torrey Club **37**: 366–369. *f. 1.* 1910.

segments. In the younger segments, however, there is often an anticlinal wall formed in the most external cell. So far as observed the basal quadrants always divide by a single periclinal wall. The attachment of the gemma is markedly excentric, and the separation takes place just as in *Cololejeunea*, a slightly projecting stalk cell being left behind.

The curious organs of attachment, noted in the genera *Cololejeunea*, *Leptocolea*, and *Aphanolejeunea*, are developed also in the gemmae of *Diplasiolejeunea*. In the vast majority of cases there are three such organs on each gemma. One arises from the outermost cell of one of the oldest segments on one side of the median wall, while the other two arise from the outermost cells of the second segments cut off from the apical quadrants. In a single instance a gemma with four organs of attachment was observed, one arising in each of the oldest segments. It will be noted that in contrast to *Cololejeunea* and its allies the basal quadrants play no part in the development of the organs of attachment. The mature gemma consists of an oval plate of cells broader than long. The margin is entire, and the apical cell in each half is clearly visible, being sometimes situated in a slight depression. The gemmae in *D. pellucida*, *D. unidentata*, and *D. Rudolphiana* are essentially alike.

The germination follows the same course as in *Cololejeunea*, one of the apical cells of the gemma functioning directly as the apical cell of the leafy shoot without the interpolation of a thalloid structure (TEXT FIGURE 2, *C*). The leaves at the base of the shoot are rudimentary and have no corresponding underleaves, but the characteristic features of the genus are very quickly acquired. In one case both apical cells had given rise to shoots, but one was much better developed than the other.

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Explanation of plates 16 and 17

The figures were drawn by the writer and prepared for publication by Mr. Stanley C. Ball.

PLATE 16

Diplasiolejeunea pellucida (Meissn.) Schiffn. 1. Part of a plant, showing a perianth borne on a leading branch, postical view, × 25. 2. A short branch bearing a female inflorescence, postical view, × 35. 3. Cells from middle of lobe, the dotted line representing the thickness of the wall about halfway between the two leaf surfaces, × 265. 4. Cells from margin of lobe, × 265. 5. Apex of lobule, × 200. 6. Part of an underleaf, × 200. 7, 8. Bract and bracteole from a single involucre, × 45. 9. Transverse section of a perianth above the middle, × 35. The figures were all drawn from specimens collected by the writer at Morce's Gap, Jamaica (*55*).

Diplasiolejeunea brachyclada Evans. 10. Part of a plant showing two female inflorescences and a male spike, postical view, × 25. 11. Part of a plant with a perianth and an antheridial spike, postical view, × 25. 12. Cells from middle of lobe, × 265. 13. Apical portion of a lobule, × 200. 14. Apical tooth of another lobule, × 200. 15. Apex of an underleaf division, × 200. 16–18. Bracts and bracteole from a single involucre, × 45. The figures were all drawn from specimens collected by the writer, FIG. 11 being from the type specimen (*24*), and the others from *no. 127*.

PLATE 17

Diplasiolejeunea unidentata (Lehm. & Lindenb.) Schiffn. 1. Female branch with perianth and innovation, the latter gemmiparous, postical view, × 25. 2. Part of a plant with two antheridial spikes, postical view, × 25. 3. Apical portion of a gemmiparous branch, postical view, × 25. 4. Cells from middle of lobe, × 265. 5. Apical portion of a lobule, × 200. 6. Apical portion of the lobule of a gemmiparous leaf, × 200. 7–9. Apices of underleaf divisions, × 200. 10–12. Bracts and bracteole from a single involucre, × 45. The figures were all drawn from specimens collected by the writer, FIG. 1, 10, 11, and 12 being from *no. 2*, and the others from *no. 145*.

Diplasiolejeunea Rudolphiana Steph. 13. Part of a leading axis, postical view, × 25. 14. Apical region of a lobule, × 200. 15–17. Bracts and bracteole from a single involucre, × 45. The figures were all drawn from specimens collected by G. V. Nash near Port Margot, Hayti (*165*).

A taxonomic study of the Pteridophyta of the Hawaiian Islands—

WINIFRED J. ROBINSON

(WITH PLATES 18–20)

The following paper is a partial result of the study of ferns and fern allies of the Pacific Islands, which was begun several years ago under the direction of the late Professor Lucien M. Underwood, whose design was to combine the regional taxonomic studies of a number of workers in a comprehensive report which should include ecological and morphological features as well. To the writer was assigned the taxonomic study of the Hawaiian fern flora.

The Hawaiian Islands lie at the crossroads of the Pacific, latitude 18° 55′–22° 15′ north, longitude 154° 50′–160° 30′ west, more than two thousand miles from San Francisco and about the same distance from the nearest islands to the southwest. They are farther from the mainland than any other group of islands of the same extent; and while a geodetic map shows that they have arisen by volcanic action through a fissure in the earth's crust, which extends from northwest to southeast, there is nothing to indicate that they were ever connected by a chain of islands with Japan, and there is very little in common in the floras of Japan and Hawaii. Hence their isolation must have been as complete through the ages as it is now. With the exception of coral limestone along the shore and a little sandstone and sedimentary rock, the soil is uniformly of basaltic origin. Kauai, geologically the oldest island of the group, about 2,000 m. high at its highest point, is most eroded and deserves its name of the garden island. Hawaii, with two snow-capped peaks, Mauna Kea and Mauna Loa, each nearly 5,000 m. high, and with its active volcano, Kilauea, is still in the making. The ridges are steep and the valleys narrow in all the islands. As a rule the northeast side of the island is covered with rain forest, while the southwest or lee side is arid because of the direction of the prevailing winds.

These winds together with the ocean currents make the temperature of the Hawaiian Islands several degrees lower than that of the West Indies, which are in the same latitude. At sea level it ranges from 16° to 30° C., while at an elevation of 365 m. it is about 20° C.

There are few wild plants in the islands that seem to owe their origin to northwest America, though a pine log of great size, evidently brought by the North Pacific Drift Current, has been known to reach the island of Maui. A correspondence between a number of South American and Hawaiian forms has been traced among flowering plants, but the affinities of the ferns seem to be with those of the islands to the southwest rather than with those of the mainland, while a large number of species are endemic. The extreme lightness of the spores makes their suspension in currents of air for long periods possible, and also may account for their transfer over great distances. In prehistoric times the journey of two thousand miles from the Society Islands was probably made several times in open boats, and since ferns were used in the religious rites of the islanders, some species may have been introduced in this way.

The material for this study consisted of the collections in the herbarium of the New York Botanical Garden (indicated by C), that of the Royal Botanical Garden at Berlin, Germany (indicated by B), the Bernice Pauahi Bishop Museum at Honolulu, H. I. (indicated by BM), the National Herbarium at the Smithsonian Institution, Washington, D. C. (indicated by N), and the herbarium of Vassar College, Poughkeepsie, New York (indicated by V). In a few cases comparisons have been made at Kew through the kindness of Mrs. N. L. Britton of the New York Botanical Garden (indicated by K). The writer spent seven weeks in the Hawaiian Islands, in the summer of 1909, in collecting ferns and observing ecological factors of their habitat.

When Captain Cook made his last South Sea voyage in 1776–9, during which he discovered the Hawaiian Islands, he was accompanied by David Nelson, who made collections of ferns and other plants, now preserved in the herbarium at Kew, that of the Linnean Society of London, and that of the British Museum. Landings were made upon Kauai and Nihau in January 1778, but the men did not remain long enough to permit exploration at any considerable distance from the shore. In November 1778 Captain Cook returned and spent ten weeks in cruising about Maui and Hawaii, making frequent landings, hence it is probable that the greater portion of Nelson's collection is from these islands.

At Kew there are also preserved specimens from the collections of Archibald Menzies, surgeon and naturalist upon Vancouver's voyage of 1790–95. Some of his specimens have reached the herbarium of the New York Botanical Garden by exchange with Kew. Vancouver's policy in dealing with the natives was so just that he secured their confidence and his men were able to explore freely. He spent about four months upon the islands.

In 1816–17 Albert Chamisso, while on the voyage of the Romanzoff, made collections of plants in Oahu and published his notes and descriptions of new species in Linnaea. His collections are at Berlin, in the herbarium of the Royal Botanical Gardens.

In 1819 Charles Gaudichaud, botanist of the French Corvette l'Uranie under Captain Freycinet made collections upon the islands, and published his account of plants in Botanique du Voyage d'Uranie, in 1830 (1826 according to the title page). He returned to the Hawaiian Islands in 1826 as botanist on the Bonite, but the only record of his collections consists of a few plates with no adequate descriptions or notes as to localities where the plants were found.

James Macrae, afterward superintendent of the Ceylon Botanical Gardens, made collections in the Pacific Islands and in South America between the years 1824 and 1826. His collections have been variously distributed by exchange and appear in herbaria in Great Britain, the Continent, and America.

In 1826–7 George T. Lay and Alexander Collie, the collectors with Captain Beechey on the voyage of the Blosssom, secured the specimens from which Hooker and Arnott made their report of the Botany of Captain Beechey's Voyage, 1830–41.

In 1833 David Douglas, sent out by the London Horticultural Society, made valuable collections of Hawaiian ferns, which are preserved in the herbaria of Hooker, Bentham, and Lindley. Douglas met his death in Hawaii by falling into a pit which was intended to entrap animals.

The United States Exploring Expedition under Captain Wilkes visited the Hawaiian Islands in 1840. Brackenridge, the botanist of the expedition, published his descriptions of ferns as a separate volume of the report of the expedition, but unfortunately the edition with the exception of about a dozen copies was destroyed by fire. A nearly complete set of his specimens is in the U. S. National Herbarium at Washington, D. C., and the collection is well represented at the New York Botanical Garden.

Rev. J. Diell, seaman's chaplain at Honolulu, aided Brackenridge materially in his collecting and also did much independently.

On the Galathea Expedition, 1845–7, sent out from Denmark, Didrichsen was the botanist. The larger part of his collections are at Copenhagen; some specimens, however, have reached other herbaria by exchange.

Between 1851 and 1855 Remy made collections for the Paris Museum, some of which may now be seen in the Gray Herbarium at Cambridge, Massachusetts.

In 1864 and 1865 Horace Mann with Dr. William T. Brigham, now Director of the Bernice Pauahi Bishop Museum at Honolulu, spent a year in botanizing over the five larger islands. With the aid of Professor Asa Gray, Mann made an enumeration of the plants found on the islands, which included one hundred and thirteen species of ferns. One set of these specimens is at the Museum in Honolulu and another at Cornell University, Ithaca, New York. Some of the numbers appear in other herbaria.

Many residents in the islands have been interested in the fern flora and have made large collections. The Reverend John M. Lydgate, of Lihue, Kauai, civil engineer and botanist, as well as clergyman, published an enumeration of Hawaiian ferns in 1873, when in college at Oberlin. His later collections have been contributed to Dr. W. Hillebrand's herbarium, now in Berlin. Many of the specimens from Kauai in the Berlin herbarium were collected by Mr. Valdemar Knudsen. The late D. D. Baldwin, at one time professor at Punahou College, has made large collections upon Oahu and Maui. Rev. Edward Bishop was an ardent collector also.

In 1883 Edward Bailey published "Hawaiian Ferns, a Synopsis," a small manual, now out of print. It contained descriptions of six new species.

Dr. William Hillebrand spent twenty years in the Hawaiian Islands, during all of which time he was an enthusiastic botanist. A part of the manuscript of his Flora of the Hawaiian Islands was with the printer at the time of his death, in 1887, and the work was published the following year by his son, Dr. W. F. Hillebrand, now Chief Chemist, Bureau of Standards, Washington, D. C. The herbarium of Dr. William Hillebrand was bequeathed to the Royal Botanical Museum, at Berlin, Germany. The accuracy of his descriptions was shown by the comparison of his specimens with the diagnoses in his Flora. He included one hundred and fifty-five species and many varieties of pteridophytes.

Mr. A. A. Heller, now of the College of Agriculture, Reno, Nevada, made a botanical exploration of Kauai and Oahu in 1895–6 under the auspices of the Minnesota State Geological Survey. The larger part of the collection is at the herbarium of the University of Minnesota, but duplicates have been distributed to several of the larger American institutions and to Kew. A complete set of his vascular cryptogams is at the New York Botanical Garden, as it was sent to Professor L. M. Underwood for determination. The report included one hundred and sixteen species, six of which were new.

In the following summary of the taxonomic study of Hawaiian ferns, diagnoses of the larger groups and also of genera have been given with keys to species, but descriptions of species already published elsewhere have been omitted.

The method in this study has been to examine the specimens as if they represented undescribed species, then to compare them with types so far as possible and with published descriptions. It has been attempted to give the name first used for the plant in Linnaeus' Species Plantarum or the name first published subsequent to 1753.

The writer is indebted to Dr. N. L. Britton, Director of the New York Botanical Garden, for suggestions and criticism, to Mr. William R. Maxon of the U. S. National Herbarium, Smithsonian Institution, Washington, D. C., for the loan of material and helpful criticism, and to Dr. J. H. Barnhart, Librarian of the New York Botanical Garden, for suggestions and criticism as to form, also to Professor A. Engler, Director of the Royal

Botanical Gardens of Berlin, Germany, for permission to study the Hawaiian ferns in the herbarium of the Royal Museum.

PTERIDOPHYTA

Plants (sporophytes) with well-defined vascular tissue, which in the homosporous series produce spores that grow into gametophytes which may be monoecious or dioecious, and in the heterosporous series produce megaspores and microspores; of these the megaspores grow into gametophytes that bear female organs (archegonia), the microspores into gametophytes that bear male organs (antheridia). As the result of the union of the egg cell in the archegonium and a motile male cell (antherozoid) from an antheridium, the sporophyte, ordinarily considered the plant, develops. Reproduction by some form of budding occurs both in the gametophyte and the sporophyte stage of the life history of many species.

Spores in capsules (sporocarps) borne upon the rhizome. 1. Salviniales.
Spores borne upon some aerial member of the plant.
  Sporangia not borne in the axils of scalelike leaves.
    Vernation circinate.
      Sporangia separate. 4. Filicales.
      Sporangia coalescent (synangia). 3. Marattiales.
    Vernation erect or inclined. 2. Ophioglossales.
  Sporangia borne in the axils of scalelike leaves; these either distant or forming compact strobili. 5. Lycopodiales.

1. SALVINIALES

Aquatic or subaquatic plants with horizontal, creeping or floating stems, which bear sporocarps containing megaspores or microspores or both; leaves various.

Plants floating; leaves with entire or 2-lobed blades folded in vernation. 1. Salviniaceae.
Plants rooting in the mud; leaves filiform or 2–4-foliate, circinate in vernation. 2. Marsileaceae.

1. SALVINIACEAE

Small floating plants, with a more or less elongated, sometimes branching axis. Leaves apparently 2-ranked. Sporocarps 2 or more borne upon a common peduncle; megaspores and microspores in separate sori.

Azolla sp. recently introduced to prevent the breeding of mosquitoes in the ditches along the rice fields.

2. MARSILEACEAE

Perennial plants; leaves 2 or 4-foliate; sporocarps on peduncles which arise with the petioles of leaves or separately from the rootstock and bear megaspores and microspores in the same sorus.

Type species:* *Marsilea quadrifolia* L.

Marsilea villosa Kaulf. Enum. 272. 1824

Type locality: Oahu, Hawaiian Islands.

Distribution: In taro patches, Hawaiian Islands.

Specimens examined: Hawaiian Islands, *Chamisso* B; *Gaudichaud* B; *Remy* B.

M. villosa is closely allied to *M. vestita* Hook. & Grev. from Oregon and California. Brackenridge referred the American plant to *M. villosa*, but the specimens examined indicate that the Hawaiian plant is a larger and less hairy species than that figured by Hooker and Greville (Ic. Fil. 159. 1829). All specimens in the Berlin herbarium are sterile; Remy's specimen has narrower leaflets and a more compact rootstock than Chamisso's.

Species inquirenda

Marsilea crenulata Desv. Reported by Hillebrand (Fl. Haw. Is. 651. 1888) as collected in Oahu and preserved in the Godet Herbarium. This herbarium is unknown to Dr. W. T. Brigham, director of the Bishop Museum at Honolulu. No specimen was found by the writer in the Berlin herbarium.

2. OPHIOGLOSSALES

Herbaceous, usually succulent plants consisting of a fleshy rootstock with fibrous or fleshy roots and one to several leaves, the latter erect or pendent, non-articulate, simple, lobed, or compound, the blade sessile or stalked; sporophyls simple or ternately compound, arising from the sterile leaf or from the rootstock. Sporangia formed each from a group of epidermal and subepidermal cells, dehiscing by a transverse slit. Prothallia subterra-

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*According to the American code of nomenclature the type species of the genus *Marsilea* L. is *Marsilea natans* L. which is based upon *Salvinia* Mich. Nov. Pl. Gen. *pl. 58.* 1729. Under the American code, therefore, the name *Marsilea* L. should be used for *Salvinia* (Micheli) Adans., while the present genus should be called *Lemma* (B. Juss.) Adans.

nean, usually achlorophyllous and nourished by an endophytic fungus.

OPHIOGLOSSACEAE

Characters of the order.

Leaf blade and sporophyl both ternately compound; veins free. 1. *Botrychium.*
Leaf blade simple, sporophyl a distichous spike; veins reticulate.
  Plants terrestrial; leaf blades petiolate. 2. *Ophioglossum.*
  Plants epiphytic; leaf blades sessile. 3. *Ophioderma.*

1. BOTRYCHIUM Sw. Jour. Bot. Schrad. **1800**^{2}: 110. 1801

Terrestrial plants; rootstock short, fleshy, erect; roots clustered, fleshy; sterile leaves 1–3-pinnately compound or decompound; veins free; sporophyls ternately compound; sporangia separate, spherical, sessile, pinnately arranged.

Type species: *Osmunda Lunaria* L.

BOTRYCHIUM SUBBIFOLIATUM Brack. Fil. U. S. Expl. Exp. 317. 1854

TYPE LOCALITY: Hawaii, District of Puna.

DISTRIBUTION: On the ground in wet forests, Hawaiian Islands.

ILLUSTRATIONS: Brack. Fil. U. S. Expl. Exp. *pl. 44.* 1854. PLATE 18.

SPECIMENS EXAMINED: Hawaii, District of Puna, *Wilkes Expedition* (type) N; Oahu, *Lydgate* B; Kauai, *Forbes 262* BM; *Wawra 2061* C; *Remy 62* B; Hawaiian Islands, *Baldwin 114* B, C, N.

The sterile leaf is always asymmetrical, one of the basal pinnae arising above the other.

2. OPHIOGLOSSUM L. Sp. Pl. 1062. 1753

Terrestrial plants; rootstock erect, less than 1 cm. in height; roots fleshy; leaves glabrous; leafstalk fleshy, not articulate; veins anastomosing, with occasional free included veinlets; sporophyl a pedunculate spike, arising from the base of the expanded blade; sporangia in two rows, coalescent.

Type species: *Ophioglossum vulgatum* L.

OPHIOGLOSSUM CONCINNUM Brack. Fil. U. S. Expl. Exp. 315. 1854

TYPE LOCALITY: Sand hills, near Wailuku, Maui, Hawaiian Islands.

DISTRIBUTION: On ground, appearing after rains; often near the seashore or in soil that has been taken from the shore; Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 44. f. 1.* 1854.

SPECIMENS EXAMINED: Maui, *Hillebrand* B; Oahu, *Forbes* BM; *Remy* B; Hawaiian Islands, *Baldwin 113* B, C.

The point of divergence between the leaf and sporophyl is on the petiole in *O. nudicaule* Sw. (Syn. Fil. *pl. 4. f. 2.* 1806), while in *O. concinnum* Brack. it is at the base of the blade; the blade is ovate in *O. nudicaule* rather than elliptical as in *O. concinnum*, and there is no trace in the Hawaiian plant of the midrib mentioned for *O. ellipticum* (Hook. & Grev. Ic. Fil. *pl. 40.* 1831). All these forms, however, are closely related.

3. OPHIODERMA (Bl.) Endl. Gen. Pl. 66. 1836

Epiphytic plants; rootstock erect, less than 1 cm. high; roots fleshy; leaves not articulate, strap-shaped, sessile, fleshy, brittle; venation reticulate, without free included veinlets; sporophyl a two-ranked spike of coalescent sporangia, arising from the middle of the blade.

Type species: *Ophioglossum pendulum* L.

OPHIODERMA PENDULUM (L). Presl, Suppl. Tent. Pterid. 56. 1845
Ophioglossum pendulum L. Sp. Pl. ed. 2. 1518. 1763.

TYPE LOCALITY: Amboina, Molucca Islands.

DISTRIBUTION: On trees or fallen logs, at elevations of 600–1,500 m.; Asia, Australia, Polynesia.

ILLUSTRATIONS: Hook. & Grev. Ic. Fil. *pl. 19.* 1831; Rumpf. Amb. *pl. 37. f. 3.* 1741.

SPECIMENS EXAMINED: Hawaii, *Robinson 212* V; *Wilkes Expedition* N; Maui, *Lichtenthaler* N; *Robinson 304* V; *320* V; Oahu, *Heller 2217* C, N; *Robinson 8* V; *43* V; *111* V; *115* V; *Safford 920* N; Kauai, *Robinson 429* V; *443* V; Hawaiian Islands, *Baldwin 112* B, C; *Miss Sessions* C; ex Herb. John Donnell Smith *618* N.

3. MARATTIALES

Plants herbaceous, consisting of a fleshy or tuberous rootstock, soft fleshy roots, and cespitose, stipulate, bipinnate to tripinnate leaves, which are articulate upon the stem and circinate in vernation; veins free; sporangia developed from a group of epidermal and subepidermal cells, separate or coalescent, in the latter case forming boat-shaped or circular synangia. Prothallia green, thalloid, large.

MARATTIACEAE

Characters of the order.

MARATTIA Sw. Prod. Fl. Ind. Occ. 128. 1788

Rootstock tuberous, starchy; leaf blades deltoid, dark green, thick, glabrous, bipinnate to tripinnate; stipules two, fleshy, at the base of the fleshy leafstalk; venation free; sporangia near the ends of the veins, coalescent, forming synangia upon a slightly elevated receptacle; these in some species subtended by a pseudo-indusium.

Type species: *Marattia alata* Sw.

MARATTIA DOUGLASII (Presl) Baker; Hook. & Baker, Syn. Fil. 441. 1868

Marattia alata Hook. & Arn. Bot. Beech. 102. 1832. Not *M. alata* Sw. 1788.
Stibasia Douglasii Presl, Suppl. Tent. Pterid. 16. 1845.
Gymnotheca Douglasii Moore, Ind. Fil. 121. 1857.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In moist, shady localities, above 600 m. elevation, Hawaiian Islands.

ILLUSTRATION: Vriese, Mon. Marat. *pl. 4.* 24. 1853.

SPECIMENS EXAMINED: Hawaii, *Robinson 202* V; Maui, *Robinson 329* V; Oahu, *Diell* C; Kauai, *Heller 2770* C, N; *Lichtenthaler* N; Hawaiian Islands, *Baldwin 111* C, N; *Wilkes Expedition* C; *Hitchcock* C; ex Herb. Mt. Holyoke College C; ex Herb. John Donnell Smith N.

The fleshy tubers taste somewhat like a turnip and are eaten either raw or baked by the native Hawaiians.

4. FILICALES

Plants terrestrial or epiphytic (aquatic in Ceratopteridaceae), varying in habit from minute herbaceous forms to arboreous forms; sporangia developed from a single epidermal cell, mainly upon the under surface of the leaf, in clusters (sori) upon the veins, or within marginal indusia, or less commonly, scattered over the entire lower surface or upon non-foliose sporophyls. Indusia various or wanting. Prothallia chlorophyllous, thalloid.

- Sporangia borne in a distichous spike; sterile leaves slender, grasslike. 1. SCHIZAEACEAE.
- Sporangia associated in indusiate or non-indusiate sori or scattered over the lower surface of the leaf.
  - Leaves pseudo-dichotomous, usually with a bud between the paired divisions, giving the appearance of indefinite growth; sori non-indusiate, small, circular. 2. GLEICHENIACEAE.
  - Leaves simple, pinnately divided, or ternately divided.
    - Sori valvate or tubular.
      - Sori valvate, the outer valve formed by a coriaceous outgrowth from the margin of the leaf, dorsal upon the veins; plants arboreous. 3. CYATHEACEAE.
      - Sori valvate or tubular, not coriaceous; terminal upon the veins; plants delicate, mostly epiphytic. 4. HYMENOPHYLLACEAE.
    - Sori not valvate or tubular; indusium various or absent. 5. POLYPODIACEAE.

1. SCHIZAEACEAE

Plants of diverse form and habit, including xerophilous forms with simple leaves and climbing plants with lobed or divided leaves. Sporangia borne singly or in rows on more or less specialized terminal segments, or upon the very slender non-foliose pinnae, indusiate or non-indusiate; annulus subapical, distally contracted; dehiscence longitudinal. Prothallia foliose or filamentous and branched.

SCHIZAEA J. E. Smith, Mém. Acad. Turin 5: 419. 1793

Rootstock short, upright, covered with dark brown scales; leaves linear, grasslike; sporophyl consisting of a long slender stalk and a digitate fertile portion folded upon the midrib; sporangia borne in two rows upon each division.

Type species: *Schizaea dichotoma* J. E. Smith.

SCHIZAEA ROBUSTA Baker; Hook. & Baker, Syn. Fil. ed. 2. 429. 1874

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: At high elevations in marshes and occasionally in exposed localities, Hawaiian Islands.

SPECIMENS EXAMINED: Oahu, *Forbes 1038* BM; *Lichtenthaler* N; *Mann & Brigham 475* N; *Wilkes Expedition* N; Kauai, *Heller 2246* C, N; *Robinson 419* V; *452* V; Hawaiian Islands, *Baldwin 115* C, N; *Baldwin* (ex Herb. Hillebrand) C; *Baldwin* (ex Herb. Mt. Holyoke College) C.

This is the species wrongly referred by Brackenridge (Fil. U. S. Expl. Exp. 302. 1854) to *S. australis* Gaud., a plant from the Falkland Islands, described by Gaudichaud (Ann. Sci. Nat. 5: 98. 1825).

Heller (Minn. Bot. Stud. 1: 789. 1907) says: "The first specimens were collected at an elevation of perhaps 762 m., on Konahuanui, Oahu, on a little spot in clay formation. The plants were small and stunted. It was found on the opposite side of the valley on the slope of Waiolani, at the same elevation. Near the Wahiawa bog, on Kauai, large and beautiful specimens were obtained." Mr. C. N. Forbes' specimen (*Forbes 1038* BM) collected at the extreme western ridge of Konahuanui, "a dry ridge in broad sunlight," is small and stunted though it has developed sporangia, while specimens from the Wahiawa bog above McBride's mountain house (*Robinson 419* V and *452* V) are large and fine.

2. GLEICHENIACEAE

Terrestial, xerophilous plants, with erect or creeping rootstocks. Leaves non-articulate, distant or cespitose, mostly consisting of an erect or ascending primary leafstalk of indeterminate growth, forking into one to several opposite divisions, these simple and determinate or one to several times dichotomous. Sori dorsal or terminal upon the veins, non-indusiate; sporangia sessile, subglobose to pyriform; annulus nearly complete, obliquely transverse; dehiscence vertical.

The family Gleicheniaceae is represented by several species of the genus *Dicranopteris*, which form nearly impenetrable thickets upon the mountain sides and sometimes in the valleys also. The attachment of the roots to the thin soil is very insecure and the man or beast that ventures to step upon the seemingly solid mass, where it has overgrown the trail in the mountains, may feel it give way, allowing him to slip far down the steep slope. *Dicranopteris* is known locally as stag-horn fern and is a pest in the cattle-raising districts, as stock refuse to graze upon it.

DICRANOPTERIS Bernh. Neues Jour. Bot. Schrad. 1^2: 38. 1806

Rootstock creeping, much branching, 0.5–1 cm. in diameter; leafstalk 1–2 m. high, not articulated to the rootstock; rachis of indeterminate growth, bearing opposite lateral branches in acropetal succession, these simple or repeatedly forked; included buds sometimes developing axes similar to the primary; ultimate divisions pectinate, pinnate, or bipinnate; veins free; sori dorsal upon the veins, non-indusiate; sporangia sessile; annulus obliquely transverse, the dehiscence vertical.

Type species: *Polypodium pectinatum* Thunb.

Ultimate divisions bipinnate, the leafstalk not forked.
  Pinnules sessile, the lower segments lobed and overlapping the rachis; leafstalk noticeably scaly. *D. glauca.*
  Pinnules stalked, the lower segments entire; leafstalk with few scales. *D. glabra.*
Ultimate divisions (pinnae) pectinate, in pairs; the leafstalk once or several times forked.
  A pair of accessory, deflexed, equal or unequal pinnae borne at all except the ultimate forkings of the leafstalk; veins 2–5-forked; segments mostly emarginate, connected by wing along rachis; sori 5–12-sporangiate.
    Segments densely tomentose when young, somewhat less so with age; texture rigid; emarginate character of pinnules constant; sori mostly 8-sporangiate or less. *D. emarginata.*
    Segments glabrous or nearly so; texture chartaceous; emarginate character of pinnules not constant; sori usually 12-sporangiate. *D. linearis.*
  Accessory pinnae wanting; segments not emarginate, nearly or quite free; rachis scaly; veins mostly once forked; sori 2–5-sporangiate. *D. owhyhensis.*

DICRANOPTERIS GLAUCA (Thunb.) Underw. Bull. Torrey Club 34: 249. 1907

Polypodium glaucum Thunb.; Houtt. Nat. Hist. 14: 177. 1783.
Mertensia glauca Sw. Sv. Vet.-Akad. Handl. II. 25: 177. 1804.

Gleichenia longissima Blume, Enum. Pl. 250. 1828.
Mertensia pinnata Kunze, Anal. Pterid. 6. 1837.
Mertensia excelsa J. Sm. Lond. Jour. Bot. 2: 381. 1843.
Gleichenia glauca Hook. Sp. Fil. 1: 4. 1844.
Hicriopteris speciosa Presl, Epim. 27. 1849.

TYPE LOCALITY: Java.

DISTRIBUTION: China, Japan, Malaysia, Tropical Australia, and Polynesia.

ILLUSTRATION: Hook. Sp. Fil. *pl. 3B.* 1844.

SPECIMENS EXAMINED: Maui, *Bailey* C; Molokai, *Hillebrand* B; Oahu, *Hillebrand* B; *Macrae* B; *Robinson 501* V; *504* V; Kauai, *Hillebrand* B, C.

D. glauca is found in fruit somewhat rarely. Both the bipinnate species are less common than *D. linearis* and grow at higher elevations.

DICRANOPTERIS GLABRA (Brack.) Underw. Bull. Torrey Club 34: 249. 1907

Mertensia glabra Brack. Fil. U. S. Expl. Exp. 292. 1854.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Above 600 m. on wet mountain slopes, Hawaiian Islands.

SPECIMENS EXAMINED: Oahu, *Hillebrand* B; *Robinson 55* V; Kauai, *Forbes 107* BM; *Heller 2613* C; Hawaiian Islands, ex Herb. Eaton C.

Dicranopteris emarginata (Brack.) comb. nov.

Mertensia emarginata Brack. Fil. U. S. Expl. Exp. 297. 1854.

TYPE LOCALITY: Hawaii.

DISTRIBUTION: Open mountain ridges, Hawaiian Islands.

ILLUSTRATIONS: Brack. Fil. U. S. Expl. Exp. *pl. 42. f. 1a, 1b.* 1854.

SPECIMENS EXAMINED: Oahu, *Robinson 40* V; Hawaiian Islands, *Hillebrand* K; *Wilkes Expedition* C.; ex Herb. Eaton C; *Lindley* C.

DICRANOPTERIS LINEARIS (Burm.) Underw. Bull. Torrey Club 34: 250. 1907

Polypodium lineare Burm. Fl. Ind. 235. 1768.
Polypodium dichotomum Thunb. Fl. Jap. 338. 1784.

Mertensia dichotoma Willd. Sv. Vet.-Akad. Handl. II. 25: 167. 1804.

Dicranopteris dichotoma Bernh. Neues Jour. Schrad. 1^2: 38. 1806.

Gleichenia linearis Clarke, Trans. Linn. Soc. II. 1: 428. 1880.

TYPE LOCALITY: Java.

DISTRIBUTION: Forming thickets at from 200–1,000 m. elevation, tropical countries.

ILLUSTRATIONS: Burm. Fl. Ind. *pl. 67. f. 2.* 1768; Thunb. Fl. Jap. *pl. 37.* 1784.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; *Robinson 240* V; Maui, *Bailey* B, C; *Robinson 316* V; Oahu, *Didrichsen 3772* C; *Forbes* BM; *Robinson 24* V; Kauai, *Forbes 80* BM; *Heller 2761* C; Hawaiian Islands, *Baldwin 1* C; *Wilkes Expedition* C; ex Herb. Eaton C; ex Herb. Mt. Holyoke College C.

Dicranopteris owhyhensis (Hook.) comb. nov.

Gleichenia owhyhensis Hook. Sp. Fil. 1: 9. 1844.

Mertensia hawaiiensis Brack. Fil. U. S. Expl. Exp. 295. 1854.

Gleichenia hawaiiensis Hilleb. Fl. Haw. Is. 544. 1888.

TYPE LOCALITY: Byron Bay, Oahu, Hawaiian Islands.

DISTRIBUTION: At elevations of 1,500–2,000 m., rare; Hawaiian Islands.

SPECIMENS EXAMINED: Maui, *Bailey* C; *Hillebrand* B; Oahu, *Baldwin 9* B; *Hillebrand* B; *Heller* C; Kauai, *Hillebrand* B; *Robinson 407* V; *410* V; Hawaiian Islands, *Baldwin 2* C; *Macrae* B, C.

The name is derived from an early spelling of Oahu; the type was collected upon this island by Macrae.

3. CYATHEACEAE

Mainly arboreous plants of the humid elevated regions of the tropics; rootstock stout and erect or decumbent; leaves cespitose, usually twice or more pinnate, rarely simple, articulate or non-articulate; leaf blades mostly one to several meters long; sori globose, dorsal or terminal upon the veins, indusiate or non-indusiate; sporangia usually numerous, ovoid, the annulus complete and oblique, with or without a definite orifice; dehiscence horizontal.

The family Cyatheaceae is represented in the Hawaiian flora by a single genus, *Cibotium*, which forms a conspicuous part of the fern forest in the region of the active volcano Kilauea, on Hawaii, and appears above 600 m. elevation on the other islands, though, doubtless, its size is greatest in the forests below Kilauea, in Puna and Olaa. Three species are associated in this locality, and these apparently intergrade.

Trunks of *Cibotium* have been used to make fences by placing them side by side like a palisade, and as they regenerate their crowns they make a most effective enclosure. On Mr. Snow's estate at Glenwood, 22 miles from Hilo, walks have been made of boards sawed from fern trunks, probably of *C. Menziesii*, which contain some boards 1 m. in width. On this estate and on the Hitchcock place adjoining, *C. Menziesii* growing in the open has attained a height of 16 m. or more.

The wooly scales at the base of the leafstalks, known commercially as pulu, were used formerly to a considerable extent as stuffing for mattresses, and the pulu-gatherers were ruthless in their destruction of old trees to obtain this commodity. Now, however, pulu has fallen into disuse and is no longer exported.

CIBOTIUM Kaulf. Jahrb. Pharm. **21**: 53. 1820

Pinonia Gaud. Ann. Sci. Nat. **3**: 507. 1824.

Rootstock usually arborescent with numerous large, chaffy scales at the apex; leafstalks not articulate; blades deltoid-ovate, bipinnate to quadripinnate, the pinnules stalked; sori valvate capsules, consisting of a cuplike outgrowth from the margin of the lobe of the pinnule and the indusium, which forms a lidlike covering. Sporangia stalked.

The leaves of all Hawaiian species are tripinnate.

Type species: *Cibotium Chamissoi* Kaulf.

Caudex 4–8 m. high; leafstalk 3–4 m. long, covered with soft, brown scales at the base, with black, hairlike scales above; blades 3–4 m. long; sinuses between the segments of the pinnules broad, shallow, often margined with sori; fertile veins mostly simple, usually 7 or less to a segment. *C. Menziesii.*

Caudex less than 3 m. high, usually about 2 m. high; leafstalk clothed at the base with soft, brownish scales, upper portion naked; blades less than 3 m. long; sinuses between segments of pinnules narrow, acute; fertile veins simple or once forked.

  Lower surface of blade dull glaucous, for the most part strongly tomentulose; veins 6–8 to a segment, simple or forked. *C. Chamissoi.*

Lower surface of blade conspicuously glaucous, for the most part slightly tomentulose, becoming glabrous; veins 9–10 to a segment, usually 1–2-forked. *C. glaucum.*

CIBOTIUM MENZIESII Hook. Sp. Fil. **1**: 84. 1844

Dicksonia Menziesii Hook. & Baker, Syn. Fil. 49. 1866.

TYPE LOCALITY: Oahu, Hawaiian Islands.

DISTRIBUTION: On ground at 600–1,250 m. elevation; usually found with lehue and other hardwood trees, in a damp forest; Hawaiian Islands.

ILLUSTRATION: Hook. Sp. Fil. **1**: *pl. 29c.* 1844.

SPECIMENS EXAMINED: Molokai, *Hillebrand* B, C; Oahu, *Beechey* K, C; *Forbes* BM; *Robinson 707* V; Kauai, *Heller 2693* C; Hawaiian Islands, *Baldwin 5* B, C, N; *Wilkes Expedition* C.

The ohia-lehue (*Metrosideros villosa* Sm.) often succeeds *Cibotium* in the forest by germinating in the crown of the fern, sending down its roots along the moist trunk and finally shutting out the light entirely, so that in time the fern dies and the lehue is left with what is apparently a hollow and fissured trunk.

Heller 2590 may be a cross between *C. Menziesii* and *C. Chamissoi*, in which more of the dominant characters belong to the former than to the latter.

CIBOTIUM CHAMISSOI Kaulf. Berl. Jahrb. Pharm. **21**: 53. 1820

Pinonia splendens Gaud. Ann. Sci. Nat. **3**: 507. 1824.

Dicksonia splendens Desv. Prod. 318. 1827.

Cibotium pruinatum Mett. in Kuhn, Linnaea **36**: 150. 1869.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On the wooded slopes of mountains, at elevations of 600–1,200 m., Hawaiian Islands.

ILLUSTRATIONS: Kaulf. Enum. *pl. 1. f. 14.* 1824; Hook. Ic. Pl. **17**: *pl. 1603.* 1886.

SPECIMENS EXAMINED: Hawaii, *Lichtenthaler* N; Oahu, *Beechey* B; *Bennett* B; *Chamisso* B; *Gaudichaud* B; *Heller 2898* C; *Robinson 35* V; *Safford 875* N; Kauai, *Heller 2600* C, K; *Knudsen 36* B; Molokai, *Hillebrand* B, C; Hawaiian Islands, *Baldwin* B; *Gaudichaud* B, C; *Lydgate* B; *Wilkes Expedition* C, N.

CIBOTIUM GLAUCUM (J. E. Smith) Hook. & Arn. Bot. Beech. 108. 1841

Dicksonia glauca J. E. Smith, in Rees, Cyc. 11. 1819.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Somewhat rare, on moist, wooded mountain slopes and wet flats, at 300–900 m. elevation.

ILLUSTRATIONS: Hook. Sp. Fil. 1: *pl. 29A*. 1841; Bed. Ferns Brit. Ind. *pl. 83*. 1865.

SPECIMENS EXAMINED: Hawaii, *Beratz* B; *Lydgate* B; *Robinson 201* V; *207* V; Maui, *Bailey* C; Molokai, *Hillebrand* B; C; Oahu, *Beechey* C, K; *Diell* C, K; *Baldwin* N; Kauai, *Forbes 34* BM; *356* BM; *Heller 2818; Knudsen* B; *Lydgate* B; *Mann & Brigham 543* N; Hawaiian Islands, *Baldwin 4a* B; *4* C; ex Herb. Mt. Holyoke College C; ex Herb. John Donnell Smith N; *Wilkes Expedition 1* C.

4. HYMENOPHYLLACEAE

Delicate ferns, the leaf blades seldom more than one layer of cells in thickness except at the veins; found in very moist localities, usually above 500 m. in elevation in the tropics. Rootstock slender, creeping or suberect; leaf blades much divided; sporangia sessile upon a filiform, usually elongated receptacle within an urn-shaped, tubular, or two-lipped marginal indusium, or protruding beyond it; annulus complete, transverse, opening vertically.

Receptacle filiform, projecting beyond the indusium. 1. *Trichomanes.*
Receptacle shorter than the indusium, or barely protruding. 2. *Hymenophyllum.*

1. TRICHOMANES L. Sp. Pl. 1097. 1753

Rootstock slender, creeping, or suberect; leaves pinnatifid to tripinnate; veins free; sori terminal upon the veins; indusium tubular or urn-shaped, occasionally 2-lipped; sporangia sessile, arranged spirally upon the receptacle, which usually projects from the margin of the leaf like a trichome.

Type species: *Trichomanes crispum* L.

Stem erect; leafstalk and midrib fibrillose; plants mostly terrestrial. *T. Bauerianum.*
Stem creeping; plants mostly epiphytic, smooth or nearly so.
  Leaf palmate or orbicular, less than 2 cm. high. *T. parvulum.*
  Leaf not palmate nor orbicular, more than 2 cm. high.

Leaf light green, less than 6 cm. high, lanceolate or oblong-lanceolate. *T. humile.*
Leaf dark green, more than 6 cm. high.
  Leaf deltoid. *T. cyrtotheca.*
  Leaf irregular in outline, usually narrowing below. *T. radicans.*

TRICHOMANES BAUERIANUM Endl. Prod. Fl. Norf. 17. 1833

Trichomanes apiifolium Presl, Hym. **16**: 44. 1843.
Trichomanes eminens Presl, Hym. **16**: 44. 1843.
Trichomanes myrioplazium Kunze, Bot. Zeit. **4**: 477. 1846.
Trichomanes meifolium Brack. Fil. U. S. Expl. Exp. 259. 1854.

TYPE LOCALITY unknown.

DISTRIBUTION: On ground in wet forests; Polynesia.

SPECIMENS EXAMINED: Hawaii, *Beratz* B; *Wilkes Expedition* B, C; Molokai, *Hillebrand* B; Maui, *Robinson 381* V; Oahu, *Forbes* BM; *Macrae* B; *Robinson 507* V; Kauai, *Heller 2179* B; *2741* B; *Johnson* B; *Remy 51* B; *Robinson 469* V.

The bilabiate form of the indusium of *T. Bauerianum* Endl. gives the appearance of *Hymenophyllum* to the young leaves, but the projecting vein with its attached sporangia and the urn-shaped form of the mature sporangium place the species in the genus *Trichomanes.*

TRICHOMANES PARVULUM Poir. in Lam. Encyc. **8**: 33. 1808

Trichomanes sibthorpioides Gaud. Bory in Willd. Sp. Pl. **5**: 498. 1810.
Trichomanes bifolium Bl. Enum. Pl. 223. 1828.
Trichomanes minutum Bl. Enum. Pl. 224. 1828.
Trichomanes saxifragoides Presl, Hym. 39. 1843.
Gonocormus saxifragoides v. d. Bosch, Hym. 9. 1861.

TYPE LOCALITY unknown.

DISTRIBUTION: Somewhat rare, on tree trunks in moist woods at 600–1,000 m. elevation; Polynesia.

ILLUSTRATION: Hook. Sp. Fil. **1**: 39. 1844.

SPECIMENS EXAMINED: Maui, *Bailey* C; Oahu, *Forbes 1083* BM; *Robinson 53* V; *502* V; *509* V; Hawaiian Islands, *Baldwin 106* B; *107* C; *Hillebrand* B; C; *Wilkes Expedition* C.

The dark green fronds appressed upon the tree trunks or upon the rocks where water is trickling over them, make a beautiful matted covering, which resembles a liverwort in general appearance.

TRICHOMANES HUMILE Forst. Prod. 84. 1786

Trichomanes minutulum Gaud. Freyc. Voy. Bot. 377. *pl. 12. f. 2.* 1827.
Didymoglossum humile Presl, Hym. 23. 1843.
Trichomanes Endlicherianum Presl, Abh. Böhm. Ges. **5**: 333. 1848.
Trichomanes Draytonianum Brack. Fil. U. S. Expl. Exp. 252. 1854.

TYPE LOCALITY: Society Islands.

DISTRIBUTION: On tree trunks in moist woods; Polynesia, Java, Formosa, New Zealand, Australia.

ILLUSTRATIONS: Presl, Epim. 10. *pl. 5A.* 1849; v. d. Bosch, Hym. Java *pl. 11.* 1861; Brack. Fil. U. S. Expl. Exp. *pl. 36.* 1854.

SPECIMENS EXAMINED: Maui, *Bailey* C; Oahu, *Robinson 55* V; *99* V; Kauai, *Heller 2556* C; Hawaiian Islands, *Baldwin 108* C; *Remy 83* B; *Wilkes Expedition 9* B, C.

TRICHOMANES CYRTOTHECA Hilleb. Fl. Haw. Is. 636. 1888

TYPE LOCALITY: Kahana, Oahu.

DISTRIBUTION: Above 600 m. elevation; Hawaiian Islands, in wet woods.

ILLUSTRATION: PLATE 19.

SPECIMENS EXAMINED: Maui, *Bailey* C; Oahu, *Hillebrand* B; *Robinson 107* V; Hawaiian Islands, *Baldwin* B; *Baldwin 106* C.

The color and size of the leaves are similar in *T. cyrtotheca* and *T. radicans* and both grow in deep wet forests, but they may be distinguished by the deltoid form of the leaf blade, the curving of the sori, and the smaller size of the rootstock of the former and the irregular outline, blunt pinnae with sori subimmersed, and thicker rhizome of the latter.

TRICHOMANES RADICANS Sw. Jour. Bot. Schrad. **1800**^{2}: 97. 1801

Trichomanes speciosum Willd. Sp. Pl. **5**: 514. 1810.
Trichomanes davallioides Gaud. Bot. Freyc. Voy. 3. 1827.
Trichomanes sandvicense v. d. Bosch, Ned. Kr. Arch. **5**^{2}: 165. 1861.

TYPE LOCALITY: West Indies.

DISTRIBUTION: Tropical countries, Ireland, Wales.

ILLUSTRATION: PLATE 20.

SPECIMENS EXAMINED: Hawaii, *Robinson 250* V; *270* V; *290* V; Maui, *Bailey* C; *Robinson 310* V; Oahu, *Didrichsen* C; *Forbes 95* BM; *Heller 2119* C; *Macrae* B; *Robinson 76* V; *108* V; Kauai, *Hillebrand* B; Hawaiian Islands, *Baldwin 109a* B, C; *Bennett* B; *Gaudichaud* B; *Lydgate* B; *Remy 52* B; *Wilkes Expedition 12* B, C (cotype of *T. sandvicense* v. d. Bosch).

Sir James E. Smith says "Few plants of any country have caused more enquiry or more diversity of opinion than this fern," and the variations in the Hawaiian forms of this species might add much material for such discussion.

2. HYMENOPHYLLUM J. E. Smith, Mém. Acad. Turin **5**: 418. 1793

Rootstock slender, creeping; leaves pinnatifid to bipinnatifid, glabrous or hairy; sori terminal upon the veins; indusium bilabiate, formed by the division of the tissue of the margin of the leaf; receptacle seldom exserted.

Type species: *Hymenophyllum tunbridgense* (L.) Sm.

Stem upright; leaves tufted, lanceolate; leafstalk clothed with reddish hairs.	*H. Baldwinii.*
Stem creeping; leaves not tufted.	
Leaves glabrous, the apexes usually curving downward.	*H. recurvum.*
Leaves hairy, the apexes vertical.	
Leaves rhomboid or obtuse-ovate, covered with reddish brown stellate hairs.	*H. obtusum.*
Leaves lanceolate, bearing simple hairs on margin and veins.	*H. lanceolatum.*

HYMENOPHYLLUM BALDWINII D. C. Eaton, Bull. Torrey Club **6**: 293. 1879

TYPE LOCALITY: Oahu.

DISTRIBUTION: On trees, above 800 m. elevation, in a lateral valley of Nuuanu, which leads up to Konahuanui.

SPECIMENS EXAMINED: ex Herb. D. C. Eaton (cotype) C; *Baldwin 110* C; *Baldwin* V.

HYMENOPHYLLUM RECURVUM Gaud. Voy. Freyc. Bot. 376. 1832

TYPE LOCALITY: Maui, Hawaiian Islands.

DISTRIBUTION: On trees above 600 m. elevation, Hawaiian Islands.

ILLUSTRATION: Hook. Sp. Fil. 1: *pl. 37*. 1844.

SPECIMENS EXAMINED: Hawaii, *Robinson 209* V; *215* V; Maui, *Bailey C; Robinson 311* V; *317* V; *326* V; Oahu, *Diell* C; *Heller 2603* C; *2620* C; *Hillebrand* C; *Macrae* B; *Robinson 39* V; *508* V; *Forbes* BM; Kauai, *Forbes 113* BM; *Hillebrand 152* B; *Robinson 835* V; Hawaiian Islands, *Baldwin 102* C; *Beechey* C; *Gaudichaud 195* B; *Lindley* C; *Wilkes Expedition 15* B, C.

Hymenophyllum recurvum is a very graceful fern, which forms a light green covering upon the tree trunks and wet rocks in deep, shady glens.

HYMENOPHYLLUM OBTUSUM Hook. & Arn. Bot. Beech. 109. 1832

TYPE LOCALITY: Oahu.

DISTRIBUTION: On trees, in wet forests, Hawaiian Islands; also reported from New Guinea and Cape of Good Hope.

ILLUSTRATION: Hook. Sp. Fil. 1: *pl. 37D*. 1844.

SPECIMENS EXAMINED: Molokai, *Hillebrand* B; Oahu, *Heller 2229* C; *2910* C; *Robinson 10* V; *37* V; *503* V; Hawaiian Islands, *Baldwin 104* C; *Wilkes Expedition* C.

HYMENOPHYLLUM LANCEOLATUM Gaud. Voy. Freyc. Bot. 109. 1832

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: On tree trunks in Hawaiian Islands.

ILLUSTRATION: Hook. Sp. Fil. *pl. 34*. 1844.

SPECIMENS EXAMINED: Hawaii, *Robinson 273* V; *278* V; Maui, *Bailey* C; Oahu, *Heller 2256* C; *2705* C; *Macrae* B; *Robinson 70* V; *94* V; *96* V; *125* V; Kauai, *Robinson 404* V; *406* V; *830* V; Hawaiian Islands, *Baldwin 103* C; *Douglas* B; *Gaudichaud* B; *Wilkes Expedition* B; C.

The fronds soon become bronze in color, partly from the hairiness of their surface, by which, as well as by their size, they are easily distinguished from *H. recurvum*.

The following specimens are smaller than the others and bear only marginal hairs: *Heller 2705*, *Robinson 302*, *404*, *406*, *830*.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1910-1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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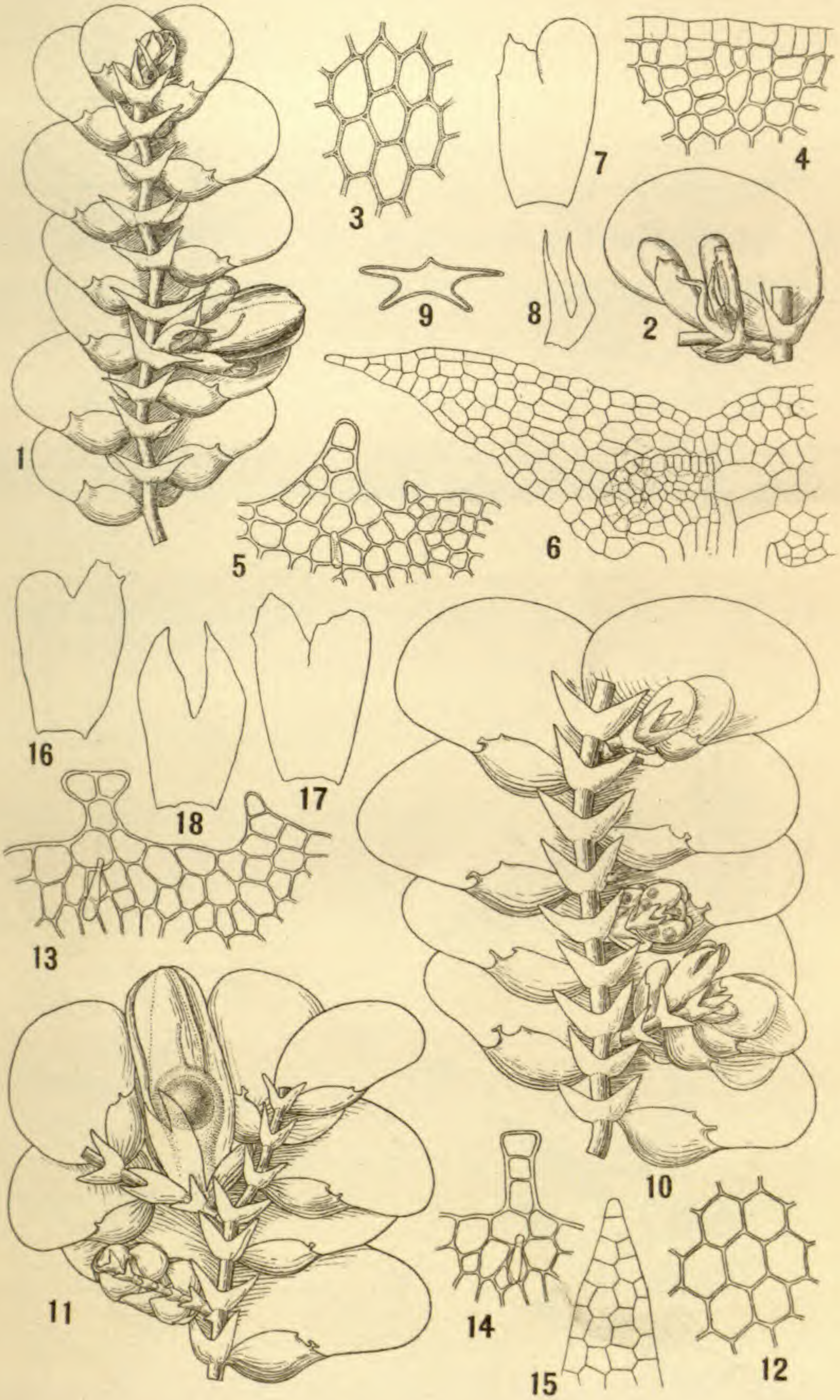

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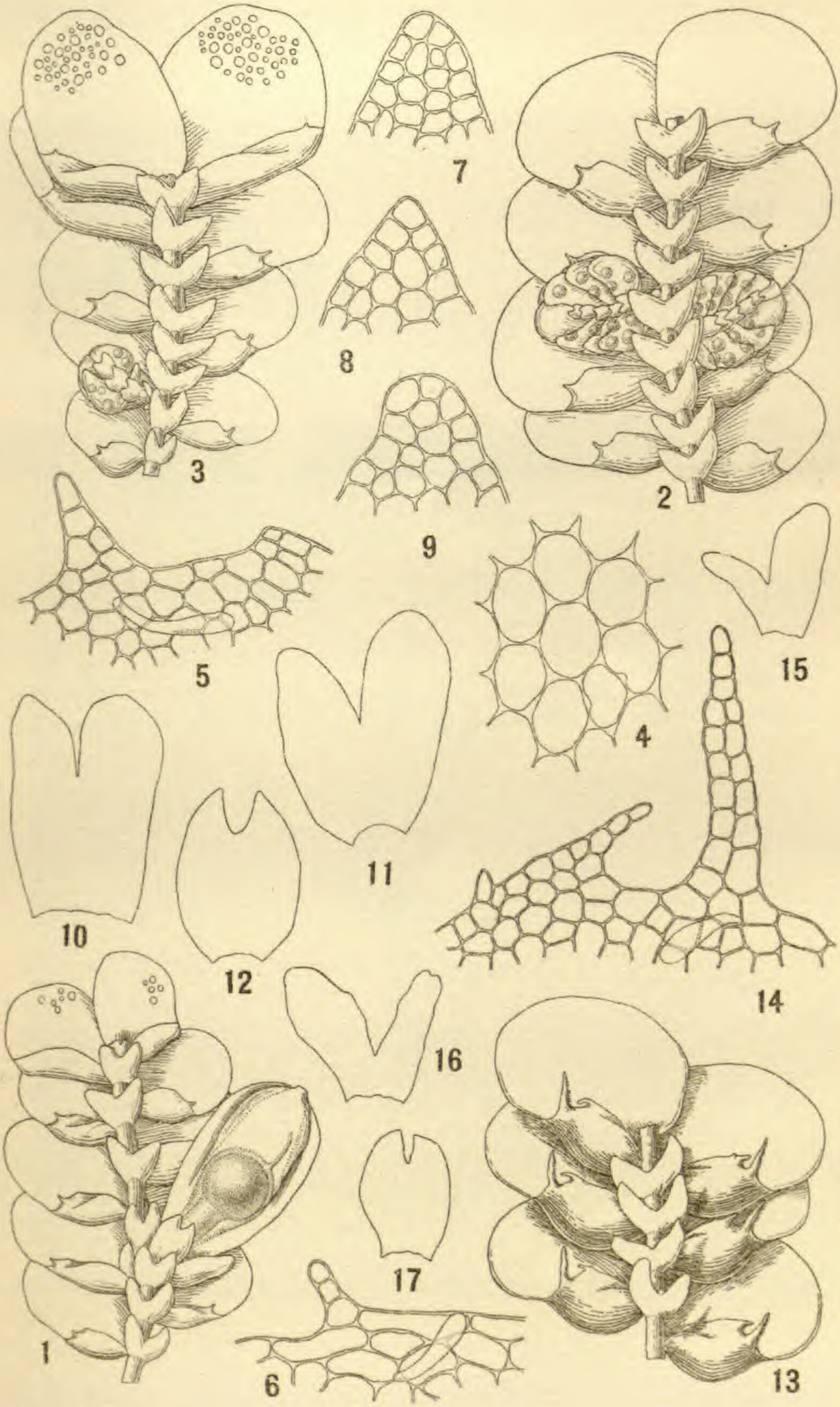

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BULLETIN

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TORREY BOTANICAL CLUB

JUNE 1912

The genus Struthiopteris and its representatives in North America—I[*]

JEAN BROADHURST

(WITH PLATES 21, 22)

Struthiopteris is here used for Willdenow's genus *Lomaria*, which was published first in 1809. It includes also Robert Brown's genus *Stegania* published in 1810. Christensen[†] reduces *Lomaria* (including *Stegania*) to a subgenus of *Blechnum* and in this subgenus recognizes one hundred species. Including the two North American species placed under *Lomaria* by Willdenow, thirty-six species have been described from North America under the generic name *Lomaria;* this does not include the species since placed in the genera *Stenochlaena*, *Salpichlaena*, and *Plagiogyra*. Twenty-five North American species are recognized by the writer; of these five are new and one must bear a new name.

Though not included by Linnaeus in his Species Plantarum, the genus *Struthiopteris* is much older than 1753. Trevisan[‡] gives 1561 for the earliest use of this name and cites Valerius Cordus[§] as using *Struthiopteris* to distinguish *Osmunda Spicant* L. It was later used in this sense by several others. The most prominent was probably Haller;[‖] in 1742 he used the monomial *Struthiopteris*, citing *Struthiopteris* of Cordus.

Soon after 1753 the generic name *Struthiopteris* was used for

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[*] Based upon a preliminary report which was submitted in partial fulfilment of the requirements for the Degree of Master of Arts in the Faculty of Pure Science, Columbia University.

[†] Ind. Fil. 150–161. 1905.

[‡] Atti Ist. Ven. III. **14**: 553–588. 1869.

[§] Hist. Pl. **2**: 170. 1561.

[‖] Enum. Stirp. Helv. 132. 1742.

Osmunda Spicant L. by Scopoli, Haller, and Weis. In 1760 Scopoli[*] used the monomial *Struthiopteris*, and included under it number 844 of Linnaeus;[†] this species Linnaeus[‡] had meanwhile named *Osmunda Spicant*. Therefore, by citation, the correct name of this genus is *Struthiopteris* (Hall.) Scop.

Haller,[§] in 1768, again used the monomial *Struthiopteris*, referred to Scopoli's work of 1760, and cited, by number, *Osmunda Spicant* of Linnaeus. The first, however, to publish a binomial under *Struthiopteris* was Weis,[||] who in 1770 (two years before Scopoli[¶]) published *Struthiopteris Spicant*. The correct name for the type species of this genus is therefore *S. Spicant* (L.) Weis. Willdenow,[**] in 1787, referred to *Struthiopteris Spicant* Weis as a synonym of *Osmunda Spicant*. Swartz[††] later included *Struthiopteris* in a list of generic synonyms for this species. Neither Swartz, however, nor Willdenow adopted it.

In the first decade of the nineteenth century four writers, Bernhardi, Robert Brown, Swartz, and Willdenow, each added somewhat to the confusion regarding the correct name of this genus. Bernhardi[‡‡] published a similar name, *Struthopteris*, for three other ferns of the Linnaean genus *Osmunda* (*O. cinnamomea*, *O. Claytoniana*, and *O. regalis*) with the caution that it was not to be confounded with *Struthiopteris* Hall. Willdenow[§§] published *Struthiopteris* for *Osmunda Struthiopteris* L. and an undescribed "*Struthiopteris* from Pennsylvania" (which he described in 1810 as *S. pennsylvanica*). Three of these workers transferred *Osmunda Spicant* L., the type of the genus *Struthiopteris*, to other established genera: Bernhardi[||||] to *Asplenium*, Willdenow[¶¶] to *Acrostichum*, and Swartz[***] to *Blechnum*. Swartz[†††] also placed several

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[*] Fl. Carn. 168. 1760.

[†] Fl. Suec. 307. 1745.

[‡] Sp. Pl. 1066. 1753; Fl. Suec. 370. 1755.

[§] Hist. Stirp. Helv. **3**: 6. 1768.

[||] Pl. Crypt. Fl. Gott. 286. 1770.

[¶] Fl. Carn. **2**: 288. 1772.

[**] Prod. Fl. Berol. 289. 1787.

[††] Under *Blechnum boreale;* Syn. Fil. 115. 1806.

[‡‡] Jour. Bot. Schrad. **1800**^{2}: 126. 1801.

[§§] Ges. Nat. Fr. Berl. Mag. **3**: 160. 1809.

[||||] Jour. Bot. Schrad. **1799**^{1}: 309. 1799.

[¶¶] Prod. Fl. Berol. 289. 1787.

[***] Syn. Fil. 115. 1806.

[†††] Prod. 127. 1788; Fl. Ind. Occ. **3**: 1583–1586, 2010. 1806.

related species first in *Osmunda* and later (following Hoffman*) in *Onoclea*. Later Willdenow and Brown each published new generic names for part of the genus under discussion. Willdenow,† in 1809, published the genus *Lomaria*, citing all of *Onoclea* of Swartz except *O. sorbifolia* as the basis of the name; and in the following year Willdenow‡ listed under *Lomaria* most of Swartz's species of *Onoclea*. In 1810 Robert Brown§ published *Stegania*, before mentioned, for eight African members of this genus. In so doing he separated *Spicant* from its relatives, just as Swartz had done when he placed it under *Blechnum*, and its relatives under *Osmunda* and later *Onoclea*.

This confusion has continued even to the present, although two authorities, Trevisan‖ and Underwood,¶ have shown independently (1) that *Osmunda Spicant* L. has "first claim to *Struthiopteris*, becoming *Struthiopteris Spicant*," and (2) that the correct generic name for *Osmunda Struthiopteris* L. is not *Struthiopteris* but *Matteuccia*, established by Todaro** in 1866.

Trevisan attempted to divide the genus *Struthiopteris*, recognizing *Lomaria* Willd. for part of it. In his key he describes *Struthiopteris* as having median sori and ascribes marginal sori to *Lomaria*. Trevisan discusses but three of the North American species, *Spicant*, *doodioides*, and *polypodioides*, which he places under *Struthiopteris*. A careful examination of the North American material in the New York Botanical Garden herbarium does not justify this division. The term "median" is not applicable, even relatively, to the indusium in any of this material; the sterile extension outside the indusium may be perceptibly wider in the young leaves, but the conditions in the mature fronds do not justify the use of the term. Nor do *S. Spicant* and *S. polypodioides* differ from any of the other species in the relative position of the indusium.

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* Deutsch. Fl. 2: 12. 1795.

† Ges. Nat. Fr. Berl. Mag. 3: 160. 1809.

‡ Sp. Pl. 5: 289. 1810.

§ Prod. Fl. Nov. Holl. 152. 1810.

‖ Atti Ist. Ven. III. 14: 556. 1869.

¶ Mem. Torrey Club 6: 257. 1899.

** Giorn. Sci. Nat. 1: 208–254. 1866. Todaro also recognized the priority of *Struthiopteris Spicant* for *Osmunda Spicant* L.

Other possible divisions of this large genus, based upon characters offered by the sterile fronds, the indusium, and the sporangia and spores, have been considered by the writer and found unsatisfactory for the following reasons: (1) The variations in the sterile leaves in proportion, cutting, and texture depend greatly upon the age of the leaf and of the plant; (2) in the fertile leaves the indusium remains entire in the pinnatifid species, and though it usually becomes lacerate or fimbriate in the pinnate species, these show all degrees of laceration; (3) a careful microscopic study of the spores and sporangia, which Fée apparently considered important, reveals no constant differences in the North American species.

The greatest variation is undoubtedly in the habit, for the North American species include: (1) Tree-climbing forms with pendent leaves, (2) terrestrial, cespitose forms, (3) terrestrial, inclined or erect forms with stems 5–45 cm. long, and (4) subarboreous forms with stems at least 20 cm. high and 12 cm. thick. These differences we are at present unable to correlate with any other character. The habits of some species are not definitely known, because collectors have so often brought back incomplete specimens without field notes; mention of the habit is rarely included in the original description; and further, even American writers have confused our own species with the descriptions of African and other foreign ones and attributed to them characters they never possess. In making the key for this genus, habit has therefore been almost ignored; the key is strictly artificial and based mainly upon the frond characters rather than upon those of the whole plant.

The following key and descriptions have been based chiefly upon the specimens in the herbaria of the New York Botanical Garden and the United States National Museum. Begun under the direction of Professor Lucien M. Underwood, this paper has been completed with assistance from Mr. William R. Maxon and Dr. Ralph C. Benedict. Dr. H. Christ and Dr. B. P. G. Hochreutiner also kindly sent tracings or material from their herbaria. Access was freely given to the herbaria at Geneva and Kew.

STRUTHIOPTERIS (Hall.) Scop.

Fronds dimorphous (otherwise resembling *Blechnum*), usually pinnatifid or once pinnate; veins free, simple or usually once forked, usually not reaching the margin; sori linear and intramarginal (not costal as in *Blechnum*); indusium intramarginal in attachment,[*] at maturity opening toward the midrib, and then either (1) entire and not reflexed or (2) more or less lacerate or fimbriate and reflexed.

Key to the non-petioled species[†]

A. STERILE PINNAE NEVER PETIOLED, THE WHOLLY ADNATE BASE THE WIDEST PART OF THE PINNA; RHIZOME SCALES NEVER RIGID; PINNAE LACKING SCALES; INDUSIUM NOT LACERATE WITH AGE

Plants epiphytic; rhizome wide-creeping; rhizome scales and basal stipe scales usually with a black median line (wholly lacking in *S. Plumieri*); stipes scattered, the fertile ones straw-colored or bicolored with dull brown or blackish; mature lamina not punctate by transmitted light; fertile pinnae not conspicuously dilated at their bases.

Lamina broadly oblong, very abruptly reduced at the base (type A,[‡] with vestigial pinnae); pinnae 22–28-jugate, 16–18 cm. long, straight or nearly so, the middle ones always straight. 1. *S. ensiformis*.

Lamina linear or very narrowly oblong to broadly lanceolate, gradually to abruptly reduced at the base (type G to D, with vestigial pinnae in D only); pinnae 25–75-jugate, 2.5–16 cm. long, slightly curved to falcate, the middle ones always falcate.

Rhizome scales usually with a black median line; lamina linear, narrowly oblong, or lanceolate, 4–17 times as long as broad, usually very gradually reduced at the base (type G to F, rarely E); leaf tissue rigid-herbaceous; pinnae usually contiguous. 7. *S. polypodioides*.

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[*] The intramarginal character of the indusium is obscured in many of the pinnate species by the thickened edges of the pinnae, due to the more or less glandular thickening of the vein apices. In the sterile pinnae these thickenings may result in dark spots, slight swellings, circular cartilaginous areas or depressions, or occasionally in more or less detachable scalelike elevations.

[†] The species having petioled sterile pinnae will be discussed in a later number of the BULLETIN OF THE TORREY BOTANICAL CLUB. The sterile fronds of the non-petioled species are cut to the rachis, but the bases of the pinnae are wholly adnate, and except in a few specimens of *S. ensiformis*, the base is always the widest part of the pinna. Fée and others classify these as pinnatifid. Petiole instead of petiolule is used throughout when referring to the pinnae.

[‡] See FIGURE 1, which gives several diagrams illustrating the variation in the bases of the laminae.

Rhizome scales never with a black median line; lamina broadly lanceolate to lanceolate, 2.5–4.5 times as long as broad, usually abruptly reduced below (type D to E, with vestigial pinnae); leaf tissue membranous to herbaceous; pinnae distant in the basal half to third of the lamina. 6. *S. Plumieri.*

Plants terrestrial; rhizome inclined to erect; rhizome scales and basal stipe scales never with a black median line; stipes clustered at the apex of the rhizome, the fertile ones partly, or oftener wholly, shining chestnut to black; mature lamina fully punctate by transmitted light (see *S. Spicant* for exceptions); fertile pinnae conspicuously dilated at their bases (except in *S. Maxonii*).

Sterile lamina gradually reduced at the base (type F–G, without vestigial pinnae); vein spaces 8–15 to 1 cm.

Rhizome erect (43 cm. high, in type); vein spaces 8–10 to 1 cm.; fertile pinnae not dilated at their bases. 5. *S. Maxonii.*

Rhizome creeping or stoloniferous; vein spaces 10–15 to 1 cm.; fertile pinnae conspicuously dilated at their bases.

Sterile fronds of two types in texture and position, 20–70 cm. long; rhizome apparently not stoloniferous; pinnae 36–80-jugate, 3–15 times as long as wide. 8. *S. Spicant.*

Sterile fronds similar in texture at least, 11–20 cm. long; rhizome stoloniferous; pinnae 16–22-jugate, 1–3 times as long as wide. 9. *S. stolonifera.*

Sterile lamina abruptly reduced at the base (type B–D, with vestigial pinnae except in *S. L'Herminieri*); vein spaces 6–8 to 1 cm.

Stipes (of the sterile fronds, at least) without scarlike vestigial pinnae; lamina lanceolate, 5–11 cm. wide; pinnae mainly falcate, ascending. 4. *S. L'Herminieri.*

Stipes with vestigial pinnae; lamina elliptical, ovate-lanceolate, oblong-deltoid, or deltoid, 12–32 cm. wide; pinnae mainly straight, diverging.

Lamina of mature fronds deltoid to oblong-deltoid, or ovate-lanceolate and very abruptly reduced below (type A or B); lower pinnae contiguous, if shorter abruptly reduced to semicircular lobes; sporophyls fertile on the dilated bases of the pinnae. 2. *S. exaltata.*

Lamina of mature fronds broadly elliptical, less abruptly reduced below (type D); lower pinnae distant or appearing so, always shorter; sporophyls not fertile on the dilated bases of the pinnae. 3. *S. jamaicensis.*

1. S. ENSIFORMIS (Liebm.) Broadh.; Maxon, Contr. U. S. Nat. Herb. **13**: 17. 1909.

Lomaria ensiformis Liebm. Vid. Selsk. Skr. V. 1: 82. 1849.
Blechnum ensiforme C. Chr. Ind. Fil. 153. 1905.

Plants epiphytic. Rhizome creeping, 5–7 cm. long in fragments seen, the scales linear, 5–10 mm. long, maroon to tobacco brown, with a black median line. Sterile fronds 90–100 cm. long; stipes scattered, 20–28 cm. long, channeled on the upper side,[*] not angulate, marked about halfway down by scarlike undeveloped pinnae, bicolored, the darker side dark chocolate brown, the deciduous basal stipe scales[†] smaller than the scales of the rhizome; lamina 40–68 cm. long, 25–35 cm. wide, broadly oblong, abruptly reduced at the base (type A, but with vestigial pinnae as described above), the apex gradually reduced, the terminal pinna 5–8 cm. long, the pinnae more or less opposite, the lower ones distant, sometimes 2–3 cm. apart; pinnae 22–28-jugate, narrowly oblong to linear, straight, not falcate (if curved, only near the apex), horizontal or ascending, 16–18 cm. long, 12–17 mm. wide,[‡] long-acuminate, the base dilated in the upper pinnae, in the lower ones occasionally slightly contracted; margins entire (or barely subentire near the apex, not definitely serrate), not at all or very slightly revolute; leaf tissue rigid-herbaceous, without scales; veins not conspicuous, usually sunken on the under side, the vein apices with very slight swellings or depressions, the vein spaces 10–13 to 1 cm. Sporophyls 60–70 cm. long; stipes[§] 20–28 cm. long, straw-colored or bicolored; lamina 32–45 cm. long, gradually reduced toward the apex, the terminal pinna 5–10 cm. long; pinnae 20–30-jugate, 10–20 cm. long, 3–4 mm. wide, with a sterile tip 3–6 mm. long, the base contracted (occasionally dilated below the contraction); indusium rather heavy, entire, not becoming lacerate; sporangia dark brown.

TYPE LOCALITY: Oaxaca, Mexico.

DISTRIBUTION: Mexico, Guatemala, Costa Rica, and Panama.

SPECIMENS INCLUDED: GUATEMALA: Baja Verapaz, "Hochwald bei Purulha," altitude 1,800 m., *von Türckheim 1693* (Y, N).[‖]

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[*] In all of the species included in this paper the rachis and stipe are channeled on the upper (ventral) side; that statement is not, therefore, repeated in the following descriptions.

[†] Unless otherwise described in the following species, the basal stipe scales are shorter and more deciduous than the rhizome scales but similar in color and texture.

[‡] Throughout this paper the measurements of the pinnae are those of the largest lateral ones; the width is measured at the adnate base of the non-petioled pinnae.

[§] Vestigial pinnae, scales, etc., as in the sterile stipes. This likeness will be understood hereafter, unless they are described separately.

[‖] N indicates that the specimen cited is in the United States National Herbarium; Y, in the herbarium of the New York Botanical Garden.

Alta Verapaz, "Waldungen," Pansamala between S. Pedro Cariha and Senahu, altitude 3,800 ft., *von Türckheim 640* (N). Alta Verapaz, near the Finca Sepacuite, *Cook & Griggs 417* and *420* (N).

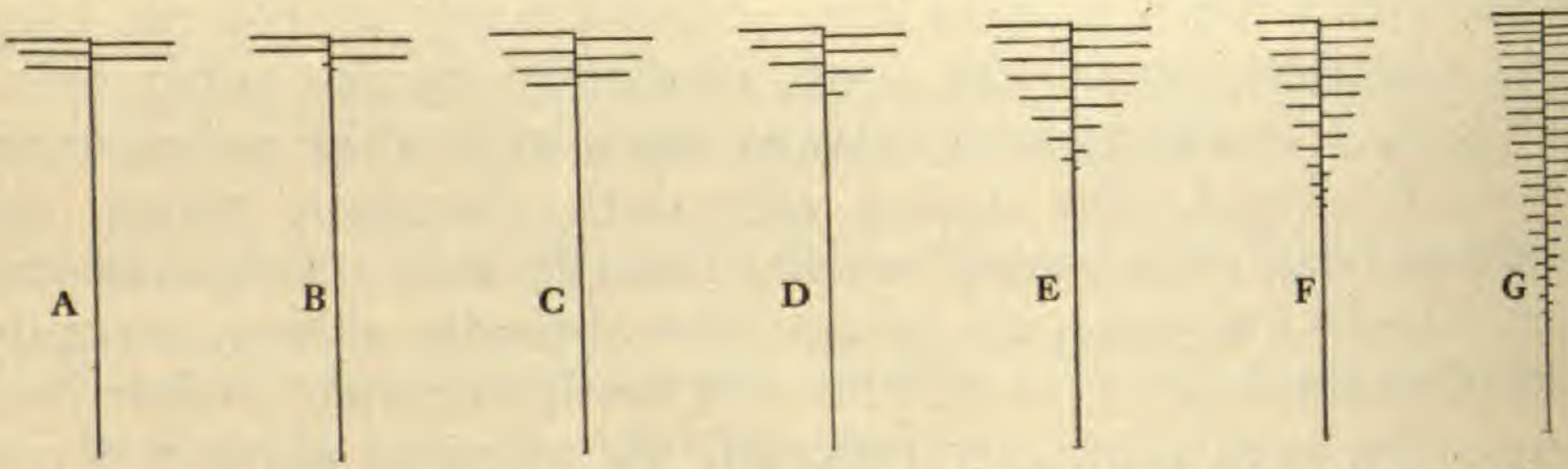

Figure 1. Types of frond bases found in the North American species of *Struthiopteris*.

The adnate dilated bases mentioned by Liebmann are most characteristic of the specimens mentioned above; though no Mexican specimens have been seen, Liebmann's full description leaves no doubt that the Guatemalan specimens belong to this species.

The Costa Rican and Panama specimens examined differ in being more gradually reduced at the base (type C), in having proportionately broader pinnae which are more abruptly acuminate, and in having shorter lower pinnae (4–6 cm. long) which are more contracted at the base and farther apart (2–4 cm.). The three Costa Rican specimens, *Pittier 10176* ("Forêts de la Palma," Pacific slopes) and U. S. National Herbarium no. 575237 and no. 575239 (both the latter without definite locality, collected by Wercklé, 1901–1905) are in these respects intermediate between the Guatemalan plants and the one from Panama, *Maxon 5526* (humid forests of Cuesta de Las Palmas, southern slope of Cerro de la Horqueta, Chiriqui, altitude 1,700–2,100 m.). Since Pittier's no. 10176 is the only one with a fertile frond it does not seem best to separate these more southern plants at present.

2. **S. exaltata** (Fée) Broadh. comb. nov.

Lomaria exaltata Fée, Mém. Foug. **11**: 10. *pl. 3.* 1866.

Plant terrestrial. Rhizome erect or ascending, 4–40 cm. long, the scales lanceolate to ovate-lanceolate, about 1 cm. long, 2–2.5 mm. wide, tobacco brown. Sterile fronds 30–90 cm. long; stipes 20–30 cm. long, slightly to decidedly angulate, marked usually throughout with vestigial pinnae varying from mere scars to lines about 1 cm. long, bicolored; lamina 22–47 cm. long, 12–24 cm. wide, deltoid to oblong-deltoid or ovate-lanceolate, the base abruptly reduced (type A or B, with vestigial pinnae), with or without 1–3 more or less semicircular contiguous lobes, gradually reduced at the apex, the terminal pinna 5–9 cm. long, the pinnae usually alternate, the lower more or less diverging but contiguous; pinnae 9–18-jugate, broadly triangular to oblong, straight (or the upper ones slightly curved), the apex acute, never acuminate, sometimes contracted near but not at their bases, 6–12 cm. long, 1.5–3 cm. wide; margins entire, not at all or but irregularly and slightly revolute; leaf tissue rigid-herbaceous, closely and markedly punctate, showing throughout rounded translucent spaces when held to the light, without scales; veins rarely conspicuous, never raised or grooved, usually ending in circular glandular swellings or in depressions which occasionally hold a more or less separable, central, scalelike swelling, the vein spaces 6–7 to 1 cm. Sporophyls 44–90 cm. long, taller than the sterile in all the complete specimens seen; stipes 24–40 cm. long, marked with vestigial pinnae, usually reddish brown, occasionally purplish black, not bicolored as in the sterile, though sometimes lighter on the upper side; lamina 22–40 cm. long, abruptly reduced at the base, gradually at the apex, the terminal pinna 5–10 cm. long; pinnae 12–22-jugate, 11–14 cm. long, 3–4 mm. wide, often with a sterile tip 3–7 mm. long, broadly dilated both ways at the base and fruited on the dilations; indusium not heavy, entire, not becoming lacerate; sporangia varying from yellow to dark brown.

TYPE: Fée, Mém. Foug. **11**: *pl. 3.* 1866. Collected by L'Herminier in 1861, Guadeloupe.

DISTRIBUTION: Jamaica, Porto Rico, the Lesser Antilles (St. Kitts, Montserrat, Guadeloupe, Dominica, and Martinique), Costa Rica, and Panama.

SPECIMENS INCLUDED: PORTO RICO: Luquillo Mountains, *Wilson 135* (Y). ST. KITTS: Top of Mt. Misery, under cliff, *Britton & Cowell 546* (Y). MONTSERRAT: Chance's Mountain, at the top, altitude 3,000 ft., *Shafer 273*. GUADELOUPE: *Duss 4167.4166*,* (Y, N). DOMINICA: Mt. Diablotin, *Lloyd 880* (Y) and *893* (Y, N).

This has been confused by Jenman and by some European

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* Often the localities given on the Duss sheets are descriptive rather than specific: different localities are given for sheets bearing the same collection number, or several localities are given on one sheet. The locality is, therefore, omitted in such cases.

writers with *Lomaria Plumieri* Desv. The broad, horizontal pinnae pictured in the type of *exaltata* separate it positively from *Plumieri* with its narrow, falcate pinnae, pictured by Plumier. *L. mucronata*, which Christensen refers to *Plumieri*, is much nearer *exaltata*. Fée, in this, as in several other original descriptions, makes contradictory statements regarding the size. This mistake led to two others: (1) the publication of *L. Féei* as a distinct species; and (2) the placing of *L. exaltata* under *L. L'Herminieri* as a variety. Christensen includes *exaltata* in *L'Herminieri;* although the immature sterile laminae of *exaltata* sometimes resemble the mature ones of *L'Herminieri* in proportion and in the shape of the pinnae, they seem otherwise distinct.

Four sheets from Grenada, collected by Sherring (October to May, 1890–91) show young specimens, which are more delicate in texture and bear pinnae which are shorter and more like those of *L'Herminieri.* The basal reduced pinnae are prominent, more numerous, and contiguous. They are accompanied by taller but immature fertile fronds; no mature sterile or fertile fronds from the island have been seen. At present it seems best to leave these Sherring specimens in *S. exaltata.*

Three sheets from Costa Rica ("Forêts de l'Achiote, Volcan de Poas," altitude 2,000 m., *Tonduz 10709*) have laminae with wider sinuses, and occasionally 2 or 3 pairs of semicircular lobes at the base. The pinnae are proportionately as well as actually narrower, and the fronds have an open appearance not really characteristic of the species. Christ named them *L. L'Herminieri*, but they seem much nearer *exaltata*, especially in the shape of the lamina and of the pinnae. Maxon's no. 5671 (humid forests of the upper Caldera watershed, between "Camp I" and the Divide, Holcomb's trail, above El Boquete, Chiriqui, altitude 1,650–1,925 m.) has pinnae which are more curved; Maxon's no. 5427 from the same region (humid forest around Los Siguas Camp, southern slope of Cerro de la Horqueta, Chiriqui, altitude about 1,700 m.) has wider sinuses in the lower part of the lamina, and the vestigial pinnae are much more prominent than in the other specimens seen.

3. **S. jamaicensis** Broadh. sp. nov.

Plant terrestrial. Rhizome ascending, 24 cm. long (in the one complete specimen seen), 2–3 cm. thick; the scales very scanty, ovate-lanceolate, about 1 cm. long, tobacco brown. Sterile fronds 80–100 cm. long; stipes numerous, close, 27–45 cm. long, usually somewhat angulate, marked throughout with vestigial pinnae, which vary from mere scars to wide but very short lobes, chestnut to reddish purple and black, light colored in the channel, scales usually lacking; lamina 60–80 cm. long, 20–32 cm. wide, elliptical, rather abruptly reduced at the base (type D, with vestigial pinnae), the lower pinnae more or less distant (1 cm.), gradually reduced at the apex, the terminal pinna 3–8 cm. long, rachis light colored on the upper side; pinnae 18–35-jugate, the upper curved or falcate, the lower less curved to straight and oblong, the apex attenuate, the base broadly dilated, especially in the lower pinnae, which are 10–16 cm. long, 1–2 cm. wide (the lowest ones 3–6 cm. long and 2.5–3.5 cm. wide at their bases); margins entire, unevenly or not at all revolute; leaf tissue membranous to herbaceous, punctate as in *S. exaltata*, without scales; veins distinct, never raised nor grooved, the apices glandular as in *exaltata*, vein spaces 6–8 to 1 cm. Sporophyls 88 cm. long (in the only complete one seen); stipes 30–40 cm. long, lighter than the sterile, the vestigial pinnae less prominent; lamina 45–52 cm. long, abruptly reduced at the base, the apex gradually reduced; pinnae 24–30-jugate, 10–15 cm. long, 3–4 mm. wide, the apex with a sterile tip 1–5 mm. long, the base dilated; indusium entire, not becoming lacerate; sporangia greenish yellow in fresh specimens. [PLATE 21.]

Type in the U. S. National Herbarium, no. 429499 and 429500, and in the New York Botanical Garden, collected near a stream in a wet ravine, forest near Hardware Gap, Jamaica, altitude 4,200 feet, *William Harris 10099*, February 19, 1908.

The type collected in 1908 has made possible the separation from *S. exaltata* of several incomplete specimens in the herbaria at Geneva and New York. *S. jamaicensis* differs from *S. exaltata* in being thinner in texture, widest at the middle, and in having more numerous pinnae with acuminate tips; it differs also in having lower pinnae which are much more dilated at the base, and which, if not separated, appear so because of the flaring sinuses; the fertile pinnae are evidently not soriated on the dilations as in *S. exaltata*.

4. **S. L'Herminieri** (Bory) Broadh. comb. nov.

Lomaria L'Herminieri Bory; Kunze, Farrnkr. 173. *pl. 73*. 1845.
Lomaridium Herminieri Presl, Epim. Bot. 263. 1851.

Spicanta L'Herminieri O. Kuntze, Rev. Gen. Pl. 2: 820. 1891.
Blechnum L'Herminieri C. Chr. Ind. Fil. 156. 1905.

Plants terrestrial. Rhizome ascending to erect, at least 4–15 cm. high, the scales not numerous, lanceolate to ovate-lanceolate, tobacco brown. Sterile fronds 30–48 cm. long; stipes 4–12 cm. long, not at all or somewhat angulate, without vestigial pinnae, bicolored; lamina 18–32 cm. long, 5–11 cm. wide, lanceolate, abruptly reduced at the base (type A or B), usually with 2 or more pairs of somewhat semicircular, contiguous lobes at the base, gradually reduced at the apex, with a terminal pinna 2–6 cm. long, the pinnae sometimes opposite; pinnae 7–16-jugate, the upper ones falcate, the lower ones more or less falcate, the apex acute, never acuminate, the base more or less dilated, 3.5–6 cm. long, 10–18 mm. wide; margins entire, slightly and only irregularly revolute; leaf tissue rigid-herbaceous, without scales; veins distinct, not definitely raised or grooved, the apices somewhat glandular, the vein spaces 6–8 to 1 cm. Sporophyls 26–50 cm. long, and often but little taller than the accompanying sterile fronds; stipes 13–35 cm. long, straw-colored to brownish, occasionally slightly purplish, but slightly or not at all marked with vestigial pinnae in the upper part; lamina 13–24 cm. long, abruptly reduced at the base, gradually reduced at the apex; pinnae 10–17-jugate, 4–9 cm. long, 2–3 mm. wide, with or without a constricted sterile tip, the base widely dilated, not fruited on the dilations; indusium not heavy, entire, not becoming lacerate; sporangia dark brown.

TYPE: *Bory 201*, from Guadeloupe (Kunze also cites *Linden 193* and *Moritz 31*, both from Caracas).

DISTRIBUTION: Known from Guadeloupe, Martinique, and Dominica.

SPECIMENS INCLUDED: GUADELOUPE: *Duss 4166* (Y, N); *Duss 4167* (N). DOMINICA: Mt. Diablotin, *Lloyd 885* (N). MARTINIQUE: *Duss 1554* (Y).

5. **S. Maxonii** Broadh. sp. nov.

Plants terrestrial. Rhizome erect, 43 cm. high (in type specimen), the scales numerous at the apex, linear to lanceolate, 5–10 mm. long, purplish brown to black. Sterile fronds 25–38 cm. long; stipes 3–6 cm. long, not at all or but slightly angulate, without vestigial pinnae, straw-colored or bicolored with reddish brown or brown, the scales not numerous, very deciduous, ovate to lanceolate, 3–5 mm. long, dull brown; lamina 22–35 cm. long, 3–5 cm. wide, narrowly elliptical, gradually reduced at the base (type F), gradually reduced at the apex, the terminal pinna 1–4 cm. long, the lower pinnae often opposite; pinnae 16–26-jugate, falcate, the apex rounded to subacute, the base somewhat dilated, 2–3 cm. long, 8–12 mm. wide; margins not at all or slightly and irregularly revolute; leaf tissue rigid-herbaceous, punctate as in *S. exaltata*, without scales; veins not distinct, occasionally slightly grooved below, the apices marked with circular glandular areas, vein spaces 8–10 to 1 cm. Sporophyls 25–28 cm. long; stipes 1–5 cm. long, usually bicolored with reddish brown; lamina 14–16 cm. long, abruptly reduced below, gradually reduced above; pinnae 14–18-jugate, 2–3.5 cm. long, 2 mm. wide, with a sterile tip 1–2 mm. long, the base but slightly or not at all dilated; indusium delicate, entire, not becoming lacerate; sporangia yellowish or brownish yellow to brown. [PLATE 22.]

Type in the U. S. National Herbarium, no. 675793 and 675794, collected in humid forests around Los Siguas Camp, southern slope of Cerro de la Horqueta, Chiriqui, altitude about 1,700 meters, *William R. Maxon 5415*, March 17–19, 1911.

SPECIMENS INCLUDED: COSTA RICA: "Barba, borde du Rio Máncaron," altitude 1,200 m., *Pittier & Durand 2001*. U. S. National Herbarium no. 154300, without definite locality and collection number, *Cooper*.

In a cover with some South American plants marked tentatively sp. nov. by Professor L. M. Underwood, are two sheets from Colombia (altitude 5,000 feet, *H. Smith 1084*). One has a rhizome 33 cm. high, and they surely belong in this species.

6. **S. Plumieri** (Desv.) Broadh. comb. nov.

Lomaria Plumieri Desv. Ges. Nat. Fr. Berl. Mag. **5**: 325. 1811.

Lomaria martinicensis Spreng. Neue Entd. **3**: 5. 1822 (cited by Desvaux in 1827 as a synonym).

Lomaridium Plumieri Presl, Epim. Bot. 155. 1851.

Spicanta Plumieri O. Kuntze, Rev. Gen. Pl. **2**: 820. 1891.

Blechnum Plumieri Diels, in E. & P. Nat. Pfl. **1**^{4}: 248. 1899.

Plants epiphytic. Rhizome creeping on rocks and trees, at least 7–12 cm. long, 1–3 cm. thick, the scales numerous, linear, 10–18 mm. long, decidedly reddish brown to burnt umber, without a black median line. Sterile fronds 65–115 cm. long; stipes scattered, 15–27 cm. long, not at all or but slightly angulate, irregularly marked with vestigial pinnae in the upper part, bicolored (uniformly straw-colored in one frond, *Lloyd 898*); lamina 30–90 cm. long, 12–28 cm. wide, lanceolate to ovate-lanceolate, abruptly reduced at the base (type D to E, with vestigial pinnae), gradually reduced at the apex, the terminal pinna 4–7 cm. long, the pinnae usually alternate, distant (1–2 cm.) in the lower third or half of the lamina; pinnae 28–60-jugate, linear, slightly curved to falcate, the apex long-acuminate, the base dilated in the upper part of the lamina, sometimes slightly contracted near the base in the lower pinnae, 7–16 cm. long, about 1 cm. wide (1–2 cm. at the dilated bases); margins entire (apparently subentire in the heavier ones owing to the shrinkage of the tissue between the vein apices); leaf tissue membranous to herbaceous, without scales; veins distinct above in membranous specimens, often appearing below as fine black lines, the glandular apices rather inconspicuous, often blackish, the vein spaces 10–14 to 1 cm. Sporophyls 40–70 cm. long; stipes 12–25 cm. long, with scarlike vestigial pinnae, brownish yellow to dull or purplish brown, or indistinctly bicolored; lamina 18–58 cm. long, abruptly reduced at the base, gradually reduced at the apex; pinnae 20–60-jugate, 7–15 cm. long, 2–4 mm. wide, usually having a sterile tip 1–3 mm. long, the base slightly contracted (sometimes with slight, thin dilations below the contraction); indusium entire, not becoming lacerate, often reflexed; sporangia dark brown.

TYPE: From Martinique, Plumier, Foug. *pl. 90.* 1705.

DISTRIBUTION: Known from Montserrat, Guadeloupe, Dominica, and Martinique.

SPECIMENS INCLUDED: GUADELOUPE: Climbing epiphyte, "Forêts de la Decouverte," *Duss 4168* (Y, N). DOMINICA: Mt. Diablotin, *Lloyd 898* (Y, N). MARTINIQUE: "Mt. de la Calebasse," *Berlanger 814* (Geneva; tracing, Y). Climbing on trees, "Forêts Deux Choux," *Duss 1555* (Y). Climbing on trees, Calebasse, *Duss 4588* (Y).

The four islands furnishing the specimens of *S. Plumieri* studied (23 sheets), lie near the middle of a chain of islands extending from Yucatan to South America. Passing either northwest or south along that chain, we find plants intermediate in character between *S. Plumieri* and the following, more widely distributed species, *S. polypodioides*. Of the few specimens from Grenada, four sheets (*Sherring 146*) are like *S. Plumieri* in the following respects: The rhizome scales lack the black median line; the stipe is marked with vestigial pinnae; the sterile lamina has the base rather abruptly reduced; the pinnae are very long; and the lower pinnae are sometimes distant. They are like *S. polypodioides* in the proportionate length of the lamina and in the more falcate pinnae. The other specimens from Grenada fall unquestionably into *S. polypodioides*.

We find similar intermediate forms in passing northwest from Guadeloupe through Porto Rico. One sheet from Porto Rico (*Hioram 275*, Mt. Torresilla, U. S. National Herbarium no. 657235) has the texture and the base of *S. Plumieri;* the other characters are all those of *S. polypodioides*. The other (5) specimens from Porto Rico are all of the *polypodioides* type except that none of them has black in the rhizome scales. This black median line is also lacking in 4 of the 28 Jamaican sheets of *S. polypodioides*, and occasionally so in specimens from Cuba and Mexico.*

Fée's description and picture of *Lomaria Plumieri* can not be separated from *L. Plumieri* Desv., and Fée himself says that his figure is given to "complete" Plumier's figure. Jenman nevertheless confused *Plumieri* with *exaltata*, thus (1) making his description of the habit of *Plumieri* untrue, and (2) leading to the establishment of *Féei* for what he mistakenly considered Fée's *Plumieri*, the raised-veined form of *polypodioides*. Christensen gives *Lomaria divergens* Kze. and *L. mucronata* Fée both as synonyms for *Plumieri*. Neither is synonymous, for *L. divergens* has pinnae with wedge-shaped bases, and *L. mucronata* is much like *exaltata* in the cutting and the proportions of the lamina and the pinnae.

7. S. POLYPODIOIDES (Sw.) Trev. Atti Ist. Ven. III. **14**: 571. 1869.

Osmunda polypodioides Sw. Prod. 127. 1788.
Blechnum onocleoides Sw. Jour. Bot. Schrad. **1800**^{2}: 75. 1801.
Onoclea polypodioides Sw. Fl. Ind. Occ. **3**: 1585. 1806.
Lomaria polypodioides Desv. Prod. 288. 1827.
Lomaria onocleoides Spreng. Syst. **4**: 62. 1827.
Lomaria fragilis Liebm. Vid. Selsk. Skr. V. **1**: 80. 1849.
Spicanta onocleoides Presl, Epim. Bot. 114. 1851.
Lomaria decrescens Fée, Gen. Fil. 68. 1852; Mém. Foug. **7**: 24. *pl. 9, f. 1.* 1857.
Lomaria mexicana Fée, Mém. Foug. **8**: 70. 1857.

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* See also the discussion under *S. polypodioides*.

Blechnum polypodioides Kuhn, Fil. Afr. 92. 1868.
Spicanta polypodioides O. Kuntze, Rev. Gen. Pl. **2**: 821. 1891.
Spicanta attenuata O. Kuntze, Rev. Gen. Pl. **2**: 820. 1891.
Lomaria Féei Jenm. Bull. Bot. Dept. Jamaica **43**: 7. 1893.
Lomaria attenuata Willd. (as used by Jenman, loc. cit.).
Blechnum attenuatum Diels (in part), in E. & P. Nat. Pfl. 1^4: 249. 1899.

Plants epiphytic. Rhizome wide-creeping, often 10–12 meters above the ground, 1–2 cm. thick, the scales linear, 7–14 mm. long, maroon to dark chocolate brown, usually with a black median line. Sterile fronds 25–95 cm. long; stipes scattered throughout 10–20 cm. from the apex of the rhizome, 6–28 cm. long, rarely angulate, without vestigial pinnae, bicolored with dark brown or blackish brown; lamina 20–80 cm. long, 4–15 cm. wide, shape either (1) narrowly lanceolate or else very narrowly oblong or linear with the greatest width the same for about half the length (15–30 cm.), gradually reduced at each end, the lower usually contiguous pinnae becoming triangular or more or less semicircular (type F base and approaching G) or (2) lanceolate in shape, gradually reduced at the apex, the lower sinuses becoming wider and the lower pinnae more abruptly reduced and sometimes distant (type F and approaching E, but rarely E), the pinnae mainly alternate; pinnae 25–75-jugate, falcate, the apex acute to acuminate, the base the widest part, but not very prominently dilated, 2.2–8 cm. long, 9–12 mm. wide; margins entire or sometimes subentire at the apex; leaf tissue rigid-herbaceous to coriaceous, without scales; veins usually indistinct above, usually appearing below as distinct, dark lines, or in the heavier plants often raised and cartilaginous, the apices somewhat glandular, the vein spaces 9–12 to 1 cm. Sporophyls 20–70 cm. long; stipes 8–24 cm. long, often with a few vestigial pinnae, usually bicolored; lamina 16–60 cm. long, abruptly reduced at the base, gradually reduced at the apex; pinnae 22–45-jugate, 3–8 cm. long, 2–3 mm. wide, with or without a contracted sterile tip 1–4 mm. long, not dilated at the base; indusium entire, not becoming lacerate; sporangia brown to dark brown.

TYPE LOCALITY: Jamaica.

DISTRIBUTION: Mexico, Central America, Panama, West Indies, and the Lesser Antilles.

SPECIMENS INCLUDED: MEXICO: State of Vera Cruz, County of Cordova, *Finck 87* (Y, N). COSTA RICA: Vicinity of Coliblanco, altitude about 1,950 m., climbing on trees, *Maxon 251* (Y, N).

Cañas Gardas, altitude 1,100 m., *Pittier 10987* (N). PANAMA: Cana and vicinity, altitude 6,000 ft., on tree, *Williams 923* (Y, N). CUBA: Without locality, *Wright 864* (Y, N). El Yunque Mt., Baracoa, climbing on tree fern, sink hole, *Underwood & Earle 980* (Y, N). JAMAICA: "Morce's Gap," altitude 5,000 ft., *Clute 81* (Y, N). Base of John Crow Peak, altitude 5,000–5,500 ft., climbing high on a tree, *Maxon 1249* (*Underwood 2377*) (N). Base of John Crow Peak, altitude 5,000–5,500 ft., *Underwood 558* (Y). HAITI: La Brande to Mt. Balance, creeping on tree, summit of Mt. Balance, *Nash & Taylor 1749* (Y). SANTO DOMINGO: Constanza, epiphytic in leafy woods, altitude 1,200 m., *von Türckheim 2996* (Y). PORTO RICO: Luquillo Mountains, *Wilson 142*.

Onoclea polypodioides Sw. is described as having clustered stipes, erect fronds, an inframarginal indusium, and as differing from *Osmunda Spicant* L. in magnitude, in the more acute and more curved pinnae, and in the remote not subconfluent fertile pinnae. These characteristics, taken with the clustered appearance of this scandent species, and with the smaller size of the European *Spicant*, fix the name without doubt upon the Jamaican fern described above. The dimorphous character of this species probably caused Swartz to change the specific name to *onocleoides*, before he finally transferred it to *Onoclea*, where he took again the original specific name *polypodioides*. He plainly states the synonym in each case, so that there is no reason for including both *onocleoides* and *polypodioides* as several fern writers have done.

Several species have been reduced to synonymy with *polypodioides*, either by Christensen or in this paper. Liebmann's own sheet of *L. fragilis* can not be distinguished from young leaves of *L. polypodioides*. The same is true of the picture and of the type sheet of Fée's *L. decrescens* (Cuba, *Linden 2019*); and Fée's description contains too many contradictions to be of any value. *L. mexicana* Fée is later described by Fée as synonymous with *L. fragilis* Liebm. The shorter fertile frond and the lack of any distinctive character even in one of Liebmann's own sheets prevent the separation of *fragilis* from *S. polypodioides*.

Neither can *L. Féei* of Jenman be clearly distinguished from *S. polypodioides* for (1) the same plants show both forms of bases of the laminae; and (2) the same collection number[*] has fronds with and also without the raised cartilaginous veins, which are but irregularly present in the plants possessing them. Several plants from Cuba, Haiti, and Jamaica, however, show such veins; they are usually coriaceous in texture, the pinnae are longer and usually *linear*-falcate in shape, and the bases of the laminae are rather more abruptly reduced (type E) with occasionally distant pinnae. These same characters are, however, found in some fronds without the raised cartilaginous veins; and like the veins, they are not uniform in all the fronds of the same plant.

The specimens from Costa Rica and Panama have very long and proportionately narrow sterile fronds, a form evidently commoner in Jamaica than in other islands. These mainland plants differ also from most of the island specimens in having very narrow, acuminate scales, with very long, slender teeth, which are variously curved and often sharply recurved and hooklike. Separation of these plants is impossible, however, because of intermediate forms. Several Mexican plants (*Finck 87*) have similar fronds; the scales are also very like those of the Costa Rican and Panama plants, except that the black median line is often wanting. Among the specimens from Jamaica are several sheets (*Underwood 558* and *Maxon 2725*) which have scale margins intermediate between those described above and the usual island type with short, straighter teeth.

Three sheets from Costa Rica ("Vallée du Dignis," epiphytic exclusively on trees, altitude 700 m., *Tonduz 12005*) are mentioned here chiefly because of their epiphytic habit. The black-centered scales are not long-toothed like the other Costa Rican plants. The entire, linear laminae with winged stipes suggest Kunze's *Lomaria pteropus*.[†] His plants had similar scales, but much shorter, broader laminae with fewer pinnae, 3–12-jugate probably, while these Tonduz specimens are 17–25-jugate. The stipes of *pteropus* are bordered by straight-edged extensions; in the Tonduz plants the wings are composed of several pairs of confluent, rounded lobes. Kunze describes his plant as barely covered with earth; Tonduz's specimens are positively epiphytic.

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[*] This variation is shown in eight sheets of *Wright 864*, and in single collection numbers of more careful collectors in recent years: Nash, Maxon, and Underwood.

[†] Kunze, Farrnkr. 97. *pl. 46*. 1840; Raddi, Pl. Bras. 1: 5. *pl. 17*. 1825.

Unfortunately the fertile fronds are lacking; if these Tonduz plants do not belong with *pteropus*, they should nevertheless be separated from *polypodioides*. Without the fertile fronds it is, of course, impossible to place them with certainty.

Two incomplete specimens from Costa Rica ("Forêts du Roble, volcan Frazu," *Pittier & Durand 4132*, and U. S. National Herbarium no. 575238, without definite locality, *Wercklé*) and one from Nicaragua (Omotepec, *C. Wright*) suggest the Tonduz plants in the breadth and texture of the lamina and in the shape of the pinnae; they lack the winged stipes, however.

8. S. SPICANT (L.) Weis, Pl. Crypt. Fl. Gott. 286. 1770.
Osmunda Spicant L. Sp. Pl. 1066. 1753.
Acrostichum Spicant Willd. Prod. Fl. Berol. 289. 1787.
Blechnum Spicant J. E. Sm. Mém. Acad. Turin **5**: 411. 1793.
Onoclea Spicant Hoffm. Deutsch. Fl. **2**: 12. 1795.
Osmunda borealis Salisb. Prod. 402. 1796.
Acrostichum lineatum Cav. Anal. Hist. Nat. **1**: 106. 1799.
Asplenium Spicant Bernh. Jour. Bot. Schrad. **1799**^{2}: 309. 1800.
Blechnum boreale Sw. Jour. Bot. Schrad. **1800**^{2}: 75. 1801.
Lomaria Spicant Desv. Ges. Nat. Fr. Berl. Mag. **5**: 325. 1811.
Lomaria crenata Presl, Rel. Haenk. **1**: 51. 1825.
Blechnum doodioides Hook. Fl. Bor.-Am. **2**: 263. 1840.
Spicanta borealis Presl, Epim. Bot. 114. 1851.
Struthiopteris doodioides var. Trev. Atti Ist. Ven. III. **14**: 571. 1869.

Plants terrestial. Rhizome more or less inclined, apparently short, 7 mm. to 2 cm. thick, the scales lanceolate, 5–10 mm. long, chestnut to maroon or brown, darker and thicker toward their base. Sterile fronds 20–70 cm. long, of two types: (1) clustered, shorter, spreading, coriaceous or rigid-herbaceous ones with very short stipes and close pinnae, and (2) from the center of those just described, taller, more or less erect, herbaceous fronds with long stipes, much longer pinnae, and wider sinuses; stipes clustered at the apex of the rhizome, 3–27 cm. long, somewhat or not at all angulate, without vestigial pinnae, variously colored, reddish brown, yellowish brown, or purplish chestnut, but not bicolored; lamina 21–60 cm. long, 2–9 cm. wide, narrowly elliptical to linear, very gradually reduced at the base (type G), and gradually reduced at the apex, the pinnae often opposite near the middle or the base of the frond; pinnae 36–80-jugate, oblong-linear to linear-falcate, the apex rounded-acute, the base prominently dilated in the larger, more open laminae, 1–5 cm. long, 4–10 mm. wide, often opposite, especially near the base; margins entire, irregularly revolute in some of the smaller, heavier fronds only; leaf tissue membranous to coriaceous as previously described, a few of the thinner ones somewhat punctate as in *S. exaltata*, without scales, except rarely a few minute fibrillose ones on the rachis; veins* neither raised nor grooved, the apices but slightly or not at all glandular, vein spaces 10–15 to 1 cm. Sporophyls 38–120 cm. long; stipes 11–60 cm. long, often marked for a short distance by vestigial pinnae, darker than the sterile; lamina 19–60 cm. long, 4–10 cm. wide, very gradually reduced at the base and at the apex; pinnae 40–50-jugate, 2.2–5 cm. long, 2–3 mm. wide, the apex acute, with or without a contracted sterile tip 1–2 mm. long, the base decidedly dilated; indusium membranous, usually entire or subentire, sometimes irregularly broken, never becoming lacerate; sporangia dark brown.

DISTRIBUTION: Pacific coast from California to Alaska.

SPECIMENS † INCLUDED: CALIFORNIA: Humboldt County, damp shady woods, *Kellogg & Hartford 1175*. OREGON: Nehalum, creek banks and dry woods, *Kirkwood 110*. WASHINGTON: Near Tacoma, shady ravines and springs, *Flett 2030*. BRITISH COLUMBIA: Revelstoke, woods, altitude 1,600 ft., *Shaw 835*. Stevens Pass, altitude 1,150 m., *Sandberg & Leiberg 774*. ALASKA: Windham Bay, *Culbertson 4936*. Ketchikan, near stream leading from Ketchikan Falls, *Broadhurst 101*.

Two fronds collected by Douglas in the interior of northwestern America (exact locality not given) formed the type of Hooker's *Blechnum doodioides;* the half sterile, half fertile leaves, with their occasionally forked pinnae indicate an abnormal condition, and could not be considered as characterizing a valid species. Similar abnormal forms are not uncommon in other species of this genus. The veining of the fertile pinnae and the short, often unconnected sori suggest *Woodwardia* or *Doodia*. The costal sori are characteristic of *Blechnum*, but there are no Blechnums in this region. Abnormal fronds in other species often show great vari-

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* The veins are normally once forked; but the *crenata* variety is often twice forked; if the margin is deeply crenate, one main vein may have two or three veinlets on each side. Another variation in the veining is found in *Umbach 611* from Skykomish, Washington, where an apparently normal *S. Spicant* has anastomosing veins in the lower half of many of the pinnae; the veins form one row of areolae along the midrib, and do not branch again before reaching the margin.

† These specimens are all in the herbarium of the New York Botanical Garden.

ation in the width of the sterile part of the fertile pinnae. The plants described under *Blechnum doodioides* therefore without doubt represent abnormal forms of *S. Spicant*, which Hooker* admits is "the only Lomarioid plant in so northern a latitude"; the general shape, the cutting, and the dark stipes support this supposition. *L. crenata* Presl (type from Vancouver Island) is described as differing from *S. Spicant* in being larger, and in having acute, crenate pinnae, the lower ones deflexed and ear-shaped. These characters are found in five sheets from Washington and Oregon (Howell's collections of 1876, 1879, and 1880 and in Flett's no. 1928); Flett's collecting note says: "this form is rare and seems to be confined to the largest plants in the dense, mossy woods." The name *L. Spicant*, var. *serratus* Wall. appears on some of these sheets. No further record of this name has been found.

9. **S. stolonifera** (Mett.) Broadh. comb. nov.

Blechnum stoloniferum Mett. in herb. Meissn.; Fourn. Mex. Pl. 1: 113. 1872.

Lomaria stolonifera Fourn. Mex. Pl. 1: 113. 1872.

Lomaria Gheisbreghtii Baker; Hook. & Baker, Syn. Fil. ed. 2. 481. 1874.

Spicanta Ghiesbreghtii O. Kuntze, Rev. Pl. 2: 821. 1891.

Blechnum stoloniferum C. Chr. Ind. Fil. 160. 1905.

Blechnum Ghiesbreghtii C. Chr. Ind. Fil. 154. 1905.

Plants terrestrial. Rhizome creeping and stoloniferous, 15 cm. long (in type), slender, 1–2 mm. thick, the scales lanceolate to ovate-lanceolate, 1–4 mm. long, yellowish brown to tobacco brown. Sterile fronds 11–20 cm. long;† stipes clustered, 5 mm. to 4 cm. long, usually slightly angulate, without vestigial pinnae, uniformly castaneous to dark violet or lighter colored in the channel, occasionally with a few ovate-lanceolate to ovate, dull brown deciduous scales; lamina 8–16 cm. long, 17–36 mm. wide, elliptical, gradually reduced at the base (type F) and slightly less so at the apex; pinnae 16–22-jugate, triangular-falcate to oblong-falcate, the apex rounded or obtuse, but often apparently acute because of the irregularly revolute margin, the base more or or less dilated, 6–18 mm. long, 4–5 mm. wide; margins entire, irregularly and but slightly revolute; leaf tissue herbaceous, roughish in drying, never smooth as in the

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* Sp. Fil. 3: 60. 1860.

† Usually less than 18 cm. long.

thinner fronds of *S. Spicant*, very finely punctate much as in *S. exaltata*, without scales; veins indistinct, without conspicuous glandular apices, vein spaces 10–12 to 1 cm. Sporophyls taller, 25–28 cm. long; stipes slender, 9–13 cm. long, reddish brown to almost black, usually shining; lamina 7–16 cm. long, abruptly reduced at the base with slight indications of vestigial pinnae or gradually reduced with the lower pinnae sterile, the apex gradually or abruptly reduced; pinnae 12–19-jugate, 1–2 cm. long, 2–3 mm. wide, falcate, with an abrupt sterile tip 1–2 mm. long, the base dilated; indusium delicate, entire; sporangia tobacco brown or darker.

TYPE: *Müller 1491*, no. 61 in Meissner herbarium (Y) from Orizaba, Mexico.

DISTRIBUTION: Known from Mexico only.

SPECIMENS INCLUDED: MEXICO: State of Hidalgo, Trinidad, wet banks, *Pringle 8752* (N). State of Hidalgo, Barranca, below Trinidad Iron Works, 5,700 ft., *Pringle 13808* (N). Chiapas, *Ghiesbreght 207* (Kew; College of Pharmacy, Columbia University).

The type of *L. Gheisbreghtii* Bak., *Ghiesbreght 207*, cannot be distinguished from *S. stolonifera*, though Christensen in his Index Filicum considers it a valid species. One or more of the taller sterile fronds in the two type numbers seen have wider sinuses, giving the lamina a slightly more open appearance than the rest of the fronds of these or of the other specimens of *S. stolonifera*. The College of Pharmacy specimen of *Ghiesbreght 207* has also a short, undeveloped stoloniferous shoot.

S. stolonifera differs from *S. Spicant* in texture, never possessing the smooth almost transparent pinnae of the more delicate specimens nor the coriaceous texture of the smaller fronds of *S. Spicant*. The lamina is much smaller, and the pinnae often lie so close together that the lamina usually appears lobed rather than fully pinnate; the pinnae are never linear, and as indicated in the key, are proportionately much broader than in *S. Spicant*. Three pots of *S. stolonifera*, now in the New York Botanical Garden conservatories, have the shorter sterile fronds arranged in a flattened rosette at the base, one of the taller sterile fronds at an angle of about 30 degrees, and the fertile ones erect or almost so. In this they resemble *S. Spicant;* it would be interesting to know if *S. Spicant* is ever stoloniferous.

(*To be concluded*)

Vegetative reproduction in the New England Frullaniae

Annie Lorenz

Very little emphasis has as yet been laid upon the occurrence of adventive branches, or propagula, in the genus *Frullania*, perhaps for the reason that such propagula, at least in the New England species examined by the writer, offer no taxonomic distinctions, as do the gemmae in *Metzgeria*. In any case, but few references to such propagula can be found in the previous literature.

Dr. Evans ('97), in his monograph on the North American Frullaniae, while he makes no reference to such propagula in his introductory remarks, describes the upright flagellate branches of *F. Bolanderi* Aust. but does not ascribe to them any characters of vegetative reproduction. In comparing this species with *F. eboracensis* Gottsche, he says: "*F. eboracensis* occasionally produces flagella-like branches, but they are always leafy, and are a rather unusual feature of the plant"; and in the description of *F. eboracensis*, "sometimes flagelliferous."

However, in his Hepaticae of Puerto Rico ('02–) he describes a variety of adventive branches, propagula and gemmae, arising from different situations upon the plant. Of these, the propagula arising from the modified leaves of *Rectolejeunea flagelliformis* Evans and *Cheilolejeunea decidua* (Spruce) Evans bear the most resemblance to those of the species of *Frullania* which are discussed below.

While a sharp distinction can hardly be made between gemmae and adventive branches or propagula, a gemma, as a rule, grows to a specific size while still united to the parent plant and germinates after being shed. An adventive branch, on the other hand, whether arising from a "Brutblatt" or from some other position upon the plant, begins as an irregular mass of cells and may develop a branch with several leaves before becoming detached.

Berggren ('65) describes in careful detail the propagula upon the leaves and lobules of *Frullania fragilifolia* Tayl. and figures three lobules with shoots of different ages. Schostakowitsch ('94) treats of the adventive branches of *F. dilatata* (L.) Dum. and *Porella platyphylla* together, figuring a "Vorkeim" of *Porella* which greatly resembles that of our Frullaniae.

Pearson ('02) and Macvicar ('10) refer to the remarkable caducous leaves of *Frullania fragilifolia* but had not observed them to be Brutblätter, although they mention the shoots on the lobules.

Cavers ('03) describes the vegetative reproduction in two European species of *Frullania*. In *F. fragilifolia* Tayl. the easily detached hooded lobules give rise to leafy shoots from their marginal cells. In *F. dilatata* (L.) Dum. "the outer surface of the perianth in this species bears numerous irregular outgrowths, each made up of from two to five or six cells. These outgrowths may be regarded as gemmae." Warnstorf ('03) describes these structures in *F. dilatata* in somewhat more detail, as well as small thin-walled Keimkörner upon the leaves of ♂ plants, and suggests that these two types of gemmae may serve to reproduce the ♀ and ♂ plants respectively.

Hans Buch ('11) merely refers to the Brutblätter of *F. fragilifolia* without any further description.

Of the eleven species of *Frullania* at present reported from New England, seven belong to the subgenus *Trachycolea*, one to *Homotropantha*, two to *Thyopsiella*, and one to *Diastoloba*.

Upon examination, adventive branches were found in three of the species of subgenus *Trachycolea*, viz., *F. eboracensis* Gottsche, *F. Brittoniae* Evans, and *F. riparia* Hampe; as well as in *F. plana* Sull., the representative of subgenus *Homotropantha*. Some scanty material of *F. inflata* Gottsche and *F. saxicola* Aust. was examined fruitlessly, but adventive branches could probably be demonstrated with a larger supply of material.

In the subgenus *Thyopsiella*, material of *F. Asagrayana* Mont. from four different states was examined, with no traces of Brutblätter. *F. Tamarisci* (L.) Dum., both Nova Scotian and Swiss material, gave similar negative results. The same was true of the only *Diastoloba*, *F. Selwyniana* Pearson from Maine.

F. eboracensis Gottsche easily leads all the New England species in regard to the abundance and luxuriance of its means of vegetative reproduction. As the adventive branches upon all species examined precisely resemble one another, only *F. eboracensis* will be considered in detail and figured. Material was examined from four states, and the Brutblätter were by far the most common upon the Connecticut plants, being observed but once each upon plants from Maine and from Waterville, N. H. These observations and figures have been almost entirely taken from material growing upon *Juniperus* in the vicinity of Dr. Hooker's Cabin, at Farmington, Conn.

Branches with deciduous leaves are frequently produced upon both ♀ and ♂ plants. These may be considered as Brutblätter, as their method of separation is schizolytic, leaving behind one row of cells and the stylus. If a branch is moistened and handled with extreme care, the Brutblätter can be seen in position, but they are excessively fragile.

Whether or not the production of Brutblätter is induced by drought, the cause has evidently no connection with the time of year, as plants collected in January and May from neighboring stations bore equally good Brutblätter. While Brutblätter are equally common upon ♀ and ♂ plants, the writer has not yet observed any upon plants with mature capsules, although thick-walled cells are occasional upon perichaetial bracts as well as upon underleaves. Neither were they observed upon perigonial bracts.

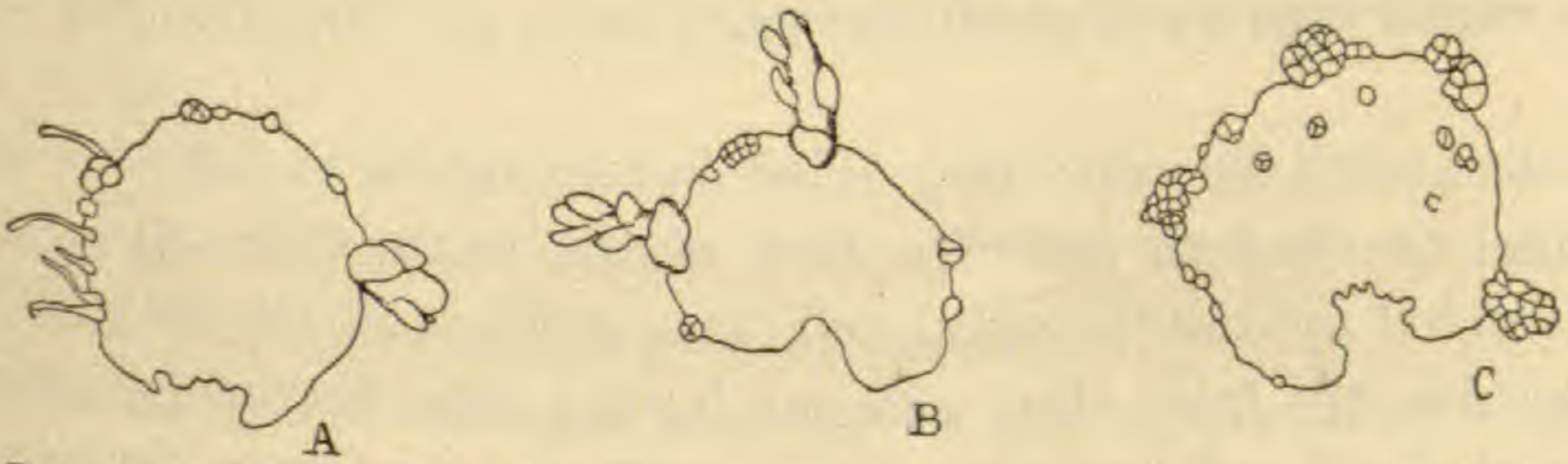

FIGURE 1. *Frullania eboracensis.* *A*, leaf with rhizoids, ×40. *B*, leaf with two shoots, ×40. *C*, leaf with seventeen cell masses, ×40.

The leaves themselves often develop rhizoids, by the projection and lengthening of marginal cells, thus being prepared to get a foothold wherever the leaves happen to be shed. (FIG. 1, *A*.)

The gemmalike masses of cells are developed from the margin or from the row or two of cells just within. A single favorable leaf may have eight or ten marginal cells in various stages of division, making quite a border, besides one or two entire shoots with more or less developed leaves. (FIG. 1, *B*.) The largest number of cell masses counted by the writer upon any one leaf is seventeen, but these were not all marginal. (FIG. 1, *C*.)

A marginal cell first becomes more or less pigmented with red-brown, or rather, with burnt sienna mixed with a very little carmin lake and just a touch of black, so that it is strikingly contrasted with the clear green of the rest of the leaf; or if upon red ♂ plants, the color becomes still deeper and richer. The cell wall thickens, and the cell expands and projects beyond the margin to some extent. (FIG. 2, *A*.) It first divides by a wall perpendicular to the margin, making two approximately hemispherical cells. These divide next in a plane about in line with the margin, but this is not a continuous line, so that the four resulting cells are not all of quite the same size. They in turn divide in a plane about parallel to the leaf surface. One of the outer cells cuts out a three-sided pyramidal apical cell (FIG. 2, *B*), and the leafy shoot arises directly from this, without having first become detached from the leaf and while the leaf is still growing upon the plant.

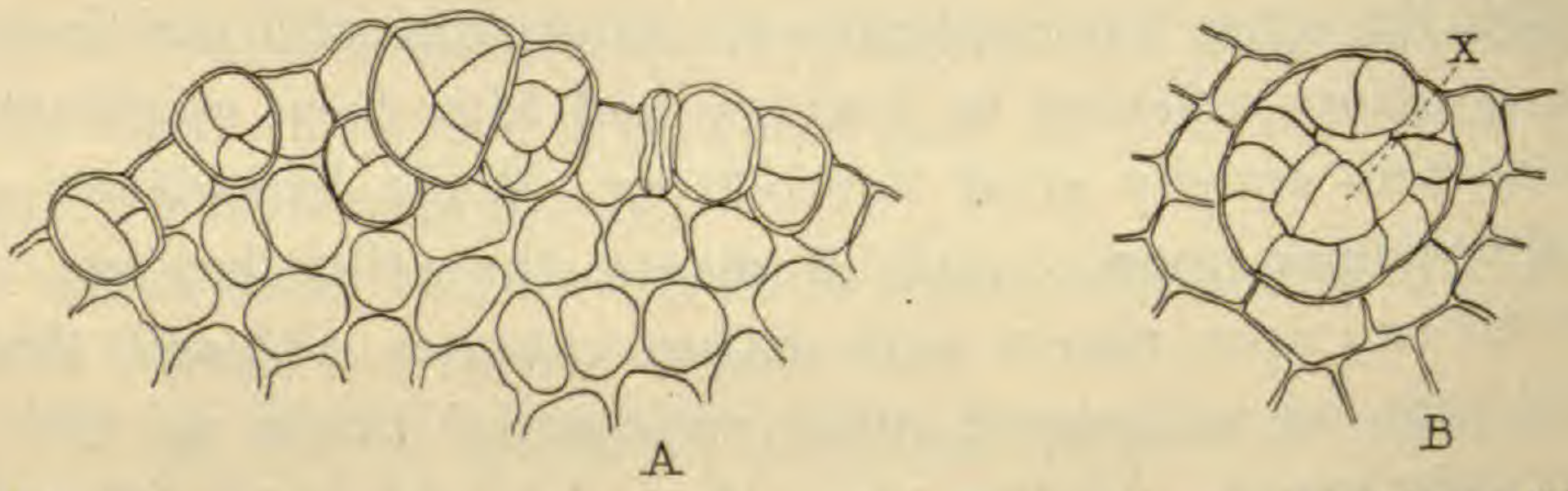

FIGURE 2. *A*, margin of leaf with cells in various stages of division: note the cell that has been compressed by its neighbors; ×250. *B*, further developed cell mass, showing triangular apical cell in center, ×250.

The lobules bear, with equal frequency, cell masses and shoots either upon the top of the hood or about its mouth. (FIG. 3, *A*, *B*.) A few hoods had shoots so well developed that several of the upper leaves had hoods of their own. (FIG. 3, *C*.)

The first leaves on the shoots are mere rudiments, but succeeding leaves are increasingly developed, and underleaves soon appear. (FIG. 3, *D*). The largest shoots have quite the aspect of normal branches. (FIG. 3, *E*.)

On some fresh material from Farmington, growing on young elm trees in a bog, the cell structure of the leaves differed in being thinner-walled, with less conspicuous trigones and almost no intermediate thickenings. This condition approaches that of *F. Bolanderi* Aust. of the Pacific coast, which besides its characteristic upright flagellate shoots has Brutblätter exactly like those first described for *F. eboracensis*.

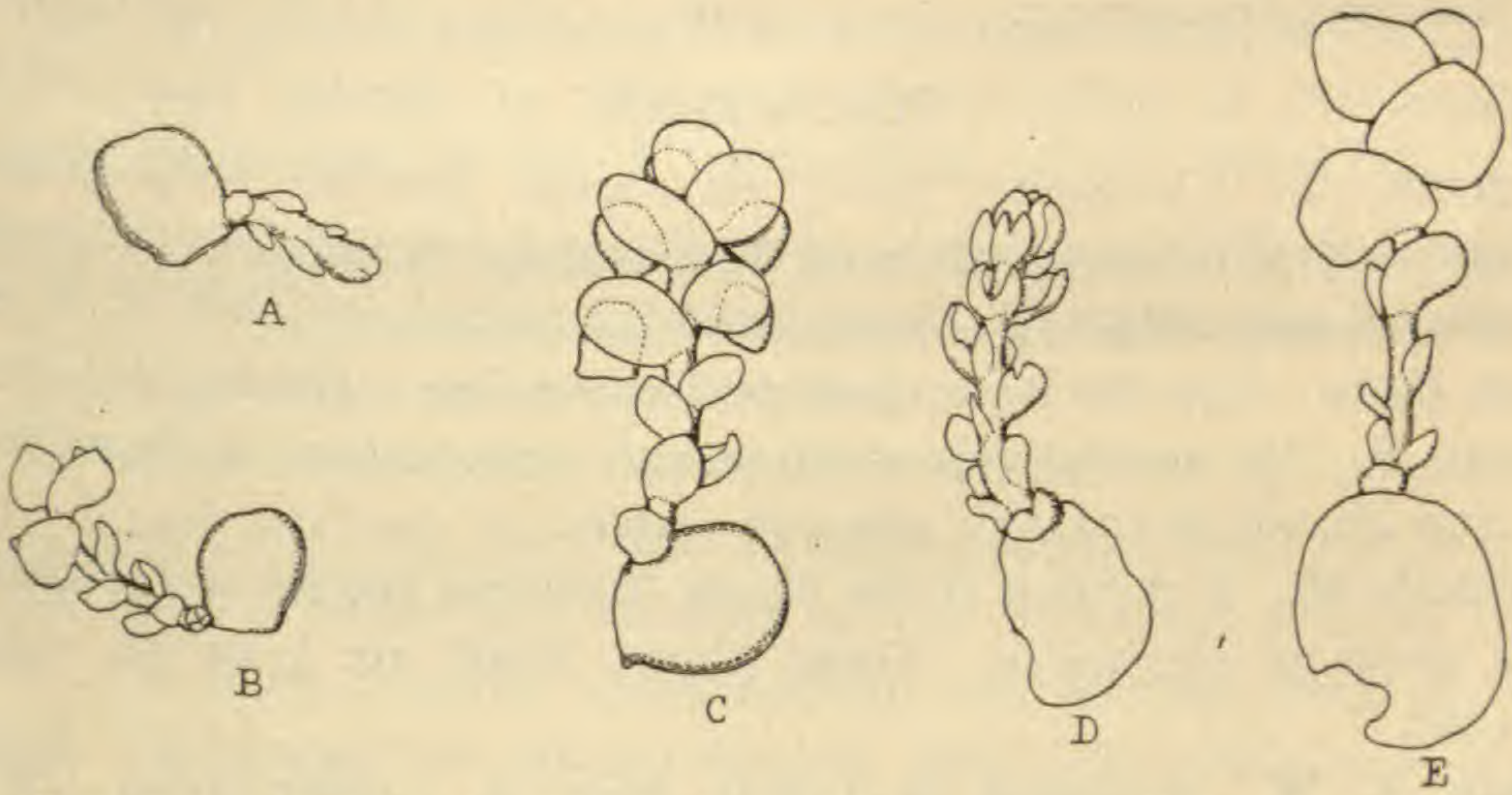

FIGURE 3. *A–C*, hoods with shoots in different stages; *D, E*, leaves with well developed shoots.

In *F. riparia* Hampe from North Pownal, Vermont, the Bruchblätter were not caducous, and the cell masses as a rule were not marginal but arose from cells about two rows back from the margin.

F. Brittoniae Evans, which is very close to the European *F. dilatata*, in some material from Waterville, N. H., bore cell masses and shoots upon leaves likewise not caducous.

The adventive branches in *F. plana* Sull. are borne, not upon the oldest and more or less dirt-encrusted portions of the plant, but upon the growth of the past season. These leaves also were not caducous, neither did they produce rhizoids. The adventive branches closely resemble those of *F. eboracensis*, except that they are of a rather dark green instead of being pigmented with red-brown.

According to these observations, the production of Brutblätter is more frequent in the dioicous rather than in the autoicous species of *Frullania*. *F. eboracensis*, *F. Brittoniae*, and *F. riparia* are all dioicous, as is *F. Bolanderi;* while *F. plana*, although autoicous, is usually sterile. All the European species of *Frullania*, with the exception of the recently described *F. cleistostoma* Schiffner & Wollny, are dioicous.

The writer would express her thanks to Dr. A. W. Evans for his kind assistance; and would be glad to examine any further propagula-bearing material of *Frullania*, other than *F. eboracensis*.

HARTFORD, CONNECTICUT.

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New ferns from Tropical America

MARGARET SLOSSON

(WITH PLATE 23)

The discovery of the two plants which are the subject of this paper, adds another species to the already vast genus of *Polypodium* and one to the meager genus of *Loxsomopsis*. The first of these two plants was brought recently from Cuba, by Dr. J. A. Shafer, and belongs to the well-known group of *Polypodium* usually designated as the *P. trifurcatum* group. The second is taken from a large and fine collection of ferns made in Bolivia by Mr. R. S. Williams during 1901 and 1902. This collection contains a number of species still to be described.

The genus *Loxsomopsis* has been known until now by two species only, found in Costa Rica and Ecuador, respectively. It is one of the most peculiar and striking in the American tropical fern flora. Its most notable characteristic, the minute erect or deflexed, cup-shaped or pitcher-shaped sori, with their extruding columellar receptacles beset with sporangia, suggesting minute lily bells on the margins of the leaves, can be seen from the accompanying illustration of the species here described. This plant, apparently the largest and most conspicuous so far discovered in the genus, may be known as:

Loxsomopsis notabilis sp. nov.

Rhizome creeping, 3 to 5 mm. in diameter, thickly clothed with blackish or purplish castaneous acicular scales 1 to 3 mm. long, the cells of the scale uniserial above its turgid base, the scale sometimes noticeably articulated; fronds borne on top of the rhizome, uniserial, scattered, up to 2.5 m. high, up to about 80 cm. broad, deltoid, bi-subtripinnate; stipe up to about 1.2 m. long, 1.3 to 3 mm. in diameter, purplish ebeneous to castaneous, rigid, terete, clothed below with scales similar to those of the rhizome, glabrous or glabrescent above; primary rachis castaneous and terete below, stramineous and narrowly elate toward the apex; secondary rachises castaneous to stramineous; pinnae opposite or subopposite, sessile or adnate, mostly remote, spreading more or less obliquely, often arcuate, at least when dried, somewhat asymmetrical, acuminate, the apices serrate to subentire, giving rise gradually to the pinnules; basal pinnae either the broadest, 7 to 25 cm. broad, or equal to the next above, broadly ovate or ovate-lanceolate, median pinnae ovate-lanceolate or lanceolate, upper pinnae lanceolate; pinnules adnate-decurrent, the inner in the inner pinnae mostly spaced, the larger lanceolate or lance-linear, acuminate, cut obliquely almost to the costa into deltoid, ovate-oblong, or oblong-lanceolate, obtuse or acute segments, the larger of which are coarsely and obliquely lobed or toothed; smaller pinnules contiguous and similar to the larger segments; both basal pinnules reduced and sometimes the next pair somewhat so, the basiscopic basal pinnule the shortest, 1.7 cm. or less long, in the upper or median pinnae often merely a toothed auricle and then adnate to the primary rachis; upper surface bright olive green, glabrous, lower surface paler, glaucous, and sparingly furnished with minute flexuose flattened articulated hairs, especially on the veins, costae, and rachises; texture chartaceous; venation prominent, pinnate, veins catadromous; sori terminal on lateral teeth of the lobes or segments, erect or deflexed, each apical on a simple vein, or the upper branch of a once forked vein or a spur produced from the upper side of the latter branch; indusia sessile, calyciform, rarely urceolate, entire; receptacle somewhat exserted; sporangia intermixed with simple articulated paraphyses; spores fuscous, subtetrahedral, convex on the upper side, verrucose.

Type in the Underwood Fern Herbarium at the New York Botanical Garden, collected in wooded ravines, near Apolo, Bolivia, South America, July 25, 1902, *R. S. Williams 1303*.

From *L. costaricensis* Christ* and *L. Lehmanii* Hieronymus,† as described, *L. notabilis* differs chiefly in the following characteristics. From *L. costaricensis*, in the bright olive green upper surface and glaucous under surface of the lamina, in the conspicuous reduction of the principal pinnae at the base on both sides, and in the verrucose spores. *L. costaricensis* is described as having the upper surface of the lamina dark green, the lower surface not glaucous, the basal acroscopic pinnules the longest pinnules of the principal pinnae, and the spores smooth. From *L. Lehmanii, L. notabilis* differs in the much greater size of the leaf, in the color, blackish or purplish castaneous to castaneous, of the rhizome, stipes, and their scales, in the shape of the lower

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* Bull. Boiss. II. 4: 399. *pl. 1.* 1904.

† Bot. Jahrb. 34: 435. 1904.

pinnae, and usually in the shape of the indusia, which for the most part are merely deeply cup-shaped. *L. Lehmanii* is described as having leaves 35 cm. or less long, stipes fuscescent, scales of the stipes and rhizome fuscous-ferrugineous, lower pinnae obliquely elongate-deltoid, and indusia urceolate.

Polypodium insidiosum sp. nov.

Rhizome erect or oblique, about 1.5 cm. or less long, about 3 mm. or more in diameter, the crown thickly clothed with yellowish brown lanceolate or oblong-lanceolate scales 1 to 3 mm. long, having minute, rarely jointed, processes on their margins; stipe dull brownish or blackish, slender, wiry, terete, often arcuate, at least when dried, 0.5 to 3.5 cm. long, glandular-pubescent, clothed at the base with a few scales similar to those of the rhizome; lamina 3 to 10 cm. long, 6 to 13 mm. broad, lanceolate and broadest at or below the middle, or linear, rarely oblanceolate, acute or obtuse, at base acutely cuneate and very shortly decurrent, entire, repand, or somewhat sinuate, glandular-pubescent, glabrescent; the margin and lower surface, especially about the sporangia, sparingly furnished with short brown spreading hairs, a few sometimes on the upper surface also; midvein flexuose, mostly concealed, or slightly evident below and then blackish; texture chartaceous-coriaceous; veins usually apparent by transmitted light; the primary veins mostly with from 2 to 4 pairs of simple or occasionally once forked, free or casually uniting branches; sori apical or dorsal on the innermost branches or on short spurs of these, irregularly 1- to 3-serial, orbicular or oval, 1 to 2 mm. broad, superficial; sporangia glabrous; spores finely papillose.

Type in the Underwood Fern Herbarium at the New York Botanical Garden, collected on mossy tree trunks near Camp La Gloria, a mining camp south of Sierra Moa, Province of Oriente, Cuba, at an altitude of about 762 meters, December 24–30, 1910, *J. A. Shafer 8043*.

This plant strongly suggests a small mock *Polypodium trifurcatum*. It is much smaller than that species, fruiting when barely 3.5 cm. high, and appears to have a somewhat different habit. When dried, the fronds are rigid and very brittle, and the stipes are more or less arcuate; the fronds thus point in various directions, but are not bent abruptly at the base of the lamina, as is apt to be the case in *P. trifurcatum*. The laminae when lobed are less deeply so than is usual in the latter plant and are often either entire or merely subentire.

NEW YORK BOTANICAL GARDEN.

Explanation of plate 23

FIG. 1–3. *Loxsomopsis notabilis; R. S. Williams 1303.* Bolivia; 1, section of pinna, enlarged, showing sori; 2, scale from leaf bud; 3, scales from rhizome.

FIG. 4–8. *Polypodium insidiosum; J. A. Shafer 8043.* Cuba; 4–6, parts of plant, natural size, showing leaf variation; 7, section of leaf, enlarged, showing venation; 8, scale from rhizome.

Three new species of Opuntia, with a discussion of the identity of Opuntia Lindheimeri

BERNARD MACKENSEN

For some years the writer has been studying the opuntias growing in the country about San Antonio, Texas. Among the large, more or less erect forms he has recognized several species described by Dr. David Griffiths in recent years, but of the remaining large forms he has not been able to discover a record anywhere. Among the latter he naturally expected to recognize *Opuntia Lindheimeri*, but careful examination revealed the fact that no single form agrees with Dr. Engelmann's description of that species and with the specimens and notes ascribed to it in the herbarium of the Missouri Botanical Garden; nor has he been able to find such a form at New Braunfels, the type locality of that species.

Of the presumably new species mentioned, three are described below. A certain other species occurs here, characterized by robustness, its height sometimes exceeding two meters, and by its white to yellow spines (resembling bone), etc. Perhaps this species approaches the description of *O. Lindheimeri* more nearly than any other occurring in this region. The two, however, differ in length of bristles, length and color of spines, shape and character of fruit, and size and character of seed. The fruit preserved in the type material of *O. Lindheimeri*, and the sketch of it accompanying them, show that organ to be very slender. None of the larger opuntias of the type locality have such a fruit, so far as the writer has been able to determine, but the low species *Opuntia macrorhiza* and *O. leptocarpa* bear fruit of that form. Some of the type material was taken from plants grown in St. Louis and for that reason is probably not normal, as the opuntias are very readily modified by changed conditions. This fact, together with the unsatisfactory condition of a part of the material, increases the difficulty of establishing the identity of *Opuntia*

Lindheimeri. The seeds in the type material agree with those of *O. macrorhiza*. The writer had long suspected that this species is a composite one, but after his examination of the material and accompanying notes and drawing in the herbarium of the Missouri Botanical Garden he has become firmly convinced that such is the case. There is another fact which supports this view: Lindheimer, in his notes accompanying the specimens of opuntias, uses the expressions "kleine Opuntia" and "grosse Opuntia," which seems to indicate that he regarded all the small flat-jointed opuntias of his region as one species and all the large (more or less erect) ones as another, just as at present most of the inhabitants of that region distinguish but two species, if indeed they recognize more than one.

It would seem that in the composition of *O. Lindheimeri* the tall form mentioned contributed the size and habit, *O. texana* the spines, and *O. macrorhiza* the fruit. All these species occur at New Braunfels. The writer has thought best to let the tall form, of which he has deposited specimens under the number 619757 in the U. S. National Herbarium, stand for *O. Lindheimeri*.

The species described below are closely related, but each, it will be seen, differs from any one of the others in several characters. The descriptions were drawn from plants growing in their native habitat at San Antonio, Texas, where the species are common, and the type material was collected in the same locality.

Opuntia convexa sp. nov.

Plants from somewhat fleshy terete roots, sometimes attaining a height of over 1 meter and a breadth of 2 to 3 meters, with normally erect or ascending stems; joints obovate to oval, often inequilateral and obtuse or acutish at apex, 1.5 to 3 cm. long, or sometimes longer, at first somewhat glaucous, later dull green, darker around the areoles, in age dirty yellow to gray, and scurfy; leaves subulate, somewhat flattened, 5 to 10 mm. long; areoles bearing formidable bristles and short wool, and on the younger joints usually armed, except the lowest; bristles dirty yellow to brown, on old joints widely spreading and attaining a length of 15 mm.; spines light brown to reddish below (soon fading to grayish), but the greater portion of spine pale yellow, straight or often curved, much flattened, mostly twisted, rather stout, unequal, 1 to 4.5 cm. long, or sometimes longer, 1 to 5 to an areole, or on the older joints sometimes more, very numerous on joints formed in droughty seasons, erect or spreading, on old joints reflexed; flowers opening yellow and turning salmon pink, 7 to 8 cm. broad and long; petals relatively thick, obovate, cuspidate, about 3 cm. broad, 4 to 5 cm. long; stigma green, 7- to 9-lobed, surpassing the stamens; fruit obovate in outline, often broadly so, 3.5 to 4 cm. broad, 4.5 to 5.5 cm. long, dark purplish red without, purple within, the umbilicus convex, the taste nauseous; seeds suborbicular, nearly or quite 4 mm. in diameter, buff, with more or less gray on the flat sides.

The plant flowers in April and May and ripens its fruit, which is often proliferous, in August.

This species is probably the commonest of the various large-jointed prickly pears growing about San Antonio.

The type is no. 619756 in the U. S. National Herbarium.

Opuntia Griffithsiana sp. nov.

Plants from somewhat fleshy terete roots, sometimes attaining a height of 8 and a breadth of 12 dm., with erect, ascending, and prostrate stems, forming a rather dense growth; joints obovate to oval (often broadly so) or circular, thin, 1.5 to 2.5 or sometimes 3 dm. long, the younger pale glaucous, the oldest dirty yellow to grayish, and scurfy; leaves subulate, from very short to 10 mm. in length; areoles bearing formidable bristles and short wool, and on the younger joints usually armed with spines, except below; bristles bright reddish brown when young, dirty yellow to brown when older, attaining on old joints a length of 12 mm.; spines brownish red to brown below (often to the middle), pale yellow or dirty white above, faded in age, straight or sometimes curved, somewhat flattened, mostly twisted, rather slender, unequal, 1 to 4.5 cm. long, or sometimes longer, 1 to 5 to an areole, or on the older joints sometimes more, very numerous on joints formed in droughty seasons, erect or spreading, or on old joints reflexed; flowers light yellow, turning darker (reddish) in center, 7 to 9 cm. broad, 8 to 10 cm. long; petals obovate to cuneate, often narrowly so, 2.5 to 4 cm. broad, 4.5 to 5 cm. long, sometimes emarginate, the midrib ending in a minute point; stigma green, usually 7- or 8-lobed, surpassing the stamens; fruit oblong-obovate to obovate, 3.5 to 4 cm. wide, 5 to 8 cm. long, dark purplish red without, the flesh purple and pale green, with a nauseous taste, the large umbilicus more or less depressed in the center; seeds suborbicular, 4 mm. in diameter, buff, with more or less gray on the flat sides.

The plant flowers in April and May and ripens its fruits, which are not proliferous, from August till winter.

The type is no. 619758 in the U. S. National Herbarium.

The species is named for Dr. David Griffiths, of the U. S. Department of Agriculture.

Opuntia reflexa sp. nov.

Plants from somewhat fleshy terete roots, attaining a height of over 1 meter and breadth of over 2 meters, with erect, ascending, and often long prostrate branches; joints obovate to oval, often broadly so, the apex often obtuse or acutish, 1.5 to 3 dm. long, or sometimes longer, the younger gray-glaucous green, the older yellowish or bluish green, and finally dirty yellow or grayish, and scurfy; leaves subulate, from very short to 10 mm. in length; areoles remote, filled with bristles and short wool, unarmed or bearing 1 or 2 or sometimes 3, and on the older joints often a greater number of spines; bristles, when young, yellow to reddish brown, when older pale dirty yellow, often mottled with brown, on old joints widely spreading and attaining a length of 15 mm.; spines, when young, pale yellow, often mottled with brown or red, when older yellowish white, mostly tinged with red at base, much flattened, mostly twisted, usually very slender, unequal, from very short to 5 or sometimes 7 cm. long, usually much or wholly reflexed; flowers opening yellow and soon turning orange, 8 to 10 cm. broad, 8 to 9 cm. long; petals obovate, cuspidate, 3.5 to 4 cm. broad, 5.5 to 6 cm. long, often some of them reflexed; stigma green, usually 7- or 8-lobed, equaling or slightly surpassing the stamens; fruit obovate in outline, about 4 cm. broad and 5 to 6 cm. long, dark purplish red without, purple within, the umbilicus usually centrally depressed; seeds suborbicular to reniform with a prominent raphe, about 3 mm. long, grayish.

Flowering in April and May. The fruit ripens in August and September and is unpalatable and non-proliferous.

The type is no. 619754 in the U. S. National Herbarium.

SAN ANTONIO, TEXAS.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1909-1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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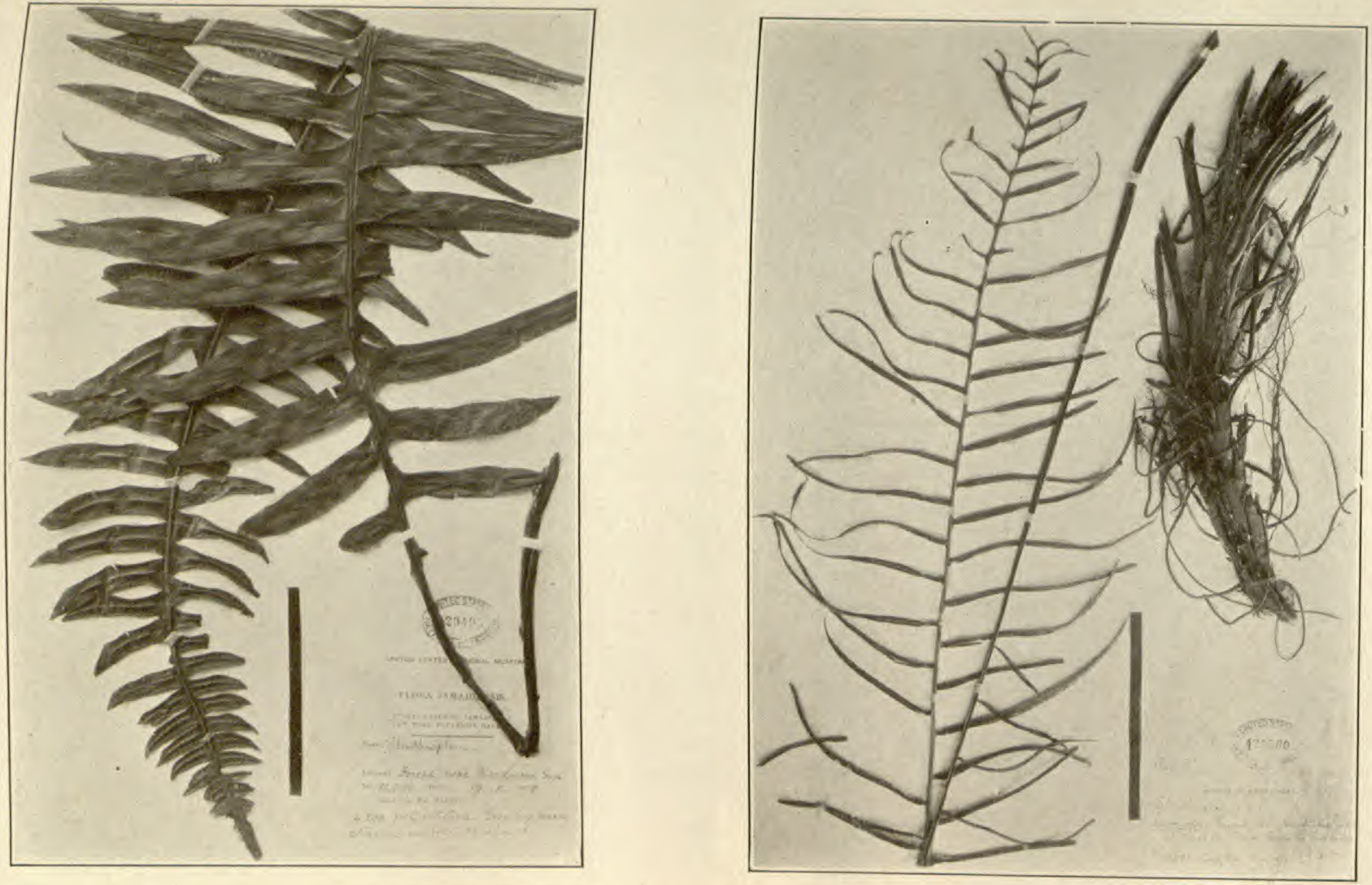

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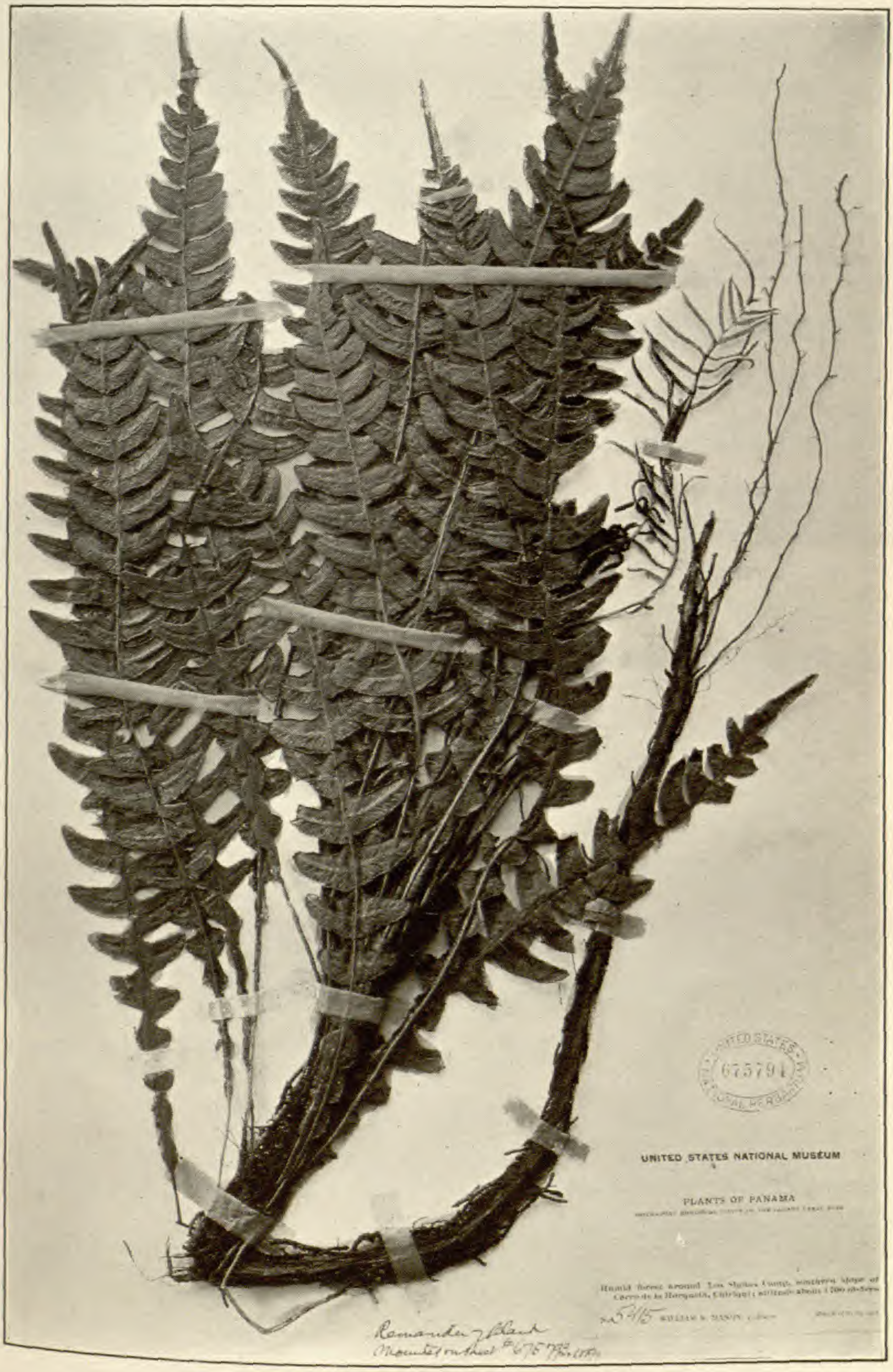

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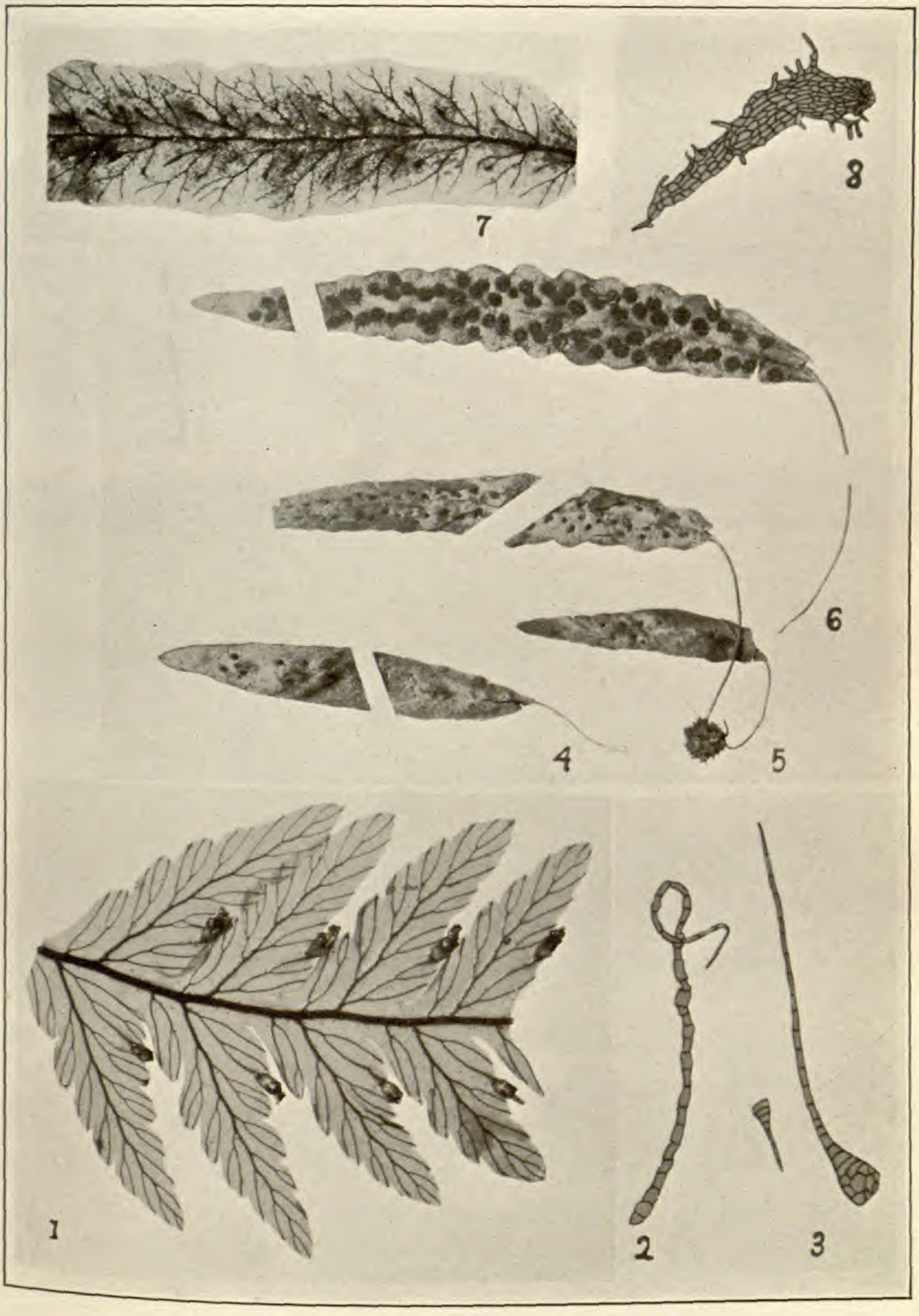

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JULY 1912

Studies on the Rocky Mountain flora—XXVII

PER AXEL RYDBERG

SALICACEAE

POPULUS HASTATA Dode, Extr. Mon. Gen. Populus (Mém. Soc. Hist. Nat. Autun **18**:) 64. 1905

Some years ago we were forced to admit one of Dode's species, *P. Sargentii.* I say forced, because Dode's paper is presented in such an unscientific way that any one might feel inclined to ignore it altogether. His differentiations are based wholly on the leaf forms, and in very few genera do the leaves show so great variation as in *Populus*. In working over Mr. Butler's collection of Montana plants I found numerous specimens of a poplar which has usually been regarded as *P. balsamifera* L., sometimes as *P. trichocarpa* T. & G. A study of the fruit shows that this poplar has the sessile and 3-carpellary fruit and the large involucral cup of *P. trichocarpa*, but the capsule is proportionally longer than in that species and perfectly glabrous. The eastern *P. balsamifera* has evident pedicels and almost always 2-carpellary ovary and much smaller involucral cup. The leaves are usually broader than in *P. balsamifera* and often subcordate at the base. They resemble much those of *P. candicans* Ait. in outline but are perfectly glabrous. *P. candicans* has also pediceled and 2-carpellary capsules. It is apparent that this species represented by Butler's material is *P. hastata* of Dode, for he associated it with *P. trichocarpa* and pointed out just the characters by which it differs from that species. The name *hastata* was given in reference to the

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form of the young leaves, which he described as being hastate. His idea of the term hastate must have been rather strange, for he figured the different leaf forms, and the form of leaf illustrated as representing the young shoots is elongate-ovate with slightly cordate base.

It is represented in the herbarium of the New York Botanical Garden by the following specimens:

ALBERTA: Bow River, May 26, 1899, *McCalla 2236.*

MONTANA: Flathead Lake, July 23, 1900, *J. W. Blankinship;* Columbia Falls, September 14, 1892, *R. S. Williams* (both determined as *P. balsamifera candicans*); various localities in Montana, *Butler 124, 125, 126, 127, 128, 137.* To this may also belong the following, which are in leaf only: *Butler 112, 113, 114, 135, 147.*

IDAHO: Salubria, July 10, 1899, *M. E. Jones 6541* (labeled *P. trichocarpa*).

POPULUS BESSEYANA Dode, loc. cit. 38

Another poplar collected by Butler seems to be impossible to identify with any of the accepted species. Butler's material is all in leaf only, but there is in our collection one specimen collected by Miss Isabel Mulford, in Idaho, which evidently belongs here, and this specimen is in fruit. It is evidently related to *P. deltoides* Marsh., but the leaf shape is different and the pedicels are very short, shorter than the capsule. The young stems are perfectly terete, not at all angled; the bases of the leaves of the mature branches are rounded or subcuneate at the base and more or less serrate along the base; the basal glands are small and the petioles flattened. In *P. Sargentii* Dode the leaves are flabellate-cordate, with an open concave sinus at the base, which is toothless. The leaves resemble much *P. acuminata* Rydberg but are broader and less cuneate at the base, and in the latter species the petioles are terete. I adopt Dode's name, not because I can definitely identify it by his diagnosis but because his illustrations of the leaves resemble those of this species.

To this belong the following specimens:

IDAHO: Fish Haven, August 8, 1898, *Isabel Mulford 263.*

MONTANA: Delta of Flathead River, Big Forks, Montana, August 14, 1901, *Umbach 192;* and from several localities, *Butler 109, 111, 115, 116, 117, 120, 136, 139, 140, 144, 145, 149, 153.*

POPULUS FREMONTII Torr.

The known range of this species was extended last summer, when it was collected by Professor A. O. Garrett and the writer in and around the town of Moab, southeastern Utah; and specimens evidently also belonging to it were seen in the Cottonwood and White canyons about 100 miles farther southwest.

Willow hybrids are not uncommon in Europe and rather common in cultivation; but we find very rarely any references to any spontaneous hybrids of American species mentioned. It will therefore not be out of place to record the following specimens probably representing hybrids, although no definite proof can be given of their origin.

Salix cordata × S. monticola

The shrubs referred here have capsules shorter than in *S. cordata* Muhl. but longer than in *S. monticola* Bebb; the habit and the bark are those of the latter; but the narrow leaves (although less serrate) and the bractlets are those of *S. cordata angustata* (Pursh) Anders., the form of *S. cordata* common in the Rockies. The capsules of the specimens seen usually remained undeveloped. The staminate catkins resemble most those of *S. monticola*. *S. monticola* was growing mixed in with the supposed hybrid. *S. cordata angustata* is also growing in the Big Cotton Canyon, although no specimens of it were noticed in the immediate vicinity where the plants were collected.

UTAH: Big Cottonwood Canyon, below Silver Lake, July 11, 1905, *Rydberg 6877*, *6878*, and *6883;* July 4, 1905, *Rydberg & Carlton 6615*.

Salix glaucops × S. monticola

The specimens resemble *S. glaucops* Anders. in the capsules and bractlets, but the former are less densely hairy; the leaves are more like those of *S. monticola*, being finely serrate, glabrate in age and glaucous beneath; the young branches are somewhat villous. Both *S. monticola* and *S. glaucops* are growing in the Big Cottonwood Canyon.

UTAH: Big Cottonwood Canyon, Salt Lake City County, August 23, 1905, *A. O. Garrett 1671*.

Salix Sandbergii sp. nov.

Bark of the branches reddish chestnut brown, finely puberulent when young; leaves oval or elliptic, 2–4 cm. long, densely white-silky on both sides, grayish above, silvery beneath, entire or nearly so; pistillate aments sessile, naked, about 4 cm. long; bractlets purple, obovate-spatulate, 3 mm. long, white-pilose; capsule glabrous, 4–5 mm. long; stipe about 1.5 mm. long; style about 0.5 mm. long; lobes of stigma short.

The type was distributed as *Salix lasiolepis* Benth., to which it is not at all closely related. The leaves resemble somewhat those of *S. sitchensis* Sanson and *S. bella* Piper, but the capsule is glabrous and the plant belongs to the *S. cordata* group. On account of the white leaves it would be placed next to *S. Hookeriana* Barrett, but the leaves are silky, not villous, and entire, and the aments and capsules are much smaller. It grows on banks of streams.

IDAHO: Valley of Hatwai Creek, April 28, 1892, *Sandberg, MacDougal & Heller 71* (type, in herb. N. Y. Bot. Garden).

The following species of willows are here recorded for the Rocky Mountain region: *Salix erythrocoma* Barrett (*S. arguta erythrocoma* Anderson), *S. lucida* Muhl., *S. Hookeriana* Barrett, *S. conjuncta* Bebb, *S. MacCalliana* Rowley, *S. alexensis* (Anders.) Coville, *S. Barrettiana* Hook., *S. Seemanii* Rydb., *S. Drummondiana* Barrett, *S. arbusculoides* Anders., *S. desertorum* Richards., *S. saskatchewana* Seem., and *S. Fernaldii* Blankinship, from the Canadian Rockies south of the 55° parallel; and *S. conjuncta* Bebb and *S. Fernaldii* Blankinship also from Montana.

ULMACEAE

Celtis rugosa sp. nov.

A tree, 5–10 m. high, with rounded crown; bark gray, corky; twigs brownish, pubescent when young; petioles 6–10 mm. long; leaf blades broadly ovate, oblique, 4–7 cm. long, somewhat cordate at the base, short-acuminate, sharply serrate except at the base and at the apex, coriaceous, dark green, very shiny and slightly scabrous above, brownish or yellowish green, dull, puberulent beneath, strongly reticulate and rugose; pedicels 15–25 mm. long; fruit globose, about 8 mm. in diameter, brownish; style short but evident.

This species is related to *C. reticulata* Torr. but differs in its longer pedicels (in *C. reticulata* 1 cm. long or less) and in its serrate, short-acuminate leaves, which are less pubescent, more shiny, and much less rough above. It grows in gulches and mountain valleys of Colorado.

COLORADO: Golden, Aug. 29, 1895, *P. A. Rydberg* (herb. N. Y. Bot. Garden); Aug. 30, 1895, *C. L. Shear 3263;* gulch west of Pennock's mountain ranch, May 26, 1897, *C. S. Crandall 2254.*

Celtis occidentalis L. is included in the Rocky Mountain flora by Coulter & Nelson,* but erroneously so, the writer thinks. *Celtis Douglasii* Planchon, *C. rugosa*, and perhaps also *C. reticulata* Torr. have been mistaken for it.

URTICACEAE

Urtica strigosissima sp. nov.

Perennial, dioecious; stem 1 m. high or more, glabrous below, strongly retrorsely strigulose above, but almost without bristles; stipules narrowly linear-lanceolate, acuminate; petioles 2–3 cm. long; leaf blades lanceolate, 3–5-ribbed, sharply serrate, rounded or acute at the base, long-acuminate at the apex, 5–10 cm. long, 1.5–5 cm. wide, finely strigulose beneath; flower clusters slender, the upper almost equalling the leaves; sepals ovate, about equalling the achenes.

This species resembles *U. gracilis* Ait. in habit and leaf form, but is more strigose and rarely at all bristly. In pubescence it resembles *U. Breweri* S. Wats. but has narrower leaves and narrowly linear-lanceolate, acuminate, instead of oblong and obtuse, stipules. It grows on river banks at an altitude of 1,000–2,500 m.

IDAHO: Forest, Nez Perces County, July 29, 1896, *A. A. & E. Gertrude Heller 3475* (herb. Columbia University).

Urtica viridis sp. nov.

Perennial with a horizontal rootstock, dioecious; stem 1–1.5 m. high, slender, glabrous or sparingly bristly, round-angled; stipules linear-lanceolate, acuminate, 5–8 mm. long; petioles short, one fifth to one third as long as the leaf blades; these from narrowly lanceolate to ovate, coarsely toothed, 4–10 cm. long, thin, light green, almost glabrous; panicles many-flowered, often equalling the upper leaves: sepals oval or ovate, usually half longer than the achenes.

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* New Man. Bot. Cent. Rocky Mts. 143.

This species is closely related to *U. cardiophylla* Rydb. but differs in its narrower leaf blades, shorter petioles, longer and denser inflorescence, and longer sepals. In habit it closely resembles *U. gracilis* but differs in its practically glabrous stem and thinner and more glabrous leaves.

MONTANA: Emigrant Gulch, Aug. 23, 1897, *Rydberg & Bessey 3935* (type, in herb. N. Y. Bot. Garden); Jack Creek Canyon, July 15, 1897, *3936;* Jocko Creek, June 10, 1901, *D. T. MacDougal 275;* Melrose, July 6, 1895, *P. A. Rydberg 2612;* Lima, Aug. 6, 1895, *Rydberg 2613*.

WYOMING: Halleck Canyon, July 4, 1900, *Aven Nelson 7444*.

IDAHO: Priest Lake, July 28, 1900, *D. T. MacDougal 235;* Cooper's Warm Springs, July 1892, *Isabel Mulford.*

ALBERTA: Rocky Mountains, 1858, *E. Bourgeau.*

Parietaria occidentalis sp. nov.

Annual; stem slender, erect, simple or branched at the base, long-villous, 1–4 dm. high; leaf blades thin, light green, lanceolate, acute at the base, obtuse at the apex, 1–4 cm. long, 5–18 mm. wide, sparingly pubescent; bracts of the involucre linear, obtuse; sepals oblong or lance-oblong, obtuse or acutish.

This species is related to *P. pennsylvanica* Muhl. but differs in the long hairs of its stem, light green color, and the more obtusish sepals. It grows in moist shaded places.

IDAHO: Clearwater River, Nez Perces County, May 14, 1892, *Sandberg, MacDougal & Heller 176* (type, in herb. N. Y. Bot. Garden).

WASHINGTON: Wawawai, May 1897, *Elmer 755;* Alamota, June 1893, *Piper 1507*.

NEVADA: East Humboldt Mountains, August 1868, *S. Watson 1084*.

POLYGONACEAE

Eriogonum biumbellatum sp. nov.

Suffruticose perennial, branched at the base; leaves basal, clustered at the ends of the short branches, 2–5 cm. long, short-petioled; blades oblanceolate, finely tomentose on both sides when young, soon glabrate and green on both sides; scapes 2–3 dm. high, sparingly tomentose; involucres in compound umbels; bracts verticillate, similar to the leaves but smaller; involucres with a turbinate tube, which is about 2 mm. long, slightly tomentose; its lobes oblong, 1.5–2 mm. long, obtuse; perianth yellow, glabrous, 3–4 mm. long, with a stipelike base; divisions elliptic, obtuse, the outer slightly longer than the inner; filaments ciliate; ovary more or less hairy above, 3-angled.

This species is related to *E. umbellatum* Torr., *E. neglectum* Greene (*E. umbelliferum* Small), and *E. croceum* Small. It has the compound inflorescence of the last one, but the leaves are green and glabrate in age and much narrower than in the other species mentioned.

UTAH: Fish Lake around Twin Creeks, August 8, 1905, *Rydberg & Carlton 7376, 7409,* and *7483;* Fish Creek Canyon, August 2, 1909, *A. O. Garrett 2568.*

Eriogonum idahoense sp. nov.

Shrub 4–6 dm. high with gray bark; branches more or less tomentose, erect; leaves 2–3 cm. long, short-petioled; blades oblanceolate, white-tomentose beneath, loosely floccose and soon glabrate above; floral branches about 1 dm. high; inflorescence a compound trichotomous flat-topped cyme; involucres in the axils peduncled; peduncles of the lower forks 1 cm. long; branches of the cymes short, not over 5 cm. long; involucres turbinate, about 3 mm. long, floccose; lobes about 1 mm. long, lanceolate-oblong, obtuse; perianth yellow, glabrous, about 2 mm. long, without stipelike base; fruit unknown.

The type was labeled *Eriogonum microthecum* Nutt., which it resembles in habit, but the flowers are yellow instead of pink or white, and the lobes of the involucres are longer and not scarious-margined. It is more closely related to *E. orendense* A. Nels. and *E. campanulatum* Nutt. From the first it is distinguished by the leaves, which are glabrate above, the tall stem, and the more open inflorescence; from *E. campanulatum* by the tall shrubby habit and the tomentose involucre.

IDAHO: Wieser, July 7, 1899, *M. E. Jones 6511* (type, in herb. N. Y. Bot. Garden).

Eriogonum spathuliforme sp. nov.

Perennial, shrubby at the base, leaves all near the base; petioles 1–2 cm. long; blades elliptic to spatulate, 1–3.5 cm. long, white-tomentose on both sides, densely so beneath; stem scapiform, 2–3 dm. high, trichotomously branched, with ascending branches; bracts triangular, 5 mm. long or less; involucres in the lower forks short-peduncled, the rest sessile, glabrous, turbinate, 3 mm. long; lobes rounded, scarious-margined; perianth white, glabrous, 2–2.5 mm. long, campanulate; divisions equal, obovate; filaments slightly hairy below; ovary glabrous.

In habit and leaf form this species resembles *E. spathulatum* A. Gray, but the involucres are glabrous instead of tomentose, and the lower ones are peduncled; the stem is also perfectly glabrous. It differs from *E. tristichum* Small and *E. salicinum* Greene in its broader leaves and the scarious-margined lobes of the involucre. Jones' specimens are smaller and more cespitose than the type.

UTAH: Sandy washes near Belknap, June 12, 1900, *Stokes* (type, in herb. N. Y. Bot. Garden); Marysvale, August 30, 1894, *M. E. Jones 5969* (?).

Eriogonum depressum (Blankinship) Rydb. comb. nov.

Eriogonum ovalifolium depressum Blankinship, Mont. Agr. Coll. Sci. Stud. Bot. 1: 49. 1905.

Eriogonum rubidum frigidum Gand. Bull. Soc. Bot. Belg. 42: 194. 1906.

Dr. J. K. Small has for some years regarded this as a distinct species, and it is found in the herbarium of the New York Botanical Garden under a manuscript name of his, which, however, was never published.

Eriogonum ramosissimum Eastwood is related to *E. Wrightii* Torr. and does not belong to the *corymbosum* group, to which it was referred.

Eriogonum crassifolium Benth. is the same as the original *E. flavum* Nutt. What Coulter & Nelson and others have regarded as *E. flavum* should be known as *E. chloranthum* Greene. *E. aureum* Nutt. is the same, but the name was first published as a hyponym, and when finally it was properly published there was already an *E. aureum* Jones.

Torrey and Gray, in their revision of *Eriogonum*, described *E. strictum* Benth. as having subequal sepals, and they have been followed by S. Watson and others. Bentham, in his original description of the species, did not mention whether the perianth lobes are equal or not, but in his subsequent treatise of the genus in De Candolle's Prodromus he expressly stated that they are unequal. In the only two specimens found in the herbarium of the New York Botanical Garden, in my opinion belonging to *E. strictum*, the outer perianth lobes are very broadly oval while the inner are oblong. The species should therefore be associated with *E. dichotomum* Dougl. and not with *E. racemosum* Nutt. and *E. Wrightii* Torr., differing from the first principally in the glabrous involucres. Both *E. strictum* and *E. dichotomum* have been collected in Idaho.

The genus *Eriogonum* is represented by over one hundred species in the Rocky Mountain region. The following ones are not recorded either by Coulter & Nelson nor in my Flora of Colorado or in my Flora of Montana, but they should be included in the flora: *E. androsaceum* Benth. in Alberta, Montana, and British Columbia; *E. thymoides* Benth., *E. compositum* Dougl., *E. proliferum* Benth., *E. elatum* Dougl., *E. strictum* Benth., *E. spergulinum* A. Gray, and *E. vimineum* Dougl., in Idaho; *E. dichotomum* in Idaho and Montana; *E. micranthum* Nutt., *E. nidularium* Coville, and *E. Baileyi* S. Wats., in Idaho and Utah; *E. Porteri* Small, *E. pulvinatum* Small, *E. longilobum* M. E. Jones, *E. ochrocephalum* S. Wats., *E. villiflorum* A. Gray., *E. Shockleyi* S. Wats., *E. polifolium* Benth., *E. Thompsonae* S. Wats., *E. aureum* M. E. Jones, *E. spathulatum* A. Gray, *E. leptophyllum* Torr., *E. bicolor* M. E. Jones, *E. clavellatum* Small, *E. sulcatum* S. Wats., *E. Mearnsii* Parry, *E. ramosissimum* Eastw., *E. densum* Greene, *E. turbinatum* Small, *E. insigne* S. Wats., *E. deflexum* Torr., *E. nutans* T. & G., *E. Wetherillii* Eastw., *E. Thomasii* Torr., *E. subreniforme* S. Wats., *E. Parryi* A. Gray, *E. Ordii* S. Wats., *E. trichopodum* Torr., *E. angulosum* Benth., and *E. puberulum* S. Wats., in Utah; *E. Hookeri* in Utah and Wyoming; *E. tenellum* Torr. in Colorado; and *E. depauperatum* Small in the Black Hills of South Dakota.

Chorizanthe spathulata Small sp. nov.

A more or less branched annual; stem 5–20 cm. high, erect, strigose-canescent; branches erect, strict; lower leaves petioled, 1.5–3 cm. long; blades broadly spatulate, somewhat fleshy, hirsute-strigose on both sides, rounded and sometimes mucronate at the apex; stem leaves few, spatulate or oblanceolate, much smaller; bracts linear or linear-oblanceolate, arcuate-recurved, spinulose-tipped; involucre cylindroprismatic, 5 mm. long, angled and grooved, strigose; lobes 6, subulate, recurved, spinulose-tipped, the alternating ones somewhat narrower; perianth about 2 mm. long, lobes ovate; stamens mostly 3 (?); filaments adnate to the lower part of the perianth.

This species is related to *C. brevicornu* Torr., and Torrey and Gray included doubtfully Watson's specimens in that species.* It differs in its broader lower leaves and its strict erect branches.

IDAHO: Big Butte Station, June 23, 1863, *Edward Palmer 230* (type, in herb. Columbia University).

NEVADA: 1875, *J. G. Lemmon;* Big Bend of the Truckee, May 1868, *S. Watson 1044.*

CHENOPODIACEAE

Chenopodium pratericola sp. nov.

Annual; stem 3–6 dm. high, striate and angled, nearly glabrous; leaves petioled; blades oblong, lanceolate, or elliptic, 2–6 cm. long, 4–18 mm. wide, entire or with a short tooth on each side, usually callous-mucronate, green and nearly glabrous above, more or less mealy beneath, usually distinctly 3-nerved at the base; flowers in small clusters forming rather dense spikes or panicles; sepals scarious-margined, green on the back, slightly carinate; seeds easily separating from the pericarp, black, shining, about 1.5 mm. in diameter.

This has been included in *C. leptophyllum* (Moq.) Nutt. by most botanists although sometimes confused with *C. oblongifolium* (S. Wats.) Rydb. on account of its broad leaf blades. It differs from the former in its broader leaves, which are practically glabrous on the upper side, distinctly 3-nerved at the base, and at least the larger ones often toothed on the margins. From the latter it differs in its thin, more glabrate leaves and less dense inflorescence.

KANSAS: Riley County, August 2, 1895, *J. B. Norton 436* (type, in herb. N. Y. Bot. Garden).

NEBRASKA: Middle Loupe River, near Thedford, June 21, 1893, *Rydberg 1386;* Forks of Dismal River, July 11, 1893, *Rydberg 1835;* Kearney County, June 13, 1891, *Rydberg 318.*

MISSOURI: Courtney, June 25, 1896, *Bush 367.*

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* See Proc. Am. Acad. **8**: 196. 1870.

IDAHO: Lewiston, June 13, 1896, *Heller 3244.*

NEW MEXICO: Mesilla, June 3, 1897, *Wooton 84.*

WYOMING: Platte River, July 14, 1894, *Aven Nelson 483;* Snake River, 1900, *C. C. Curtis.*

ARIZONA: 1876, *Palmer 448.*

Chenopodium succosum A. Nels. is in my opinion a synonym of *C. rubrum* L., being the common American form thereof, and *C. desiccatum* is probably only a small form of *C. oblongifolium* (S. Wats.) Rydb.

Chenopodium lanceolatum Muhl. and *C. paganum* Reich., the former an eastern plant and the latter a European weed, both often erroneously known as *C. viride* L., have been collected in Colorado. The original *C. viride* L. is the same as *C. opulifolium* Schrad. of Europe, not known as occurring in this country. *C. viride* and *C. opulifolium* were based on the same illustration.

Monolepis spathulata A. Gray has been collected in Idaho.

Atriplex odontophora Rydb. is not a synonym of *A. canescens* (Pursh) James but of *A. aptera* A. Nels. instead.

Atriplex buxifolia sp. nov.

A suffruticose perennial; stem branched near the base, with simple branches, 3–4 dm. high; leaves sessile, elliptic or oval, thick, 1–2 cm. long; pistillate flowers in axillary clusters; fruiting bracts ovate, acute, 4–5 mm. long, toothed on the margins, with thick, often flattened processes on the faces.

This is related to *A. Nuttallii* but distinguished by its short oval or elliptic, often fascicled leaves, its simple wandlike branches and small fruit. It grows on dry plains at an altitude of about 1,200 m.

WYOMING: Dayton, Sheridan County, September 1899, *F. Tweedy 2656* (type, in herb. N. Y. Bot. Garden).

Atriplex tetraptera (Benth.) Rydb. comb. nov.

Obione tetraptera Benth. Bot. Sulph. 48. 1844.

This has usually been regarded as the same as *A. canescens* (Pursh) James but differs in its narrow, linear leaves, only 2–5 mm. wide, in its more strongly reticulate fruit wings, which have a broad sinus at the apex, and in that the free portion of the bracts is less than half as long as the width of the wing. It differs from *A. occidentalis* Torr. in its narrower and sharply toothed wing.

Atriplex Garretti sp. nov.

A low shrub, with straw-colored branches; leaves short-petioled, oval, 2–3 cm. long, grayish, scurfy on both sides, acute at the base, abruptly acuminate at the apex; flowers in axillary and terminal clusters; bracts about 8 mm. long and about as broad, 4-winged, coarsely toothed and occasionally with a few additional processes, with a broad open sinus at the apex; free portion 1–2 mm. long.

The fruit would associate this species with *A. canescens*, *A. occidentalis*, and *A. tetraptera*, but the leaves are quite different in shape. The plant looks in general habit somewhat like *A. confertifolia*, but the fruiting bracts are altogether different. It grows in arid valleys at an altitude of about 1,200 m.

UTAH: Vicinity of Moab, July 1, 1911, *Rydberg & Garrett 8465* (type, in herb. N. Y. Bot. Garden).

Endolepis phyllostegia (Torr.) Rydb. comb. nov.

Obione phyllostegia Torr. in Wats. Bot. King Exp. 291. 1871.
Atriplex phyllostegia S. Wats. Proc. Am. Acad. [illegible]. 1874.

This species should be transferred from *Atriplex* to *Endolepis*, as sepals are present in the pistillate flowers.

Eurotia subspinosa sp. nov.

A dioecious shrub, 6–10 dm. high; branches ascending or spreading, becoming more or less spinescent, finely grayish stellate-tomentose but without longer hairs; leaves linear or oblong, obtuse, entire, 1–3 cm. long, or the secondary ones only 5 mm. long and comparatively broader, with revolute margins; flower clusters axillary, those of the staminate plant crowded and forming simple leafy spikes; fruiting bracts lanceolate, about 6 mm. long; horns usually about 2 mm. long.

This species is more decidedly shrubby than *E. lanata* (Pursh) Moq. and evidently always dioecious, has ascending or spreading branches, which become spinescent, lacks the long hairs intermixed with the stellate pubescence characteristic of *E. lanata*, and has usually longer horns. In *E. lanata* the branches are erect, and the plant is shrubby only at the base. The predominantly staminate plant has a few pistillate flowers borne on the lower part of the branches. The predominantly pistillate plant has often a few staminate clusters above but is sometimes wholly pistillate. *E. subspinosa* grows on rocky hills in the desert regions.

UTAH: Rocky summits, St. George, May 15, 1903, *Goodding 810* (type, in herb..N. Y. Bot. Garden); 1874, *C. C. Parry 725;* 1875, *E. Palmer;* April 9, 1880, *M. E. Jones 1642;* Virgin River, 1844, *Fremont 440.*

ARIZONA: Fort Verde, October 11, 1887, *E. A. Mearns 188;* Holbrook, August 10, 1897, *Myrtle Zuck;* Total Wreck Mine, 1903, *Thornber 60;* Rincon Mountains, October 7, 1900, *D. Griffiths 1781.*

NEVADA: Thousand Spring Valley, September 1868, *S. Watson 990* (in part); Muddy Valley, Lincoln County, May 6, 1906, *Kennedy & Goodding.*

CALIFORNIA: Mohave Desert, April 1905, *Mrs. C. DeKalb;* Radsburg, April 14, *A. A. Heller 7705;* Red Hill, west of Bishop, May 14, *A. A. Heller 8253.*

SONORA: Genaga di San Bernardino, 1855, *Schott.*

Dondia calceoliformis (Hook.) Rydb. comb. nov.

Chenopodium calceoliformis Hook. Fl. Bor.-Am. **2**: 126. 1838.

This, I think, deserves specific rank. It is characterized from *D. depressa* (Pursh) Britton and *D. erecta* (S. Wats.) A. Nels. by its broad and short, ovate or ovate-lanceolate bracts over 2 mm. wide.

AMARANTHACEAE

Amaranthus pubescens (Uline & Bray) Rydb. comb. nov.

Amaranthus graecizans pubescens Uline & Bray, Bot. Gaz. **19**: 317. 1894.

This probably deserves specific rank. It has been collected in Colorado.

Amaranthus carneus Greene and *A. californicus* S. Wats. should be added to the region. The former has been collected in Montana, and both in Idaho.

PORTULACACEAE

Limnia utahensis sp. nov.

Annual; stem 2–15 cm. long; basal leaves petioled; blades spatulate to linear, 1–3 cm. long, 2–6 mm. wide; stem leaves connate, forming an oblique, 2-lobed disk, 1–2 cm. broad; inflorescence very short, corymbiform; fruiting sepals ovate, acute, 2–3 mm. long, about equalling the pedicels; seeds about 1.5 mm. in diameter, minutely muricate.

This species resembles in habit *L. depressa* (A. Gray) Rydb. and *L. spathulata* (Dougl.) Heller but differs from the former in the long and narrow blades of the basal leaves and more connate stem leaves, from the latter in the large and broad stem leaves, and from both in the large seeds.

UTAH: St. George, 1877, *Palmer 56* (type, in herb. Columbia University); 1874, *C. C. Parry 23* and *24*.

I have not seen the type of *Montia Viae* A. Nels.,* but from the description and specimens named by Professor Nelson I judge it is the same as *Limnia depressa* (Robinson) Rydb.† published a few months earlier.

Coulter and Nelson report *Calyptridium roseum* S. Wats. from western Wyoming, but I think this must be a mistake.

Professor A. O. Garrett and myself collected *Talinum brachypodum* S. Wats. in southeastern Utah. Miss A. Eastwood has reported it from the same region.

ALSINACEAE

Cerastium thermale sp. nov.

Cerastium arvense fuegianum Hollick & Britton, Bull. Torrey Club 14: 50. 1887. Not Hook. 1854.

Cerastium fuegianum A. Nels.; Coult. & Nels. New Man. Bot. Rocky Mts. 184. 1899.

Densely cespitose perennial; stems decumbent at the base, 5–10 cm. long, viscid-puberulent; leaves yellowish green, less than 1 cm. long, lanceolate, acute, or the lower oblong or spatulate and often obtuse, coriaceous, with a very thick midrib, finely viscid-puberulent; cymes 1–7-flowered, usually condensed and with short pedicels; sepals 4 mm. long, glandular-puberulent, ovate, scarious-

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* Bot. Gaz. 42: 48. 1906.

† Bull. Torrey Club 33: 139. 1906.

margined; petals about 5 mm. long; capsule about 6 mm. long, slightly curved near the upper end.

This is *Cerastium arvense fuegianum* Hollick & Britton, but not that of Hooker. It differs from *C. strictum* L., its nearest relative, in the low, depressed stem, yellowish herbage, thicker and smaller leaves, the lower of which are often obtuse, and the smaller more condensed flowers. It grows on geyser formations in the Yellowstone National Park, at an altitude of about 2,000 m.

WYOMING: Lower Geyser Basin, Aug. 4, 1897, *Rydberg & Bessey 4025* (type, in herb. N. Y. Bot. Garden); Aug. 11, 1872, *J. M. Coulter.*

Alsine Palmeri sp. nov.

A cespitose perennial; stems several, spreading, 5 cm. high or less, glabrous; leaves ovate or ovate-lanceolate, 2–5 mm. long, fleshy, acute; cyme 3–7-flowered; bracts lanceolate, green; sepals lanceolate, 2.5–3 mm. long, acute; petals about equalling the sepals.

The type was named *Stellaria borealis* by Dr. Watson but is evidently not closely related to it. *A. Palmeri* has the thick leaves of *A. Edwardsii* (R. Br.) Rydb., but the midribs are not prominent, the flowers smaller, the sepals decidedly acute, and the petals only about equalling the sepals in length.

UTAH: Beaver Valley, 1877, *E. Palmer 54* (type, in herb. Columbia University).

Alsine alpestris (Fries) Rydb. comb. nov.

Stellaria alpestris Fries, Mant. 1: 10. 1832.

Alsine strictiflora Rydb. nom. nov.

Stellaria stricta Richards. Frankl. Jour. ed. 2. App. 15. 1823. Not *Alsine stricta* Wahlenb. 1812.

This is the *Stellaria longipes* of most western reports and of Coulter & Nelson's New Manual. It has a short pod and acute sepals, while the original *Stellaria longipes* Goldie has the pods twice as long as the obtuse sepals. If I am not mistaken the latter is the same as *Stellaria valida* Goodding.

Alsine subvestita (Greene) Rydb. comb. nov.

Stellaria subvestita Greene, Ottawa Nat. 15: 42. 1901.

Arenaria cephaloidea sp. nov.

Somewhat cespitose perennial; stem strict, 2–4 dm. high, glabrous; leaves glabrous, erect, filiform-subulate, 3–10 cm. long; flowers in dense headlike cymes; bracts lanceolate, often 1 cm. long, scarious except the thick midrib, scabrous-ciliolate; sepals similar or somewhat broader, 4–5 mm. long; petals oblong, about half longer than the sepals.

This is related to *A. congesta* Nutt. but differs in its narrower bracts, which are wholly scarious, except the midrib, and scabrous-ciliolate on the margins; also in its larger flowers, stricter stem, and less cespitose base.

WASHINGTON: Spokane, Sept. 10, 1902, *O. Kreager 617* (type, in herb. N. Y. Bot. Garden); Clark Springs, July 17, 1902, *Kreager 100;* Loon Lake, July 20, 1897, *J. B. Winston*; Spokane County, June 27, 1884, *Suksdorf.*

IDAHO: Lake Coeur d'Alene, June and July 1892, *G. B. Aiton;* Little Potlatch River, June 2, 1892, *Sandberg, MacDougal & Heller 478.*

Arenaria lithophila Rydb. comb. nov.

Arenaria subcongesta lithophila Rydb. Mem. N. Y. Bot. Gard. 1: 148. 1900.

This, I think, deserves specific rank. Some of the specimens recorded as *A. subcongesta* (S. Wats.) Rydb. should also be referred to it.

Alsinopsis dawsonensis (Britt.) Rydb. comb. nov.

Arenaria dawsonensis Britt. Bull. N. Y. Bot. Gard. 2: 169. 1901.

This species has been collected in the Black Hills of South Dakota.

Alsinopsis pusilla (S. Wats.) Rydb. comb. nov.

Arenaria pusilla S. Wats. Proc. Am. Acad. 17: 367. 1882.

This species has been collected in Idaho.

Arenaria laxiflora nom. nov.

Arenaria Fendleri diffusa Porter, Syn. Fl. Colo. 13. 1874. Not *A. diffusa* Ell. 1818.

Ammodenia oblongifolia (T. & G.) Rydb. comb. nov.
Arenaria peploides major Hook. Fl. Bor.-Am. 1: 102. 1831.
Honckenya oblongifolia T. & G. Fl. N. Am. 1: 176. 1838.
Arenaria sitchensis Dietr. Syn. Pl. 2: 1565. 1840.

B. T. Butler has collected in Montana what seems to be *Arenaria laricifolia* L. At least it is the same plant as the one collected by Turner on the Porcupine River, Alaska, on the strength of which *A. laricifolia* is included in the American flora.

Sagina occidentalis S. Wats. has been collected in Idaho by Leiberg.

CARYOPHYLLACEAE

WAHLBERGELLA Fries, Bot. Not. 1843: 143. 1843

The treatment of the Silenoid genera of this family has been very different in this country and in Europe. S. Watson and B. L. Robinson admitted only two genera, *Silene* and *Lychnis*, while Pax* admitted beside *Silene* the genera *Lychnis*, *Melandryum*, and *Viscaria*, and Williams† admitted *Lychnis*, *Coronaria*, *Viscaria*, *Eudianthe*, and *Melandrium*. The only distinction given by Watson and Robinson is the number of styles, in *Silene* 3, in *Lychnis* 5, but Robinson admits that in some species of *Silene* the styles are sometimes 4 or 5. The number of styles is therefore not a very reliable character. Continental authors usually differentiate *Silene* from *Melandrium* (by Americans included in *Lychnis*) by the partially septate capsule of the former. According to Robinson this character is unreliable in our American species. Perhaps the species included in *Silene* without septum should be removed to *Melandrium* or to *Eudianthe*. As these doubtful species are not found in the Rockies, I shall give no opinion on them here. It is evident that the genus *Lychnis* as treated in America is an unnatural and composite group. Williams' treatment is perhaps the most logical. Pax included our native American species of *Lychnis* in *Melandrium* but divided the genus in three subgenera. One of these subgenera corresponds to *Eudianthe* with only 3 styles. The other two subgenera correspond to the original species of *Melandrium* and the genus *Wahlbergella* of Fries,

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* Engl. & Prantl, Nat. Pflanzenf. 3: 1*b*: 70, 73. 1889.
† Jour. Bot. 31: 170, 171. 1893.

respectively. The typical species of *Lychnis* have 5-valved capsules with entire valves. In the typical species of *Melandrium* the valves are 2-cleft at the apex. In *Wahlbergella* the valves are also more or less notched. In that respect the species belong rather to *Melandrium* than to *Lychnis*. But the typical species of *Melandrium* are dioecious plants with ample long-exserted petals and of a different habit from that of our native species. These all have hermaphrodite flowers with very small and inconspicuous or even no petals. In my opinion the genus *Wahlbergella* should be taken up for our native species usually included in *Lychnis*. *Lychnis Drummondii* (Hook.) S. Wats. is somewhat different in habit and fruit and was referred to *Elisanthe* by Ruprecht, but I think it can well be included in *Wahlbergella*. Of course *L. striata* Rydb. is closely related to it and should be referred to the same genus, whatever disposition of it is made. The species of *Wahlbergella* in America are as follows:

Wahlbergella Drummondii (Hook.) Rydb. comb. nov.
Silene Drummondii Hook. Fl. Bor.-Am. **1**: 89. 1830.
Elisanthe Drummondii Rupr. Fl. Cauc. **1**: 200. 1869.
Lychnis Drummondii S. Wats. Bot. King Exp. 37. 1871.

Wahlbergella striata Rydb. comb. nov.
Lychnis striata Rydb. Bull. Torrey Club. **31**: 408. 1904.

WAHLBERGELLA TRIFLORA (Vahl) Fries, Summa Veg. Scand. 155. 1845
Lychnis triflora R. Br. Ross. Voy. App. CXLII (hyponym). 1819.
Melandrium triflorum Vahl, in Liebm. Fl. Dan. 14^{40}: 5. 1843.

Wahlbergella Taylorae (Robinson) Rydb. comb. nov.
Lychnis Taylorae Robinson, Proc. Am. Acad. **28**: 150. 1893.

WAHLBERGELLA AFFINIS (Vahl) Fries, Bot. Not. **1843**: 143. 1843
Lychnis affinis Vahl, in Fries, Nov. Mant. **3**: 36. 1842.
Melandrium affine Vahl, in Liebm. Fl. Dan. 14^{40}: 5. 1843.

Wahlbergella montana (S. Wats.) Rydb. comb. nov.
Lychnis montana S. Wats. Proc. Am. Acad. **12**: 247. 1877.

Wahlbergella Kingii (S. Wats.) Rydb. comb. nov.
Lychnis Kingii S. Wats. Proc. Am. Acad. **12**: 247. 1877.

Wahlbergella attenuata (Farr) Rydb. comb. nov.
Lychnis attenuata Farr, Contr. Bot. Lab. Univ. Pa. **2**: 419. 1904.

Wahlbergella Parryi (S. Wats.) Rydb. comb. nov.
Lychnis Parryi S. Wats. Proc. Am. Acad. **12**: 248. 1877.

WAHLBERGELLA APETALA (L.) Fries, Summa Veg. Scand. 155. 1845
Lychnis apetala L. Sp. Pl. **1**: 437. 1753.
Melandryum apetalum Fenzl; in Ledeb. Fl. Ross. **1**: 326. 1842.
Wahlbergella uniflora Fries, Bot. Not. **1843**: 143. 1843.

RANUNCULACEAE

Ranunculus rivularis sp. nov.
Ranunculus repens S. Wats. Bot. King Exp. 9. 1871.

A perennial with a fascicle of fibrous roots; stem hirsute, producing long stolons sometimes over 1 m. long, rooting at the nodes and there producing plantlets; leaves ternate, 5–15 cm. wide, divisions petiolate, ovate, usually truncate or subcordate at the base, 3-cleft and coarsely toothed; petals rounded-obovate, about 4 mm. long, scarcely equalling the sepals; head of fruit globose; achenes glabrous, beaks about one third their length.

The type was determined as *R. repens* L. by Dr. Watson, but is not so closely related to that species as to *R. Macounii* Britton. It was probably on account of the creeping and rooting habit that it was referred to the former. The small petals should at a glance have revealed the error, for in *R. repens* the petals are large and rounded, much exceeding the sepals. *R. Macounii* is occasionally decumbent but not rooting, and the outline of the leaflets or divisions is different and the beak about one half as long as the body of the achenes. My own specimens from Kimball, Nebraska, had stems over 1 m. long. It grows on wet river banks.

NEVADA: Huntington Valley, August 1868, *S. Watson 27* (type, in herb. Columbia University).

ARIZONA: Clark Valley, August 1883, *Rusby.*

NEBRASKA: Kimball, August 12, 1891, *Rydberg 7.*

TEXAS: 1851, *Wright 839.*

Thalictrum columbianum sp. nov.

A plant resembling *T. venulosum* Trelease in habit; stem 3–5 dm. high; leaves 2–4 times ternate, petioled except the uppermost; leaflets rather crowded, thick, and veiny, 1–2 cm. long, cuneate to nearly orbicular, 3-lobed and deeply toothed; inflorescence narrow; achenes oblong- or ovate-lanceolate, somewhat flattened, 4–5 mm. long, 1.5–2 mm. wide; veins strong, but not corky, and with broad and shallow grooves between.

The western specimens referred to *T. venulosum* by Dr. W. Trelease belong to this species, which differs mainly in the structure of the achenes, these approaching those of *T. megacarpum* Torr.

WASHINGTON: Loomiston, August 1897, *Elmer 599* (type, in herb. N. Y. Bot. Garden); Yakima County, 1892, *Henderson 2376.*

IDAHO: Pend d'Oreille River, 1861, *Lyall;* Lake Waha, July 1896, *A. A. & E. Gertrude Heller 3361;* De Lamar, July 7, 1892, *Miss Mulford.*

OREGON: 1886, *Cusick 1337.*

Delphinium Leonardi sp. nov.

A perennial with a tuberous root; stem 2–5 dm. high, viscid-pubescent, especially above; blades of the basal leaves 4–5 cm. wide, dissected into oblong, obtuse divisions, more or less viscid-pubescent; upper leaves with linear, acute divisions; lower pedicels 4–8 cm. long, ascending; sepals dark blue, oblong, obtuse or the upper acute; spur about 2 cm. long, slightly *s*-curved; upper petals whitish, veined with blue, emarginate; lower petals blue, with short lobes; follicles over 2 cm. long, curved, viscid-pubescent or in age glabrate; seeds dark brown, wing-margined.

It grows on river banks and beaches at an altitude of 1,800–2,400 m. It is related to *D. bicolor* Nutt. but differs in its longer spur, which is half longer than the obtuse instead of acute lateral sepals.

UTAH: Garfield, May 30, 1884, *Leonard 205* (type, in herb. N. Y. Bot. Garden); City Creek Canyon, April 21 and May 17, 1883, *Leonard 32* and *24.*

Delphinium coelestinum sp. nov.

A perennial with a short rootstock and strong woody roots; stem 3–5 dm. high, glabrous or slightly pubescent above, leafy; leaves long-petioled; blades about 3 cm. broad, sparingly pubescent, divided to the base into 3–5 narrowly cuneate divisions, these again cleft into linear-oblong, obtuse, mucronate lobes; sepals light blue, slightly pubescent outside, oblong, obtusish, about 1 cm. long; spur about 1 cm. long, usually somewhat curved; upper petals 8 mm. long, yellowish white, slightly lobed; lower petals light blue, with obtusish, wavy lobes; follicles 8–10 mm. long, slightly puberulent, nearly straight.

This species is related to *D. scaposum* but differs in its more leafy stem and in the more deeply dissected basal leaves with narrower segments. It grows in arid places.

UTAH: Southern Utah, 1877, *Palmer 11* (type, in herb. Columbia University).

ARIZONA: 1876, *Palmer 3*.

Delphinium xylorrhizum sp. nov.

A perennial with a stout woody root, related to *D. scaposum* but not at all scapiform; stem 2–3 dm. high, glabrous; leaves petioled, glabrous, fleshy; blades of the basal ones divided into 3–5 broadly cuneate divisions, these cleft and lobed with ovate or rounded lobes; stem leaves with linear-oblong lobes; sepals dark blue, oval, obtuse, pubescent outside; spur stout, about 15 mm. long; upper petals yellowish, about 7 mm. long, slightly cleft, with obtuse lobes; lower petals blue, with sinuate, obtuse lobes; follicles canescent-strigose.

This species differs from *D. scaposum* Greene in its leafy stem and its strigose follicles. It grows on clayey hillsides.

MONTANA: Lima, July 1, 1895, *Shear 3429* (type, in herb. N. Y. Bot. Garden).

Delphinium Helleri sp. nov.

A perennial with a short rootstock and fleshy roots; stem about 3 dm. high, viscid-pubescent throughout, few-leaved; leaf blades 3–5 cm. broad; the lower dissected into linear, obtuse divisions, more or less viscid-pubescent; the upper with narrowly linear, acute divisions; flowers few; the lower pedicels 4–6 cm. long, ascending; bractlets subulate, inserted some distance below the calyx; sepals dark blue, more or less pubescent, oval, about 15 mm. long; spur 2–2.5 cm. long, straight and attenuate; upper petals blue, tinged with yellow only on the lower edge, entire or slightly cleft, lower petals blue, with acute, crenate lobes; follicles viscid-pubescent, nearly straight, 2 cm. long.

This is related to *D. bicolor*, but the upper petals are dark blue and the spur is much longer.

IDAHO: Lewiston, April 1896, *A. A. & E. Gertrude Heller 2951* (type, in herb. Columbia University); region of Coeur d'Alene Mountains, June 24, 1895, *Leiberg 1031*.

Delphinium viscidum sp. nov.

Perennial with a woody root; stem about 3 dm. high, grayish strigose below, densely glandular-viscid above; leaf blades 5–7 cm. broad, densely grayish strigose, dissected into narrowly linear lobes; inflorescence branched; sepals dark blue, 12–15 mm. long, oblong, acute; spur 10–12 mm. long, somewhat *s*-curved; upper petals yellowish, tinged with blue, obtuse, entire; lower petals dark blue, with obtuse, sinuate lobes; follicles densely strigose.

This species is related to *D. multiflorum* and *D. reticulatum*, but the leaves are finely dissected as in *D. Geyeri* and *D. scopulorum*.

WYOMING: Near Tie Siding, July 6, 1896, *Osterhout* (type, in herb. N. Y. Bot. Garden); Evanston, August 1878, *Harry Edwards*.

BRASSICACEAE

Lepidium hirsutum nom. nov.

Lepidium intermedium v. *pubescens* Greene, Bot. Gaz. **6**: 157. 1880. Not *L. pubescens* Desv. 1814.
Lepidium medium pubescens Robinson, Syn. Fl. 1^1: 127. 1895.
Lepidium virginicum subsp. *texanum* v. *pubescens* Thell. Mitt. Univ. Zürich **28**: 230. 1906.

Physaria lanata (A. Nels.) Rydb. comb. nov.

Physaria didymocarpa lanata A. Nels. Bull. Torrey Club **31**: 241. 1904.

This, I think, deserves specific rank, but *P. grandiflora* Blankinship is nothing but the typical *P. didymocarpa*.

Radicula trachycarpa (A. Gray) Rydb. comb. nov.

Nasturtium trachycarpum A. Gray, Bull. U. S. Geol. & Geog. Surv. **2**: 233. 1876.

CHEIRINIA Link, Enum. Hort. Berol. 2: 170. 1822

The type of the genus *Erysimum* (Tourn.) L. is *E. officinale* L., usually known under the name *Sisymbrium officinale* Scop. If the genus which has usually passed under the name *Erysimum* is regarded as distinct from *Cheiranthus*, it must be known under another name. The oldest available name is *Cheirinia*, with *Erysimum cheiranthoides* as the type. As I regard the Rocky mountain species well distinct generically from the wallflower of Europe, I adopt *Cheirinia* as the name for the genus.

CHEIRINIA CHEIRANTHOIDES (L.) Link, Enum. Hort. Berol. 2: 170. 1822

Erysimum cheiranthoides L. Sp. Pl. 661. 1753.
Cheiranthus cheiranthoides Heller, Cat. N. Am. Pl. 4. 1898.

Cheirinia syrticola (Sheld.) Rydb. comb. nov.

Erysimum syrticolum Sheld. Bull. Torrey Club 20: 285. 1893.
Cheiranthus syrticola Greene, Pittonia 3: 136. 1896.

Cheirinia inconspicua (S. Wats.) Rydb. comb. nov.

Erysimum parviflorum Nutt. in T. & G. Fl. N. Am. 1: 95. 1838. Not *E. parviflorum* Pers. 1807.
Erysimum asperum inconspicuum S. Wats. Bot. King Exp. 24. 1871.
Erysimum inconspicuum MacMillan, Metasp. Minn. Valley 268. 1892.
Cheiranthus inconspicuus Greene, Pittonia 3: 134. 1896.

Cheirinia arida (A. Nels.) Rydb. comb. nov.

Cheiranthus aridus A. Nels. Bull. Torrey Club 26: 351. 1899.

Cheirinia aspera (Nutt.) Rydb. comb. nov.

Cheiranthus asper Nutt. Gen. N. Am. Pl. 2: 69. 1818.
Erysimum asperum DC. Syst. 2: 505. 1821.

Cheirinia elata (Nutt.) Rydb. comb. nov.

Erysimum elatum Nutt. in T. & G. Fl. N. Am. 1: 95. 1838.
Cheiranthus elatus Greene, Pittonia 3: 135. 1896.

Cheirinia asperrima (Greene) Rydb. comb. nov.

Cheiranthus asperrimus Greene, Pittonia **3**: 133. 1896.

Cheirinia oblanceolata Rydb. comb. nov.

Erysimum oblanceolatum Rydb. Bull. Torrey Club **31**: 557. 1904.

Cheirinia Bakeri (Greene) Rydb. comb. nov.

Cheiranthus aridus Greene, Pittonia **4**: 198. 1900. Not *C. aridus* A. Nels. 1899.
Cheiranthus Bakeri Greene, Pittonia **4**: 235. 1901.
Erysimum Bakeri Rydb. Bull. Torrey Club **33**: 141. 1906.

Cheirinia argillosa (Greene) Rydb. comb. nov.

Cheiranthus argillosus Greene, Pittonia **3**: 136. 1896.
Erysimum argillosum Rydb. Bull. Torrey Club **33**: 141. 1906.

Cheirinia nivalis (Greene) Rydb. comb. nov.

Cheiranthus nivalis Greene, Pittonia **3**: 137. 1896.
Erysimum nivale Rydb. Bull. Torrey Club **31**: 558. 1904.

Cheirinia radicata Rydb. comb. nov.

Erysimum radicatum Rydb. Bull. Torrey Club **31**: 558. 1904.

Cheirinia Wheeleri (Rothr.) Rydb. comb. nov.

Erysimum Wheeleri Rothr. Rep. U. S. Geog. & Geol. Surv. **6**: 64. 1878.
Cheiranthus Wheeleri Greene, Pittonia **3**: 135. 1896.
Erysimum asperum alpestre Cockerell, Bull. Torrey Club **18**: 168. 1891.
Erysimum alpestre Rydb. Bull. Torrey Club **28**: 277. 1901.

Cheirinia amoena (Greene) Rydb. comb. nov.

Cheiranthus nivalis amoenus Greene, Pittonia **3**: 137. 1896.
Erysimum amoenum Rydb. Bull. Torrey Club **33**: 143. 1906.

Cheirinia Pallasii (Pursh) Rydb. comb. nov.

Cheiranthus Pallasii Pursh, Fl. Am. Sept. 436. 1814.
Cheiranthus pygmaeus Adams, Mém. Soc. Nat. Mosc. **5**: 144. 1817.

Hesperis pygmaeus Hook. Fl. Bor.-Am. 1: 60. 1830.
Erysimum pygmaeum J. Gay, Erysim. Nov. 4. 1842.

Cheirinia brachycarpa sp. nov.

Biennial; stem 3–6 dm. high, from a taproot, grayish canescent, somewhat striate; leaves all linear-spatulate or oblanceolate, 5–10 cm. long, sparingly canescent; the lower petioled and often minutely denticulate, the upper ones mostly entire; sepals oblong, about 1 cm. long, yellowish green; petals nearly 2 cm. long; claw long and slender; blades rounded-obovate, about 7 mm. wide, bright yellow; fruiting pedicels about 8 mm. long, strongly ascending; pods erect, 4–6 cm. long, 2.5 mm. thick; beak about 1 mm. long.

This species resembles *C. oblanceolata*, but the pod is much thicker and shorter and the flowers larger. It differs from *C. aspera* in its ascending, not divergent, and shorter pod. It grows on dry hillsides at an altitude of 2,500–3,000 m.

UTAH: Abajo Mountains, August 17–20, 1911, *Rydberg & Garrett 9713* (type, in herb. N. Y. Bot. Garden, flowers and young fruit); *9765* (well-developed fruit); Cottonwood Canyon, June 27 and July 1, 1905, *Rydberg & Carlton 6333* and *6570*.

Sophia leptostylis sp. nov.

Annual; stem 3–6 dm. high, rather simple below, sparingly stellate-pubescent or glabrous; leaves 3–10 cm. long, obovate in outline, twice pinnatifid, with oblong divisions, sparingly stellate-pubescent; the uppermost reduced and with narrower lobes; flowers numerous; sepals elliptic, yellow, 1–1.5 mm. long; petals spatulate, a little surpassing the sepals; pedicels in fruit 5–8 mm. long, spreading-ascending; pods about 5 mm. long, tapering to each end, nearly erect, somewhat curved; styles 0.5–0.7 mm. long; seeds more or less in two rows.

This resembles somewhat *S. procera*, especially in the form of the pods, but the inflorescence is more open and the pedicels more spreading. It grows at an altitude of 2,000–3,000 m.

UTAH: Big Cottonwood Canyon, July 4, 1905, *Rydberg & Carlton 6629* (type, in herb. N. Y. Bot. Garden); also June 29, *6498*, and July 8, *6806;* Big Cottonwood Canyon, June 1905, *Garrett 1361;* near Milford, June 22, 1905, *Rydberg & Carlton 6283;* mountains north of Bullion Creek, near Marysvale, July 23, *Rydberg &*

Carlton 6283; Fish Lake, August 2, 1909, *Garrett 2578;* Elk Mountains, August 8, 1911, *Rydberg & Garrett 9552;* Head of Dry Wash, August 11, 1911, *9628;* Mount Ellen, July 25, 1894, *M. E. Jones 5684g;* Logan Canyon, June 28, 1910, *C. P. Smith 2226.*

Arabis MacDougalii sp. nov.

Perennial; stem 4–6 dm. high, simple below, densely stellate-pubescent; basal leaves narrowly oblanceolate, 2–4 cm. long, entire or denticulate, densely stellate-pubescent; stem leaves linear or linear-lanceolate, sagittate at the base; sepals oblong, stellate-pubescent; petals white, oblanceolate, 5–6 mm. long; pedicels in fruit reflexed, 5–10 mm. long; pods finely stellate-pubescent, reflexed, 4–5 cm. long, 1.5 mm. wide; seeds in one row.

This species is related to *A. subpinnatifida* but differs in its smaller white petals and its entire leaves.

MONTANA: Old Sentinel, near Missoula, June 12, 1901, *MacDougal 191* (type, in herb. N. Y. Bot. Garden).

NEVADA: King Canyon, Ormsby County, June 4, 1902, *C. F. Baker 986* (referred here doubtfully).

Arabis brevisiliqua sp. nov.

Biennial; stems 3–4 dm. high, sparingly stellate-pubescent below, otherwise glabrous; basal leaves narrowly oblanceolate, 1–2 cm. long, finely stellate-pubescent; stem leaves linear, sagittate at the base, glabrous; sepals scarious-margined, 3 mm. long, glabrous or nearly so; petals purplish, about 6 mm. long; pedicels in fruit 3–5 mm. long, recurved pods 2–3 cm. long, 2 mm. wide, glabrous; seeds in two rows.

This species resembles *A. lignifera* A. Nels., but the pod is much shorter, less than 3 cm. long, with the seeds in two rows, and the sepals are glabrous instead of stellate-pubescent.

BRITISH COLUMBIA: Skagit Valley, July 6, 1905, *J. M. Macoun 70825* (type, in herb. N. Y. Bot. Garden); near international boundary, between Kettle and Columbia rivers, July 16, 1902, *J. M. Macoun 63496.*

ALBERTA: Trail to Lake O'Hara, August 8, 1904, *John Macoun 64517* in part.

Parrya platycarpa sp. nov.

Parrya macrocarpa S. Wats. Bot. King Exp. 14. 1871. Not *P. macrocarpa* R. Br. 1821.

Perennial with a stout caudex; leaves basal, runcinate, more or less glandular-hirsutulous, thick, 6–8 cm. long, oblanceolate in outline; scape 1–1.5 dm. long, glandular-hirsutulous; sepals oblong, 8 mm. long, saccate at the base; petals 15–18 mm. long, purplish; claws long, exceeding the sepals; blades obovate; fruiting pedicels 8–15 mm. long, ascending; pod erect, glandular-hispidulous, 3–4 cm. long, 6–7 mm. wide, acute at both ends, slightly constricted between the seeds, these broadly winged, 3–4 mm. wide.

This is characterized by its deeply lobed leaves, the hispidulous pubescence, the broad hispidulous pod, and the longer narrow petals with slender claws.

UTAH: Uintah Mountains, August 1869, *S. Watson 54* (type, in herb. Columbia University); also August 1889 and Aug. 11, 1890, *M. E. Jones*.

Smelowskia lobata sp. nov.

A densely cespitose perennial; earlier basal leaves cuneate or oblanceolate, merely lobed, with oblong divisions or even some of the earliest entire; the rest of the leaves pinnatifid, densely white stellate-floccose; stem 1 dm. high or less; sepals densely villous, 3 mm. long, ovate, acute; petals white, clawed; blades rounded-obovate; pod glabrous, about 5–6 mm. long, oblanceolate, tapering at the base; style very short.

This species has the pubescence of *S. ovata*, but the pod is tapering at the base. It has whiter and longer pubescence than *S. americana*, and the pod is much shorter. It differs from both in the shape of the earlier leaves.

ALBERTA: Northern Rocky Mountains, *Bourgeau*, Palliser Expedition (type, in herb. Columbia University).

MONTANA: Midvale, June 28 and July 9, 1903, *Umbach 206* and *325*.

MACKENZIE: *Richardson* (Franklin's Journey).

Draba pectinata (S. Wats.) Rydb. comb. nov.

Draba glacialis pectinata S. Wats. Proc. Am. Acad. **23**: 260. 1888.

This has been confused with *D. andina* Nutt. and *D. densiflora* Nutt., but it is easily distinguished by the leaves. They are scarcely stellate-pubescent, merely strongly ciliate on the margins and with an incurved tip. In the other two species the leaves are densely stellate-pubescent and their tips not incurved but spreading. The pods of *D. andina* and *D. pectinata* are nearly the same, but that of *D. densiflora* is larger and more elongated.

Nelson, in the New Manual of the Central Rocky Mountain Region, cited *Draba uber* A. Nels., *D. aureformis* Rydb., and *D. decumbens* Rydb. as synonyms of *D. luteola* Greene. The species he described under that name is evidently *D. aurea* Vahl, of which *D. uber* apparently is a synonym. *D. luteola* and *D. aureformis*, on the contrary, are closely related to *D. surculifera* A. Nels. but have light yellow flowers. A "conservative" botanist would unite the three. *D. decumbens* Rydb. is not closely related to either. Very likely Professor Nelson had not seen a specimen of the last named.

Fortunately, *Draba lapilutea* A. Nels. and *D. yellowstonensis* A. Nels. become synonyms of *D. praealta* Greene. *Draba deflexa* Greene has erroneously become *D. reflexa* in the New Manual.

NEW YORK BOTANICAL GARDEN.

Discoid gemmae in Radula

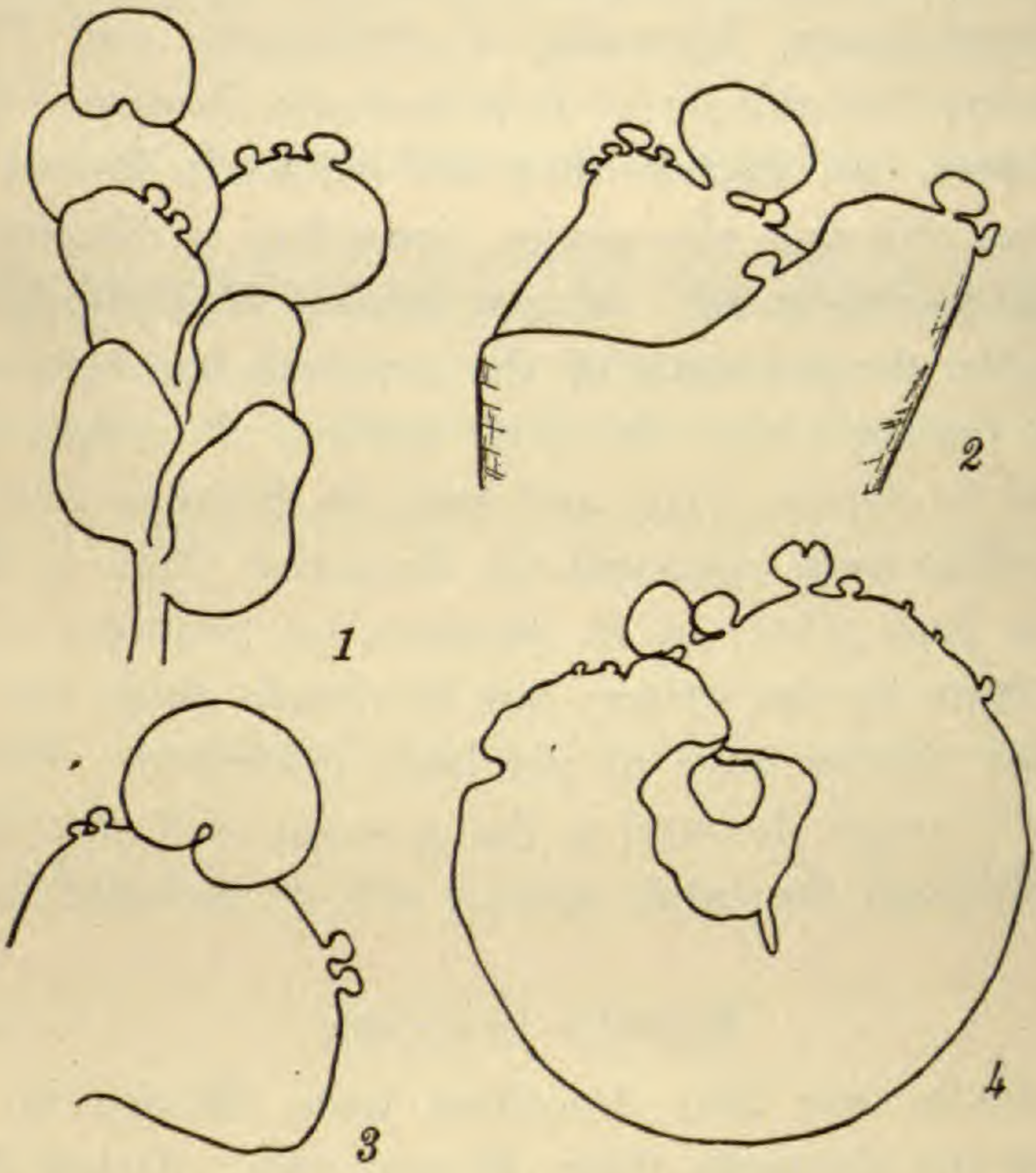
RUTH WILLISTON

Discoid gemmae, borne on the margins or surface of the leaves or on the thallus, have been reported in the following twelve genera of the Jungermanniales: *Metzgeria*, *Radula*, *Porella*, *Metzgeriopsis*, *Colurolejeunea*, *Diplasiolejeunea*, *Cololejeunea*, *Leptocolea*, *Aphanolejeunea*, *Lejeunea*, *Cyclolejeunea*, and *Frullania*. (See Evans, '04, '10, and '11.) It is probable, however, that they occur in others. In *Radula* they are definitely known in only seven species, although the genus, according to Stephani ('10), contains 220 species in all. In two species, *R. Hedingeri* and *R. tjibodensis*, the development of the gemmae has been carefully studied by Goebel ('87). A third species, *R. complanata*, was investigated by Cavers ('03) and later by Stevens ('10). In *R. flaccida* gemmae were observed by Gottsche ('63), in *R. Lindbergiana* by Jack ('81), in *R. protensa* by Schiffner ('93), and in *R. subtropica* by the writer; but no details about the gemmae in these four species have as yet been published. The present paper will be largely devoted to the gemmae of *R. flaccida* and *R. protensa*, although the other species will be included in the discussion.

RADULA FLACCIDA

This species was first described from Mexico in 1847 by Lindenberg and Gottsche (Syn. Hepat. 726). It has since been found widely distributed throughout the West Indies and the lowlands of tropical America. The material used in this study was collected by Dr. A. W. Evans at Bath, Jamaica (no. 332). *R. flaccida* is a dioecious species with a prostrate stem. It is epiphyllous. The gemmae are disklike bodies, one cell thick, attached to the dorsal margins of the leaves. They are the largest and most highly differentiated gemmae known in the genus, averaging at maturity 0.5 mm. in diameter, while the leaves themselves measure only 0.8 mm. in length. The cells nearest the center of the gemmae are the largest, averaging 0.02 mm. in diameter.

Toward the periphery they decrease gradually in size, those at the very edge averaging about 0.01 mm. Gemmae occur in this species on leaves of vegetative branches (FIG. 3), on male bracts (FIG. 1), on the margins of old perianths (FIG. 2), and on other gemmae (FIG. 4). Gemmae occurring on leaves or bracts were most numerous along the acroscopic margins, and in no case were gemmae found on the lobules of the leaves. There is apparently some relation between the stage of development of a vegetative branch and its capacity to produce gemmae, for the gemmae are rarely found on young plants. The fact that gemmae are never found on the youngest leaves indicates, however, that their production does not absolutely limit the growth of the shoot. When a branch produces gemmae at all, they generally occur on several of the leaves. A leaf may produce gemmae singly or in groups. In the latter case two or three gemmae are usually found together,

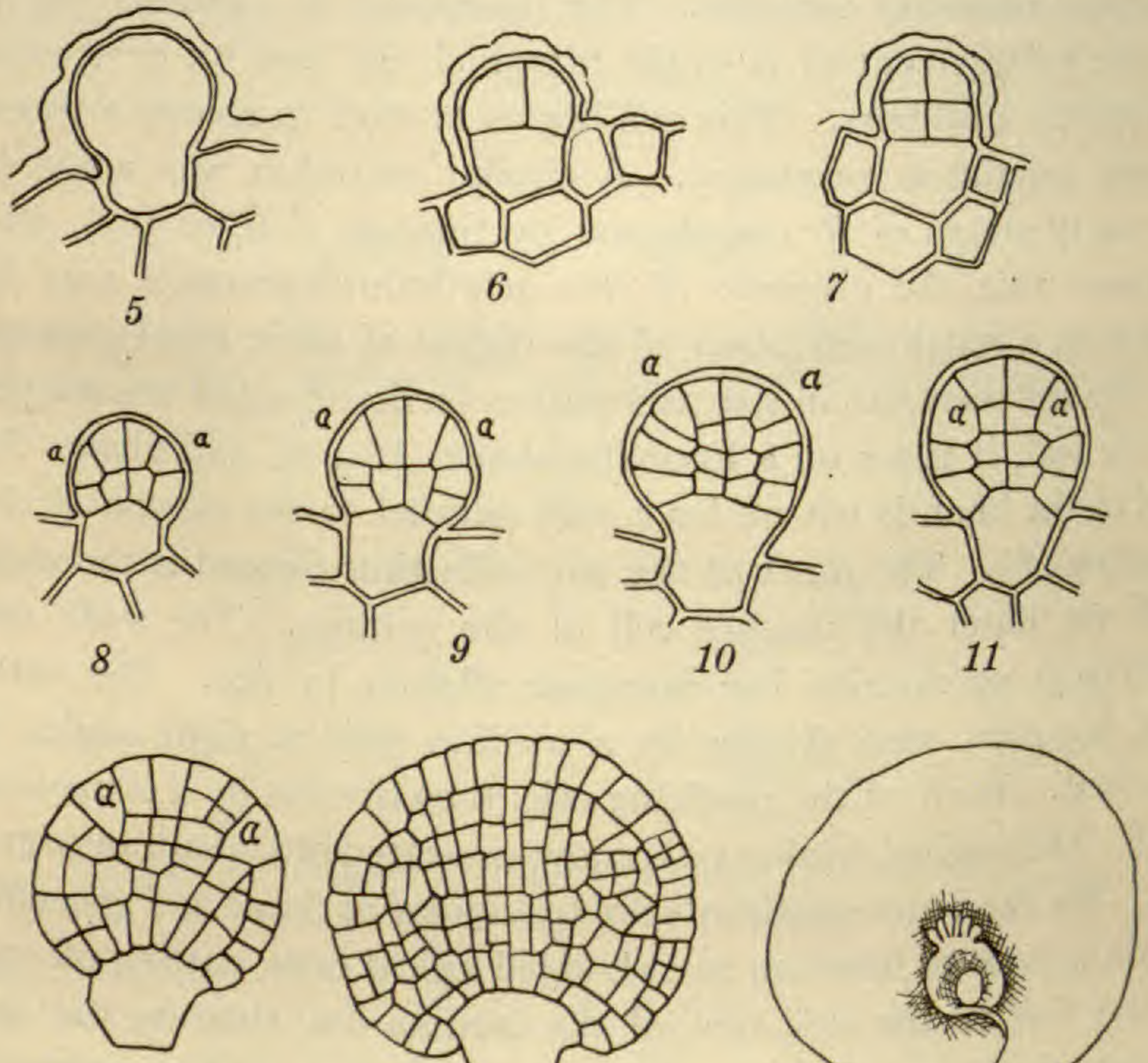


FIGURES 1–4. *Radula flaccida*. 1, male bracts and proliferation of antheridial branch bearing gemmae, ×266. 2, old perianth bearing gemmae, ×66. 3, normal vegetative leaf with gemmae, ×266. 4, small gemmae growing on the margin of a mature gemma, ×66.

though groups of seven or eight may occur. In instances where more than one are produced on a single leaf, usually only one matures, and the others either become abortive or delay their development until the first one is shed.

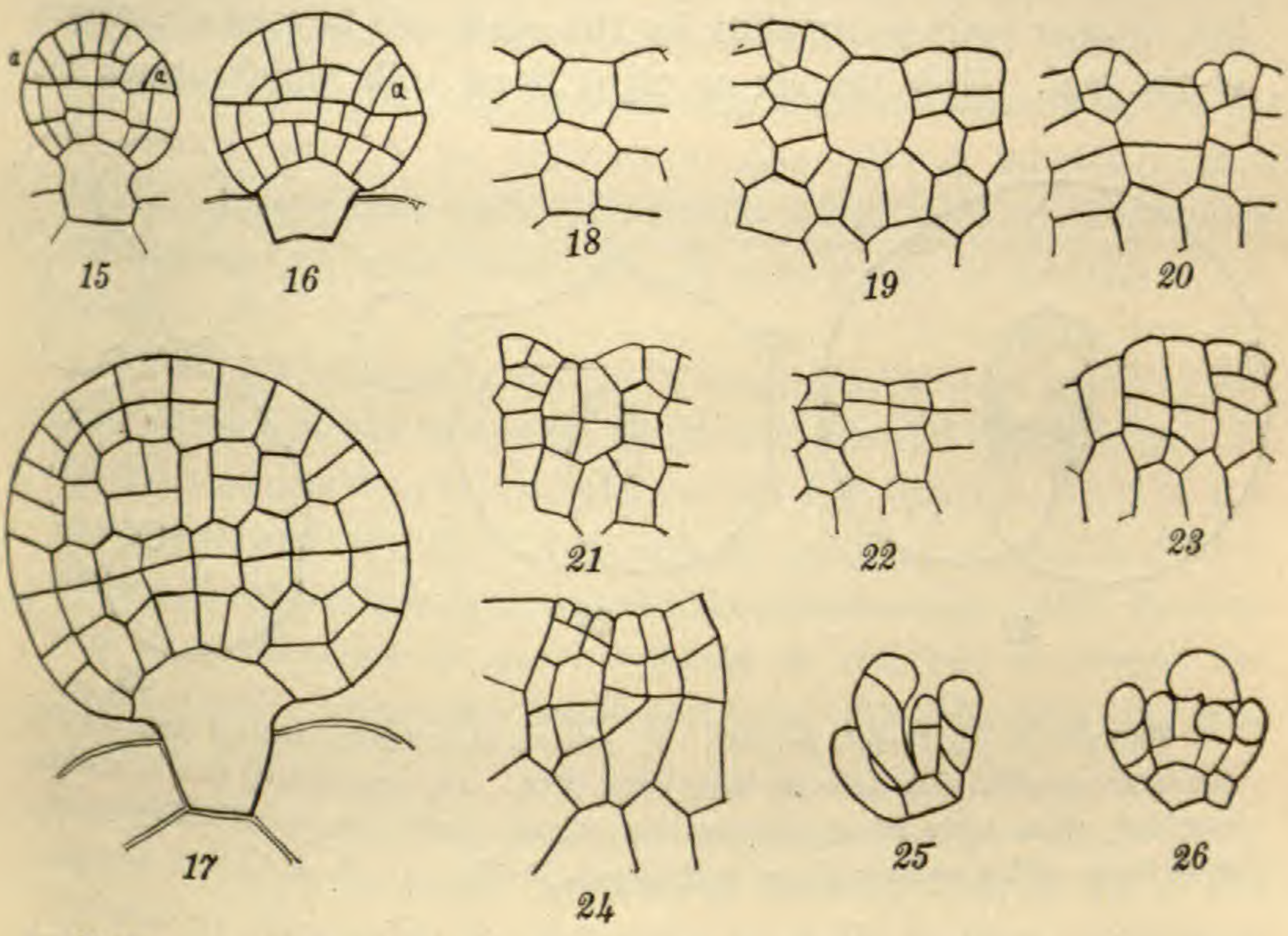
In the development of the gemmae the sequence of cell division can be traced accurately only in the earlier stages, as with the increasing complexity of the gemmae the order of cell formation becomes somewhat variable. The formation of a gemma begins by the enlargement of a single marginal cell and its protrusion beyond its neighbors. This cell begins at once to secrete a transparent gelatinous substance. A similar secretion was noted in the early stages of *R. complanata* by Stevens ('10, p. 369), who suggests that the presence of this gelatinous substance may be taken as a rough indication of the region of most rapid growth. As this cell increases in size and pushes farther beyond the margin of the leaf, it takes on a knoblike shape (FIG. 5), and finally the end of the knob is cut off by a wall parallel to the margin of the leaf (FIG. 6). The inner of the two cells thus formed is the stalk cell, the outer the mother cell of the gemma. The stalk cell undergoes no division but increases slightly in size. The outer cell, however, soon divides by a median wall at right angles to the first. Each of the resulting cells then divides by a transverse wall. The original mother cell is now separated into quadrants (FIG. 7). The two outer quadrants are triangular in shape and generally begin at once to function as two-sided apical cells, cutting off segments first on the side toward the median line then on the side toward the lower quadrant, and so on until three or four segments have been formed (FIG. 8, 9, 10, 11, 12). The earlier segments divide first by periclinal walls and later by anticlinal walls, so that by the time the last segment is cut off by the apical cell the first may have divided into as many as six or eight cells. The apical cells both cease to function after a short time; and instead of cutting off segments in the normal way each divides by a periclinal wall followed by an anticlinal wall in the peripheral cell, thus giving rise to three cells.

The establishment of the apical cells is not always simultaneous on the two sides of a single gemma. The original triangular quadrant on one side or both may cut off an extra cell parallel to the median wall before the apical cell becomes established. In case the two apical cells of a single gemma behave differently, there is an asymmetrical development of the gemma. If one apical cell becomes established before the other, it usually but not always ceases to function before the other; so that it is common to find a gemma with one apical cell cutting off a segment in the normal way while the other has already divided by a periclinal wall (FIG. 17). The same condition was observed in *R. complanata* by Stevens ('10, p. 370). This irregularity in the manner of establishment of the apical cell makes it possible to distinguish three types of gemmae: those in which the original apical quadrants begin immediately to function as apical cells (FIG. 9, 10, 11), those in which the apical quadrants cut off cells parallel with the



FIGURES 5–14, *Radula flaccida*. Gemmae in various stages of development from single cell stage to the mature form. 5–7 show the gelatinous substance *m* and early divisions, ×400. 8–12 show the apical cells *a*, ×400. 14, mature gemma with funnellike elevation and basal cells, ×66.

median wall before beginning to function as apical cells (FIG. 15), and those in which the establishment of the two apical cells is not simultaneous (FIG. 16). In any case the shape and size of the two sides of the gemma are not noticeably affected (FIG. 16 and 17). The two lower quadrants of the gemma mother cell do not produce apical cells but divide by longitudinal walls followed by transverse walls. After the apical cells in the upper half of the gemma cease to function, the whole gemma increases in size by the same method of cell division, followed by the inner or lower half from

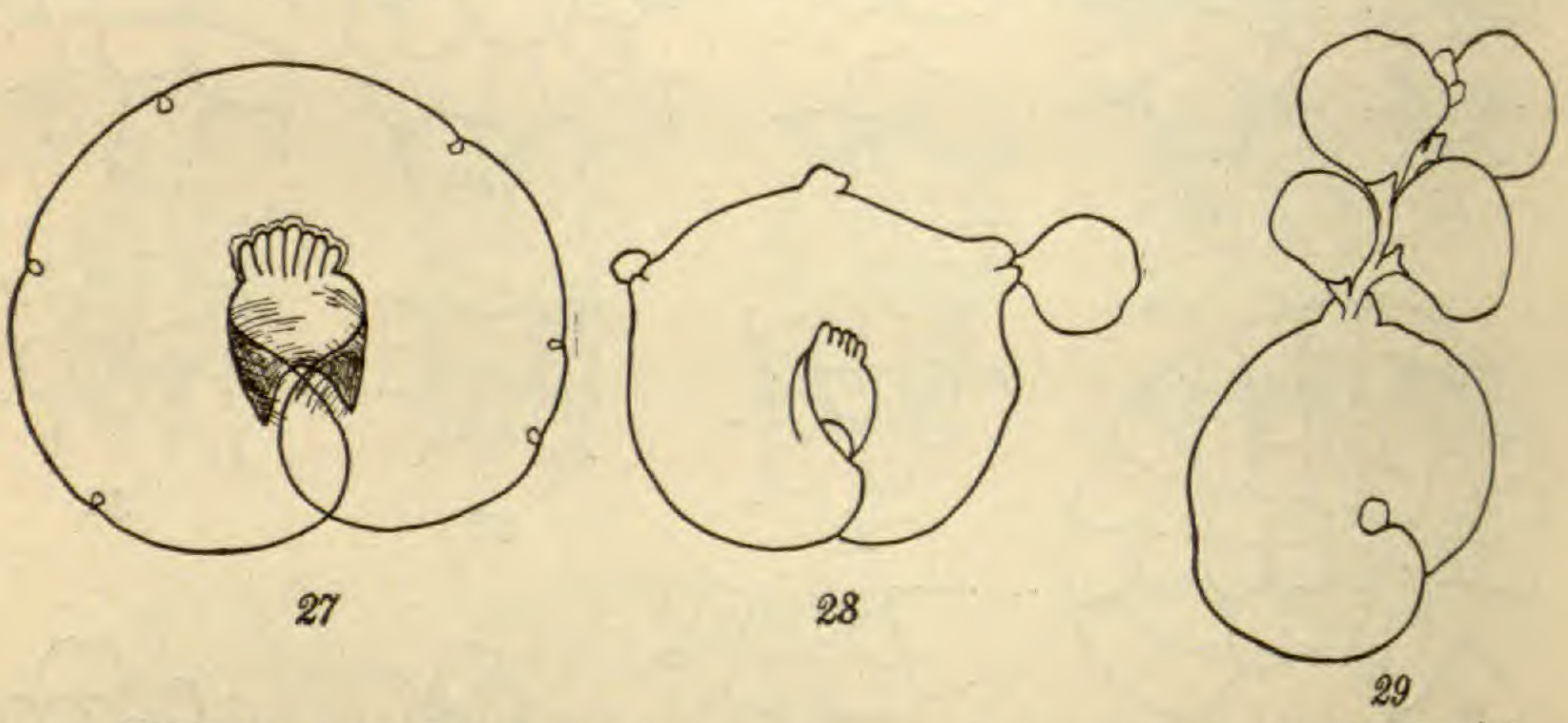


FIGURES 15–26, *Radula flaccida*. Gemmae with irregularities in the formation of the apical cells. 15, gemma which has cut off a segment on each side toward the median line before the apical cell has begun to function, ×400. 16, gemma in which the development of the two apical cells is not simultaneous, ×400. The apical cell on the left was formed from the original triangular quadrant, cut off one segment toward the median line, and ceased to function. The apical cell on the right was formed from the outer half of the original triangular quadrant and is still functioning. 17, gemma in which the apical cell on the left has ceased to function, while that on the right is still cutting off segments, ×533. 18 and 19 show the method of the development of the marginal cell, which later produces the leafy shoot, ×400. 20–22, stages in development of the leafy shoot from a single marginal cell, ×400. 23 shows a variation in the sequence of cell division, ×400. 24, dorsal view of later stage in development of the leafy shoot, ×533. 25 and 26 show the leafy shoot, ventral view, developing in dextrorse and sinistrorse spirals, ×800.

the beginning, each cell dividing by longitudinal walls followed by transverse walls; but as the gemma grows older the order of cell division is reversed, and the transverse walls are formed first and the longitudinal later.

In *R. Hedingeri* Goebel reports ('87, p. 52) that there are no apical cells whatever, and the gemma mother cell divides by a series of longitudinal walls between which transverse walls are formed.

Soon after the apical cells cease to function, the gemma begins to change its position and shape. Up to this time it has been a flat circular body protruding by the stalk cell beyond the margin of the leaf. Now the six or eight basal cells which attach the gemma to the stalk begin to grow, especially in length, and curve upwards so that they stand at right angles to the leaf. As this change in position takes place the cells adjacent to the large basal cells begin to divide and grow very rapidly, and to curve outward in such a way that the gemma again becomes parallel with the leaf surface but raised above it by a funnel-shaped tube. A short time before the gemma is mature several large cells become differentiated at intervals along the margin (FIG. 27). These vary in number from three to eight, but there are usually five. Each one arises through the enlargement of one of the peripheral cells, while the adjoining peripheral cells divide by periclinal walls



FIGURES 27–29, *Radula flaccida*. 27, gemma at maturity, ventral view, showing the large marginal cells and the basal cells, ×66. 28, germinating gemma showing one leafy shoot more advanced than the others, ×266. 29, germinating gemma, later stage, with a well-developed leafy shoot, ×266.

(FIG. 18 and 19). If the growth and division of the neighboring cells are very rapid, the large cell may appear in a temporary depression, but it soon increases in size so that the mature gemma shows no marginal indentations (FIG. 27).

After the large cells are fully differentiated, the gemma is shed. Shedding takes place by means of a splitting between the stalk cell and the long basal cells (FIG. 16). This splitting is probably caused by a gelatinization of the walls in this region. The stalk cell does not come off with the gemma, as it does in *R. complanata*, but remains a part of the leaf, as in the two species studied by Goebel ('87, *f. 61*). Cell divisions are now at an end until germination takes place, but the gemma may increase slightly in size by the enlargement of its individual cells. When mature it is a slightly concave disk with a funnellike outgrowth near the center and with the six large basal cells often adhering to the edge of the funnel.

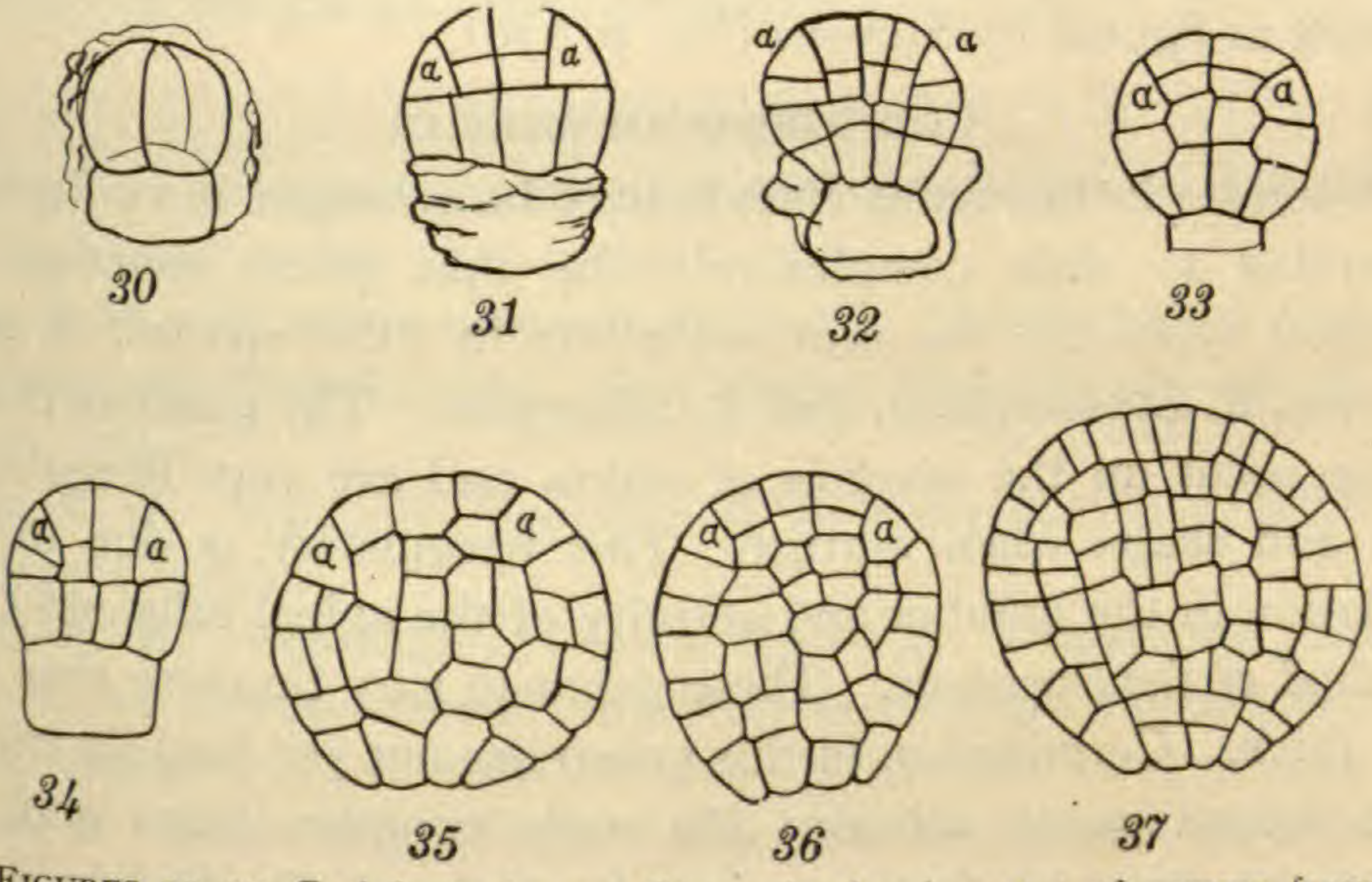
All the germinating gemmae in this material were found on the lower surface of the leaves on which the plants were growing. It seemed remarkable that the spaces on the upper surface of the leaves were entirely free from isolated gemmae or young plants. After a gemma comes to rest with its concave side down, the first step in germination is the formation of rhizoids to anchor the young plant. These are developed from the cells near the periphery where the tissue comes in contact with the substratum. The rhizoids consist of short prolongations of the cells, with irregular lobes at the apex. According to Goebel ('87, p. 53, *f. 66*) the similar rhizoids in *R. Hedingeri* probably secrete a gelatinous substance by means of which they adhere to the substratum.

When the gemma is firmly anchored, the five large peripheral cells (FIG. 19) begin to divide (FIG. 20–23). The first wall is always periclinal, and the inner cell thus formed gives rise to the young shoot. The outer cell, as well as the neighboring cells, proceeds to divide and form a tissue which protrudes beyond the margin of the gemma (FIG. 20). This thalluslike body protects the tiny shoot coming out on the ventral side of the concave gemma. The sequence of divisions in the inner cell of the original peripheral cell is very complicated and difficult to follow; but a tetrahedral apical cell is soon formed, the divisions of which correspond to those described by Leitgeb ('79) for the vegetative shoots of *R. complanata*, the cell cutting off segments on three sides only. The fourth face, which does not cut off segments, is the free one of the apical cell and lies toward the apex of the branch. Each segment cut off by a lateral face divides into two cells, an external cell and an internal cell. The external cell gives rise to the two lobes of the leaf and the cortical cells of the stem, while the internal cell by further division forms the axial cells of the stem. The segments cut off by the ventral face never form leaves but give rise to cells of the stem only. The three faces of the apical cell cut off their segments in spiral sequence, but the spiral may be either dextrorse or sinistrorse (FIG. 25 and 26).

RADULA PROTENSA

Lindenberg first described *R. protensa* from Java in 1848 (Meissner, p. 462). It is a tropical species native to Asia and various islands of the Pacific. The material used in this study was collected by Lamberto Loria in New Guinea (no. 114). *R. protensa* agrees with *R. flaccida* in being epiphyllous and prostrate. The gemmae are smaller than in *R. flaccida*, averaging only 0.2 mm. in diameter at time of shedding. It is possible, however, that the gemmae examined had not attained their full size, in spite of the fact that cell division had apparently ceased. In this species gemmae occur on vegetative branches and on male bracts. Schiffner ('93, p. 249) reports them also on the margins of old perianths. They are most commonly found scattered over the ventral surface of the leaves or along the margins and stand at right angles to the surface. They usually appear in groups, a single leaf sometimes bearing fifty or more in various stages of development.

As in *R. flaccida* the development of the gemma begins by the protrusion of an ordinary leaf cell. This cell, however, unlike that of *R. flaccida*, may occur in the surface of the leaf or in the margin. It also becomes covered with a much heavier covering of gelatinous material than is found in *R. flaccida*. The outer half of the cell is then cut off by a transverse wall. This division forms the stalk cell, which does not project beyond the surface of the leaf, and the gemma mother cell, which soon divides into quadrants. The early walls are very delicate and scarcely show through the surrounding gelatinous layer. As the gemma increases in size it breaks through this sheath, which remains clinging to the base like a collar (FIG. 30). In the further development of the gemma the two apical quadrants function for a time as two-sided apical cells. As described for *R. flaccida*, the stage at which the apical cell becomes established and the stage at which it ceases to function vary. There is no curving or change in position in this gemma as is noted in *R. flaccida;* and at the time of shedding, the gemma is a circular body, one cell thick, slightly concave, but without any funnel-shaped outgrowth similar to that of *R. flaccida*



FIGURES 30–37. *Radula protensa.* Stages in development of gemma from the two-celled stage until the apical cell ceases to function, ×400. 30–32 show the stalk cell and the gelatinous sheath.

(FIG. 14). Shedding takes place by means of a splitting of the wall between the stalk cell and the basal cells. The stalk cell remains as a part of the leaf. The form of the gemma when shed is almost identical with that of the mature gemma of *R. Hedingeri.* Soon after shedding, the basal cells begin to elongate. On account of lack of germinating material it was impossible to trace the further development of the gemma. However, a few gemmae were found in which the marginal cells halfway between the basal cells and the apex, on one side or the other, were dividing and growing, apparently beginning to form a thalluslike outgrowth. So far as could be determined, there were no enlarged cells functioning as differentiated peripheral growing points, and no gemmae were found in which the leafy shoot had begun to appear. Several young plants showed thalloid fragments clinging to them, but it was impossible to determine in any of these cases whether the fragment was a part of the gemma itself, as in *R. flaccida*, or part of a thallus such as is formed in *R. Hedingeri*.

RADULA LINDBERGIANA AND RADULA SUBTROPICA

R. Lindbergiana, a species native to Europe, Asia, and Algeria, first described by Gottsche in 1864, and *R. subtropica*, native to Brazil, and described by Stephani in 1910, were also studied. In these the gemmae were essentially the same as those of *R. complanata* as figured by Stevens ('10, p. 370).

COMPARISON OF SPECIES

Gemmae in the genus *Radula* may be arranged in two groups according to their complexity. The first group contains the simplest types and has representatives in three species, *R. complanata*, *R. Lindbergiana*, and *R. subtropica*. The gemmae in this group occur on the margins of leaves and are very irregular in size and shape when mature. This irregularity is due to the variation in the number and activity of the apical cells and their method of development. These gemmae may be more than one cell thick. Germination in this group has not yet been described. The second group contains the more complex types and has representatives in four species, *R. protensa*, *R. Hedingeri*, *R. tjibodensis*, and *R. flaccida*. These gemmae occur not only on the margins but also on the surface of leaves and follow a more regular course of development, the mature gemmae in a given species being uniform in shape and size. In *R. flaccida* and *R. protensa* apical cells are present, but *R. Hedingeri* and *R. tjibodensis*, while developing after a fixed plan, do not, according to Goebel ('87, p. 62), possess any apical cells. All the gemmae belonging to this group are only one cell thick. Germination in this group may be divided into two categories. In the gemmae of *R. Hedingeri*, and *R. tjibodensis*, as described by Goebel, the procedure is as follows: The circular gemma develops at some point on the margin a thalluslike body as large as the gemma itself. One of the marginal cells of this thalloid outgrowth in turn gives rise to the leafy shoot, but by the continued growth of the tissue adjoining this marginal cell the shoot later appears to arise from the central part of the thallus. The second type of procedure is seen in the germinating gemmae of *R. flaccida*. In this species from five to eight differentiated peripheral growing points immediately give rise to the apical cell of the shoot. The formation of a thallus-like body preliminary to this stage seems to be suppressed. The growth of the outer peripheral cell and its adjoining cells in *R. flaccida* to form a thallus, corresponds to the growth of the thallus in *R. Hedingeri* after the differentiation of the apical cell of the shoot. *R. protensa* probably belongs to the first category and germinates according to the procedure followed by R. *Hedingeri*.

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Notes on the genus Widdringtonites

EDWARD W. BERRY

(WITH PLATES 24, 25)

It is the fashion among a large proportion of botanical students either to ignore or actually to deride botanical determinations based upon the remains of the foliage of fossil plants. While this is perhaps justified in some instances by the sanguine determinations of some paleobotanists, particularly those who might with propriety be referred to as the "fathers" of this as yet young science (such men as Unger, Heer, and Ettingshausen), the real importance of their work is generally underestimated.

The careful description and illustration of a fossil flora is of immense importance even if seventy-five per cent of the identifications are wrong, and for the following reasons: For the purpose of correlating distant geological formations fossils are theoretically almost as useful unnamed as named, or at least they would be if there were some medium for intellectual exchange that did not require names.

To illustrate their value to the botanist I will take the case of A who describes the flora of the Cretaceous or Tertiary of Bohemia, misidentifying half of his species. B studies the Cretaceous or Tertiary flora of Greenland and finds a number of specimens like A's types. Several of B's specimens are better preserved, or are represented by more material, or have attached fruits or seeds, thus enabling B to correct some of A's wrong determinations. C studies the Cretaceous or Tertiary flora of America or Asia and in a like manner corrects or substantiates beyond cavil some of A's or B's determinations. Thus in time we come to know A's original flora and are enabled to make many deductions regarding phylogeny, climate, and distribution, which would be entirely impossible if A had waited until he had his species represented by flowers, fruits, and seeds, which would probably have been never.

I have assumed that foliage remains are not capable of unequivocal identification but this is far from being the case in most instances. I did not start, however, to write a plea for paleobotanists, but with the purpose of describing some rather exceptional coniferous material from the Upper Cretaceous of this country, which serves to substantiate a generic determination made years ago by that most sagacious and illustrious of paleobotanists, the late Professor Oswald Heer.

The genus *Widdringtonites* was established in 1847 by Endlicher* with *Thuites gramineus* Sternberg from the Tertiary of Perutz, Bohemia, as the type. This he named *Widdringtonites Ungeri*, including in its synonymy *Juniperites baccifera* Unger, *Thuia graminea* Brongniart, and *Muscites Stolzii* Sternberg. Three additional species were listed, one from the Cretaceous, one from the Wealden, and one from the Lias. His characterization of the genus was as follows: "Folia spiraliter inserta, pleraque squamaeformia adpressa. Strobilus globosus, valvatus."

There are perhaps a score of species, ranging in age from the Triassic to the Miocene, that are referred to this genus at the present time. It has been commonly used for foliar specimens that resembled the living forms but lacked the certainty furnished by associated cones. These are known, however, in a large number of species, many of which, especially those of Tertiary age, are now often referred directly to the genus *Widdringtonia*.

Named originally for its resemblance to the living species of *Widdringtonia* of southern Africa and Madagascar, it is to be noted that in the latest treatment of the modern Cupressineae, by Eichler in Engler and Prantl's Die Natürlichen Pflanzenfamilien (1889), *Widdringtonia* is made a subgenus of *Callitris* Ventenat, the latter being divided into four subgenera as follows: *Octoclinis* F. v. Müller (*Frenela* Bentham) with eight scales to the cone and a single species inhabiting Australia; *Hexaclinis* (*Frenela* Mirbel) with six scales to the cone, 3 large and 3 small, and nine species of Australia and New Caledonia; *Pachylepis* Brongniart (*Widdringtonia* Endlicher) with thick woody cones of four subequal scales and having three or four species of South Africa and Madagascar; *Eucallitris* Brongniart (*Tetraclinis*) with four scales to the cone and a single species of northern Africa.

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* Endlicher, Synopsis Coniferarum 271. 1847.

However admirable this arrangement may be when only the living species are considered, it will not answer for the fossil forms, and paleobotanists quite rightly maintain the various genera *Frenelites, Frenelopsis, Widdringtonia, Widdringtonites, Callitris,* etc., ranging in age from the older Mesozoic through the Tertiary and abundantly fortified by fruiting specimens. Fossil fruits of still other species and perhaps genera occur in the late Tertiary formations of Australia, the weight of the evidence showing that this type was considerably more varied in the past, the existing forms being isolated remnants of a once almost worldwide distribution.

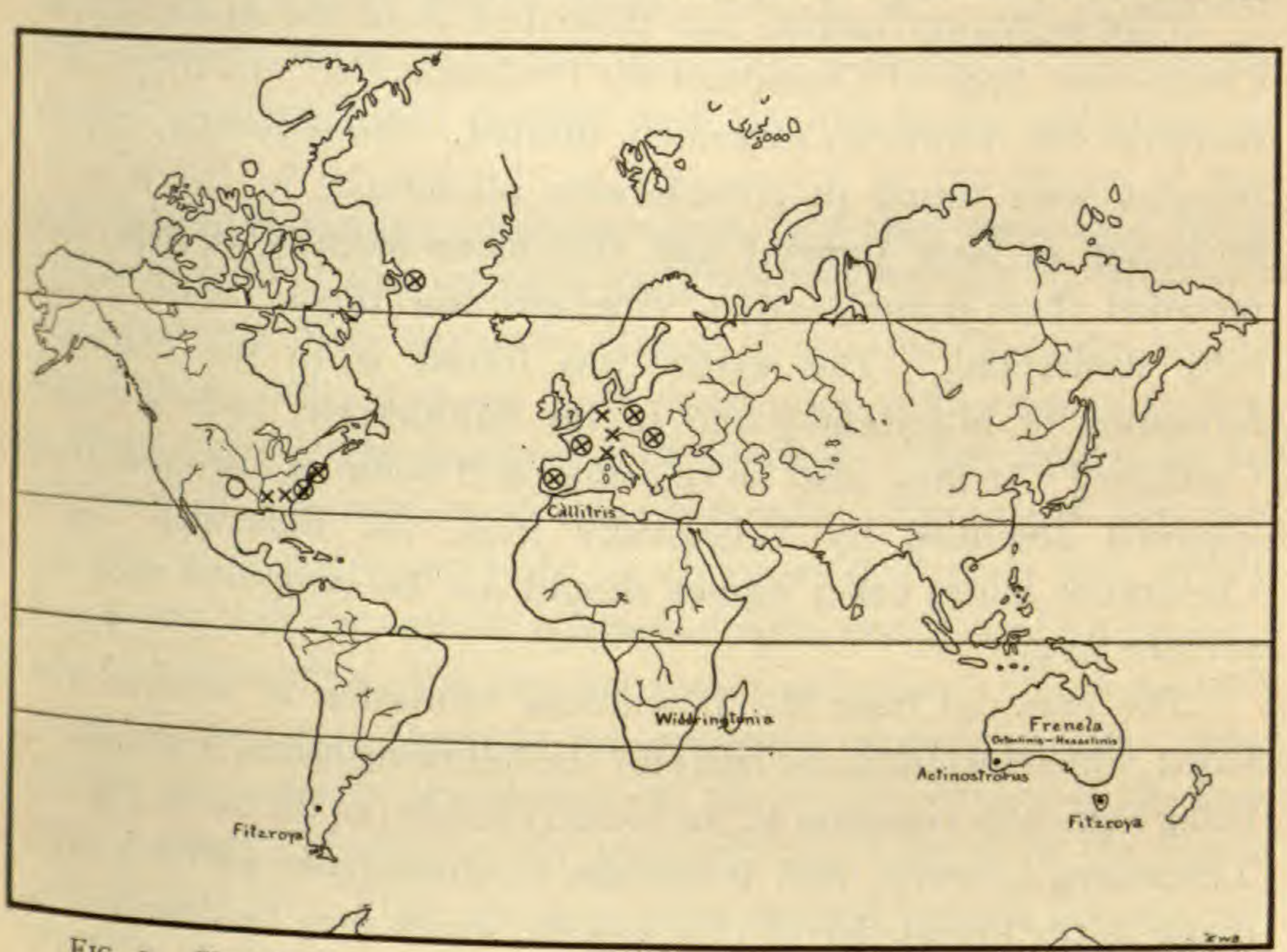

FIG. 1. Sketch map of the world showing the segregation of the existing Actinostrobinæ and the Mesozoic occurrences of *Frenelopsis* and *Widdringtonites.* Circles indicate *Frenelopsis* and crosses indicate *Widdringtonites.*

The accompanying sketch map of the world partially indicates the former wide range of these forms. It is incomplete in that it shows only the reported occurrences during the Mesozoic age and does not include the numerous Cenozoic records. It will be seen that *Widdringtonites* is recorded in North America from western Greenland southward to Alabama and *Frenelopsis* from Greenland to Texas. Abroad both types occur abundantly in central and western Europe. Like so many other types of plants which were widespread in Mesozoic time, they became more and more restricted in their range during the Tertiary, until today they are not found at all in the western hemisphere and are confined to the limited areas indicated on the accompanying sketch map (FIG. 1).

If we refer only to the Cretaceous forms of *Widdringtonites* there are four species in the Neocomian, one in the Barremian, one in the Albian, three in the Cenomanian, and one in the Senonian.

Widdringtonites subtilis was described from the Atane (Upper Cretaceous) beds of Greenland by Professor Heer* in 1874. His material was, however, extremely limited. Subsequently, similar remains were found in considerable abundance in the Raritan formation of New Jersey,† and still more recently Hollick‡ has recorded them from Marthas Vineyard and Block Island (Magothy formation). The writer has found it in the Magothy formation of Maryland § and in the Middendorf beds of South Carolina.‖ It may also be questioned if some of the coniferous material described by Velenovsky from the Bohemian Upper Cretaceous under other names should not be compared with the present form.

The material from the Tuscaloosa formation of western Alabama, which furnishes the basis for the following notes, is abundant, being especially common at the locality known as the Snow Place in Tuscaloosa County; and it enables a considerable addition to be made to the knowledge of this species, which may be described as follows:

Foliage more or less dimorphic, very variable in this respect. Leaves, especially those on the young twigs, arranged in a crowded spiral, small and pointed; the inner surface comparatively flat and bounded laterally by sharp, somewhat thickened angular edges, the outer side broad, full, and rounded. The young leaves are crowded and relatively short, broad, and appressed, the short incurved pointed tips giving them the appearance of being rounded

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* Heer, Fl. Foss. Arctica 3^2: 101. *pl. 28. f. 1, b.* 1874.

† Newberry, Fl. Amboy Clays 57. *pl. 10. f. 2–4.* 1896.

‡ Hollick, Mon. U. S. Geol. Surv. **50**: 45. *pl. 4. f. 2–5.* 1907.

§ Berry, Johns Hopkins Univ. Circ. New series 7: 81. 1907.

‖ Berry, Bull. Torrey Club **38**: 421. 1911.

apically (see FIG. 1 and 2). These leaves are not so short and broad as they appear in FIG. 1, 3, 4, 5, since in these specimens the entire leaf substance, except the cuticularized epidermis, has disappeared, and they are much flattened. The older leaves usually become elongated proximad and somewhat spreading and falcate distad, with a considerable decurrent base as shown in FIG. 2. The leaves on twigs of the year are about 1.5 mm. in length while those on old twigs are about 2 to 3 mm. in length. Along their lateral angles the former bear minute spines, which increase in size and length distad (FIG. 3, 3*a*). The epidermal cells are small, about 0.025 to 0.0333 mm. in diameter, the longest diameter approximately parallel with the axis of the leaf, more or less regularly rectangular in outline except at the angles of the leaf and in the vicinity of the stomata, and they have very thick yellowish walls. The stomata are about 0.0333 mm. in diameter and show two thick, generally almost closed, nearly white, blunt-ended guard cells, without fixed orientation with respect to the different pairs or the major axis of the leaf. They appear to lie just beneath the surface of the epidermis. The guard cells are surrounded by a ring of five or six accessory epidermal cells, which are smaller than the regular epidermal cells, nearly uniform in size, and with their inner walls thinner than their outer. These appear to be on the same level as the ordinary epidermal cells. The stomata are sparsely scattered over the major portion of the leaf but are usually absent or but sparingly represented in the distal half of the leaf. They are somewhat massed toward the base on the sides of the leaf.

The position of the stomata on the leaf shown in FIG. 5 is indicated in the enlarged drawing which forms FIG. 5*a*. The degree of spreading or appression of the leaves varies from specimen to specimen, due, I suppose, in some measure to the conditions attending fossilization. A form with uniformly slender and spreading leaves is common at Shirley's Mill, Fayette County, Alabama.

In his discussion of this species Professor Newberry mentions a vague cone about one cm. in diameter as included in the Raritan material from New Jersey. I have not seen this specimen, but I have found a number of poorly preserved detached cones among the abundant remains of this species in the Upper Cretaceous beds of South Carolina. A number of specimens from the Tuscaloosa formation have these cones attached to the characteristic twigs of this species (PLATE 24, FIG. 2). These cones are terminal, roughly spheroidal in outline, and apparently consist of four thick scales with wide blunt tips and somewhat extended bases. They are 7 to 9 mm. in length and 4 or 5 mm. in diameter and are closely comparable to the cones from the Cretaceous of eastern Europe ascribed to *Widdringtonites Reichii* by both Velenovsky[*] and Krasser.[†] One of the best preserved of these attached cones from Alabama is shown enlarged ten times in FIG. *2a*.

So far as I know, the only previous description of stomatal or epidermal characters in fossil species of the genus *Widdringtonites* refers to species preserved in the Baltic amber, which is of Tertiary age and some millions of years younger than the species just described. One of these species, *Widdringtonites oblongifolius* Goeppert and Menge, is extremely close to the Cretaceous species *Widdringtonites subtilis* Heer not only in its general facies but in the details of its epidermal characters. As described recently by Caspary,[‡] the chief difference is the more elongated leaf bases, a feature that is always of extreme variability in this genus, and even within the limits of a single species, as is well shown by the specimens of *Widdringtonites subtilis*, which are figured in the present connection.

Although so little has been published that refers to *Widdringtonites*, several authors have described the somewhat similar epidermal characters in the allied extinct genus *Frenelopsis*. Thus Zeiller[§] described these features for the type of the latter genus, *Frenelopsis Hoheneggeri* Schenk, in 1882, and Velenovsky[‖] described the very similar *Frenelopsis bohemica* in 1888. Recently the present writer described[¶] these features in *Frenelopsis ramo-*

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[*] Velenovsky, Gym. Böhm. Kreidef. 27. *pl. 8. f. 4–6; pl. 10. f. 1, 11, 12.* 1885; Sitz. K. Böhm. Gesell. Wiss. **1886**: 639 (6). *pl. 1. f. 14–16.* 1887.

[†] Krasser, Beitr. Paläont. Ost.-Ung. u. Orients **10**: 126. *pl. 14* (4) *f. 6; pl. 17* (7). *f. 4, 7, 8.* 1896.

[‡] Caspary, R. Abh. K. Preuss. Geol. Landesanstalt. Neue Folge, Heft 4. **1906**: 66. *pl. 9. f. 52–53c* (see especially *f. 53a, b, c*).

[§] Zeiller, Ann. Sci. Nat. Bot. VI. **13**: 231. *pl. 11.* 1882; Elements de Paleobotanique 274. *fig. 196.* 1900.

[‖] Velenovsky, Sitz. K. Böhm. Gesell. Wiss. **1888**: 590. *f. 1–3, 10.* 1888.

[¶] Berry, Bot. Gaz. **50**: 305–309. *f. 1, 2.* 1910.

sissima Fontaine, a Lower Cretaceous species of eastern North America.

In all of these three species the epidermal cells are small, more or less rectangular, and thick-walled, as they are in *Widdringtonites subtilis*. The stomata consist of a ring of from four to six radially arranged and more or less elevated guard cells. These cells are represented in *Widdringtonites subtilis* by the ring of accessory epidermal cells shown in FIG. 6, which occupy the same level as the rest of the epidermis, while lying below this level are the two stout guard cells.

Frenelopsis ramosissima differs from the other two species of *Frenelopsis* previously mentioned in having certain of the epidermal cells spined, and *Widdringtonites subtilis* Heer curiously resembles *Frenelopsis ramosissima* in that the epidermal cells along the lateral angles of the leaf have more or less developed small spines, which increase in length and size distad, as shown in FIG. 3*a* and 5*a*.

A consideration of the sum of the known characters in the genera *Widdringtonites* and *Frenelopsis* leads to the conclusion that they are surely related.

The combination of similar foliage, similar four-valved cones; and similar epidermal and stomatal features in *Widdringtonites* and *Widdringtonia* render certain the reference of the Upper Cretaceous species *Widdringtonites subtilis* Heer to what represented the modern subfamily Cupressineae during the Cretaceous.

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Explanation of plates 24, 25

PLATE 24

FIG. 1. From a photograph of a specimen from the Tuscaloosa formation at Big Gully, Snow Place, Tuscaloosa County, Ala., natural size.

FIG. 2. Another specimen from the same horizon and locality, showing a number of poorly preserved attached cones.

FIG. 2*a*. One of the cones from the specimen shown in FIG. 2, enlarged ten times.

PLATE 25

FIG. 1. From a photograph of a small terminal twig which was much flattened during fossilization, enlarged five times.

FIG. 2. Drawing of a twig showing the dimorphic character due to the elongation of the leaves on the older twigs, enlarged five times.

FIG. 3. Microphotograph of a leaf showing the indistinct outlines of the epidermal cells and the spinous character of the distal margins, enlarged ten times.

FIG. 3*a*. Drawing of the distal part of the preceding specimen showing the spines, enlarged 50 times.

FIG. 4, 5. Microphotographs of two additional leaves, enlarged ten times.

FIG. 5*a*. Drawing in outline of the specimen shown in FIG. 5, to show the location of the stomata, enlarged 50 times.

FIG. 6. Drawing of one of the stomata and the adjacent epidermal cells, enlarged 205 times.

FIG. 7, 8. Drawing to show the character of the epidermal cells, enlarged 205 times.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1908-1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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A plant from Mexico.

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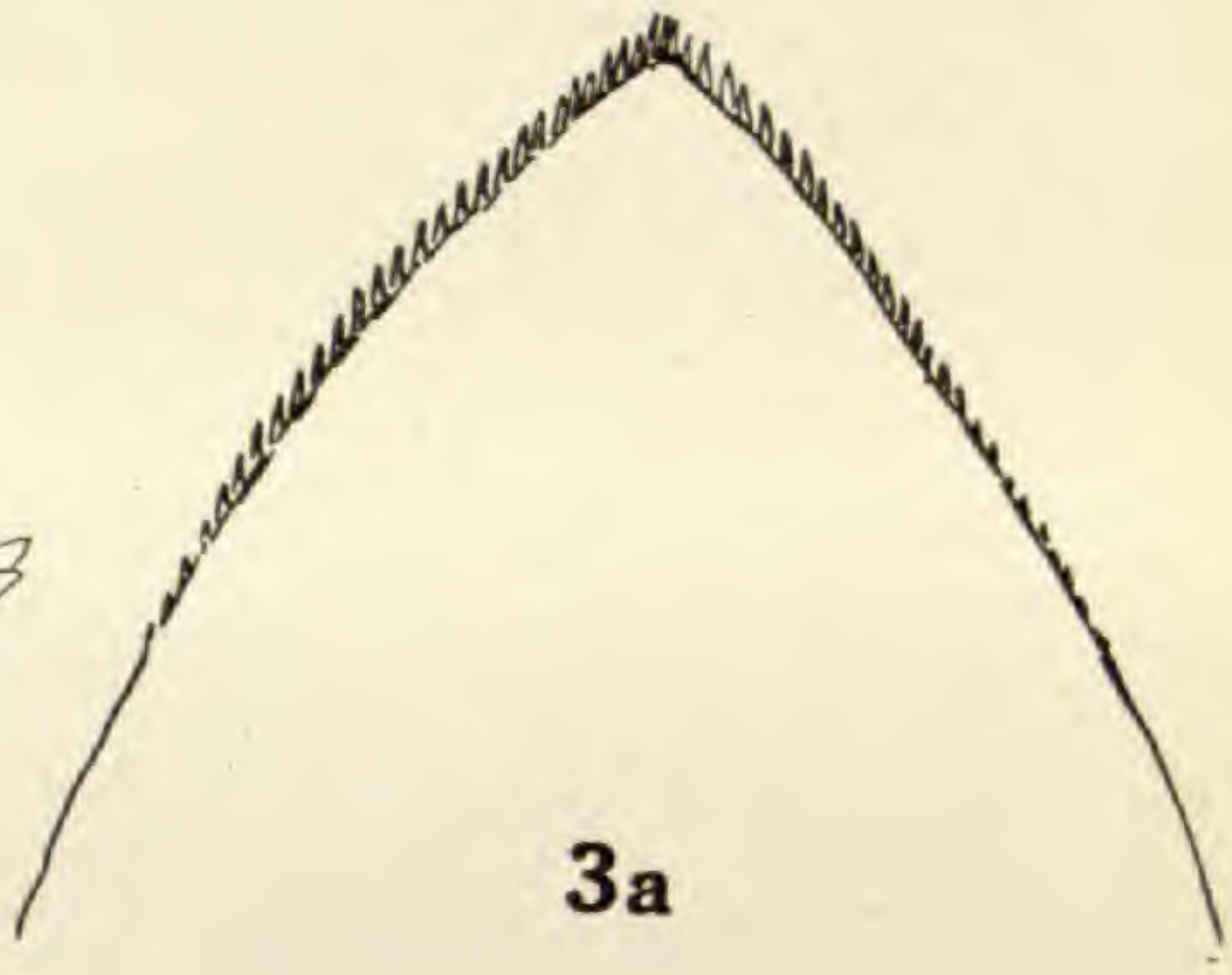

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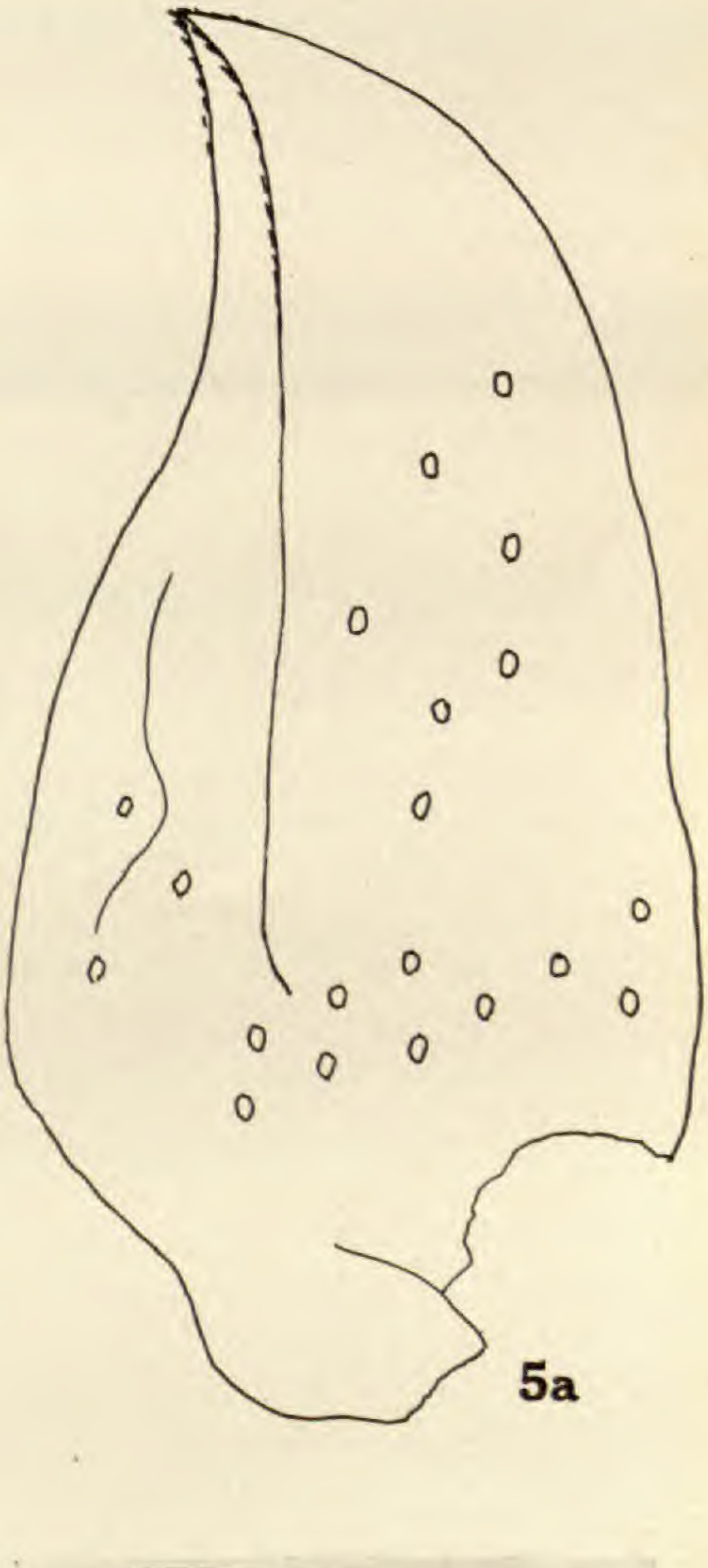

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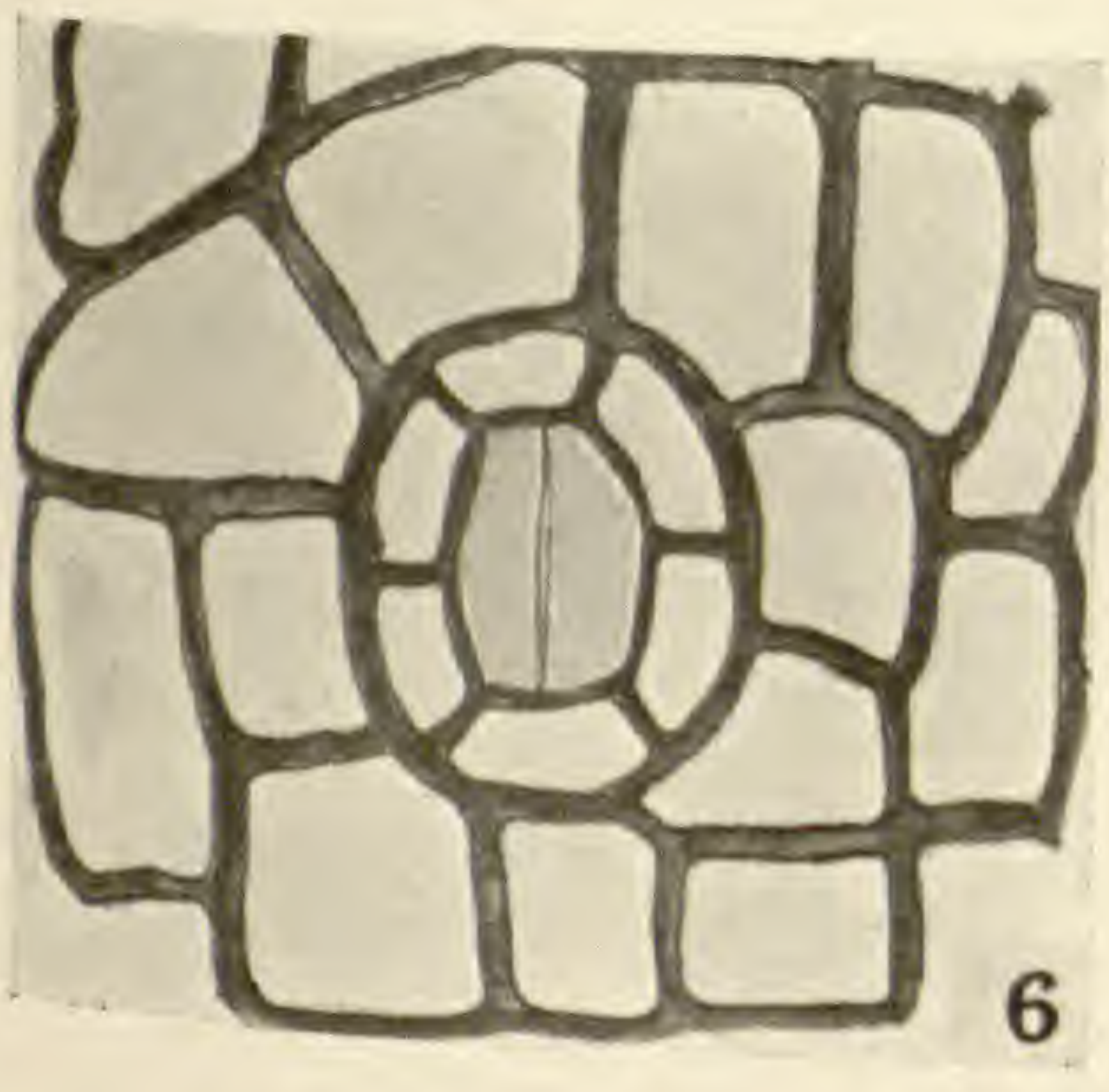

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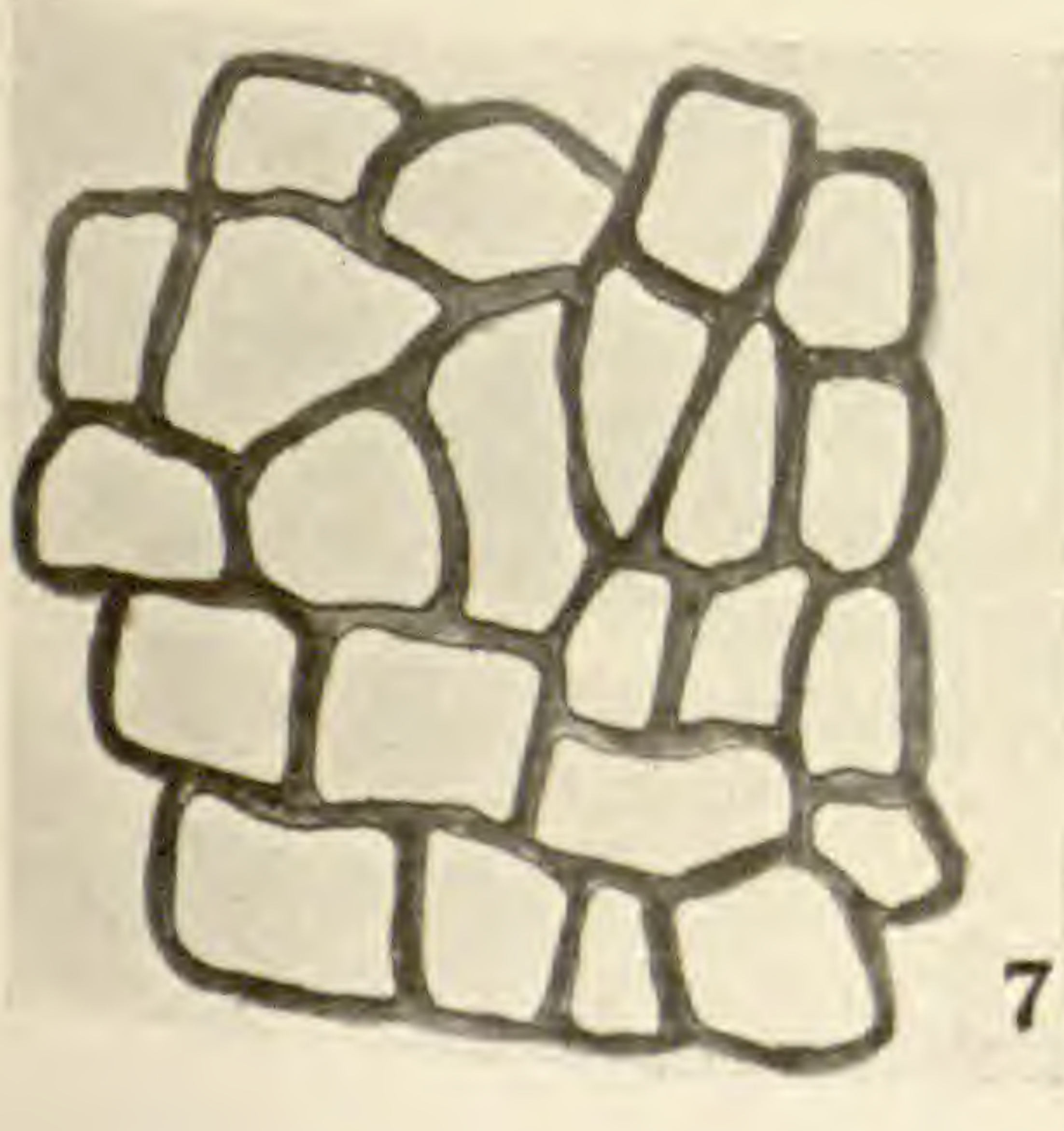

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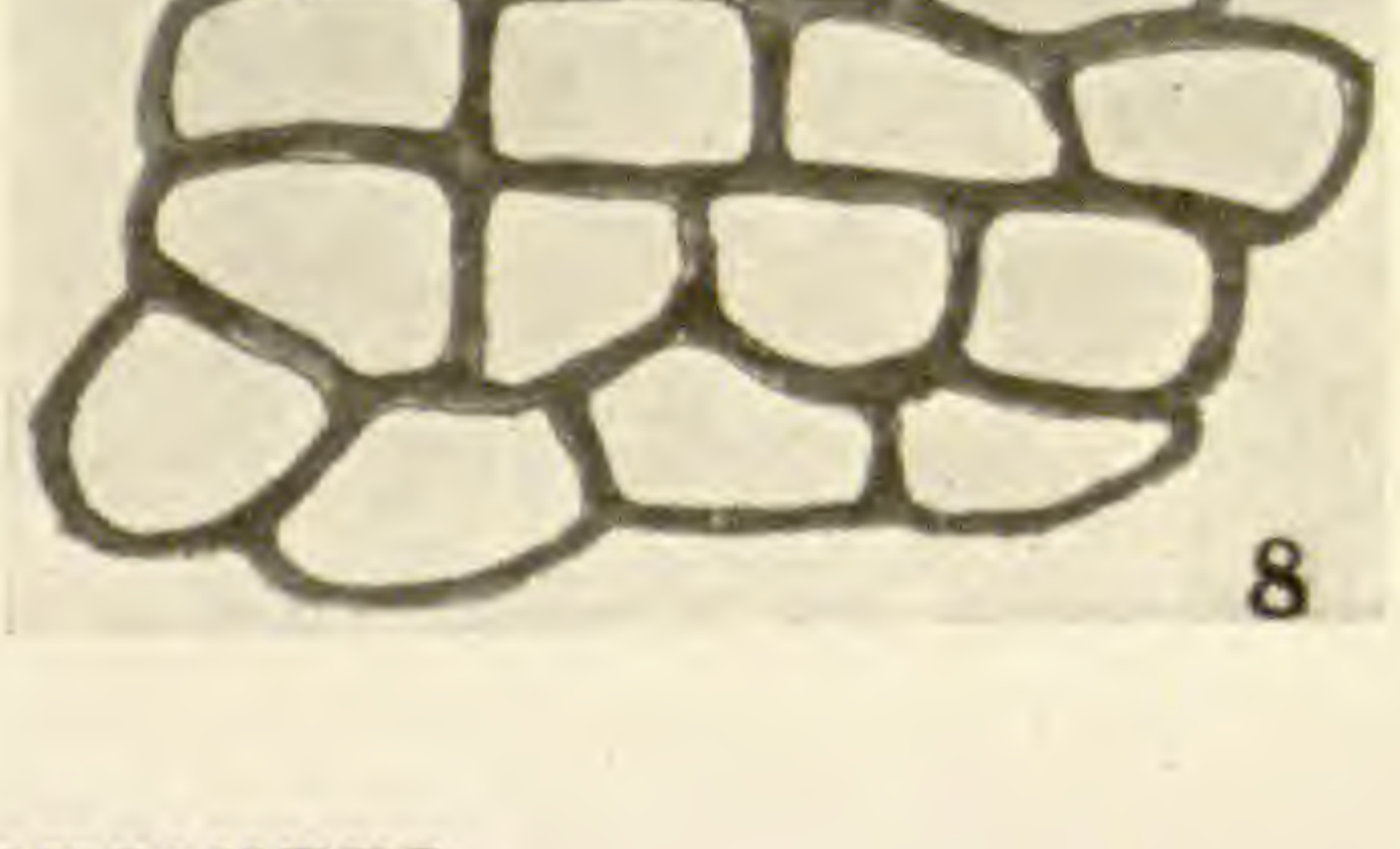

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BULLETIN

OF THE

TORREY BOTANICAL CLUB

AUGUST 1912

The genus Struthiopteris and its representatives in North America—II*

JEAN BROADHURST

(WITH PLATES 26–29)

The bases of the pinnae in the species previously described are fully adnate; in the following species the lower pinnae, at least, are distinctly petioled, except possibly in two species. Usually the upper pinnae are more or less adnate or even somewhat decurrent; when they are free throughout, the fact is definitely stated.

The petioled species, except in *S. Shaferi*, *rufa*, *Underwoodiana*, and *Werckleana*, have somewhat cartilaginous margins; the swollen or glandular vein apices usually give a subserrate to serrate character to this margin. When fully revolute, both the serrate and the cartilaginous character might pass unnoticed; extremes with regard to both of these characters are found in the non-revolute forms, *S. varians* and *S. falciformis*. In such plants as *S. falciformis* the veins could not, of course, be described as "not reaching the margin."

In the non-petioled species the scales are usually confined to the rhizome and the basal part of the stipe. In the following group the basal stipe scales are much more numerous, and similar but smaller ones are found on the rachis and often on the costae. Even the veins of the pinnae may have a delicate araneous covering of minute scales or fibrils. These araneous scales are definitely mentioned when present; the scales of the rachis and costae are not separately described unless they are very numerous or differ greatly from those of the stipe.

[The BULLETIN for July 1912 (**39**: 301–356. *pl. 24, 25*) was issued 23 Jl 1912.]

*For part I see Bull. Torrey Club **39**: 257–278. *pl. 21, 22.* 10 Jl 1912.

Most of the petioled species are very large, and complete sterile and fertile leaves are not always found in the same herbarium number; therefore, in this paper the comparative height is often omitted, though it may be more or less accurately deduced from the figures given for the length of the sterile and the fertile fronds, respectively.

Key to the petioled species

B. STERILE PINNAE (AT LEAST THE LOWER ONES) PETIOLED;[*] RHIZOME SCALES RIGID OR FLACCID; PINNAE MORE OR LESS SCALY; INDUSIUM IRREGULARLY LACERATE TO FIMBRIATE WITH AGE

Rhizome scales very slender, rigidly erect, with dark centers; vestigial pinnae[†] present; margins entire; coriaceous (rigid-herbaceous in *S. Underwoodiana*).

  Sterile lamina very abruptly reduced at the base (type A, with vestigial pinnae); pinnae crowded to overlapping, elliptical, obtuse; dried pinnae rolled and rufous below; margins revolute. 16. S. *rufa.*

  Sterile lamina abruptly reduced at the base (type D, with vestigial pinnae except in *S. Shaferi*); pinnae never crowded or overlapping, narrowly oblong to linear, acute to acuminate; dried pinnae not rolled, gray-green to yellowish brown or brown below; margins[‡] not revolute.

    Apex of the sterile lamina gradually reduced; upper sterile pinnae not conspicuously dilated both ways at the base, the base of the lower ones cuneate, petioled; deciduously araneous below; vein spaces 18–20 to 1 cm.; rachis scales mixed with white, fibrillose ones. 25. *S. Werckleana.*

    Apex of the sterile lamina not reduced; upper sterile pinnae conspicuously dilated both ways at their base, the bases of the lower ones barely petioled, rounded; not araneous below; vein spaces 10–16 to 1 cm.; rachis without white, fibrillose scales.

      Lower sterile pinnae prominently dilated or auricled at the base; stipes short, 3–10 cm. long, without vestigial pinnae; costae not flattened on the under side; vein spaces 15 or 16 to 1 cm.; indusium light-colored, regularly lacerate to its base, concavely hollowed on the sides of the lacerations. 19. *S. Shaferi.*

---

[*] *S. Underwoodiana* and *S. Shaferi*, the only forms not distinctly petioled, have rigid rhizome scales which are never found in the species in the preceding division.

[†] Except in *S. Shaferi*.

[‡] Incompletely and very narrowly so in *S. Shaferi*, which is peculiarly glandular; see description.

Lower sterile pinnae not dilated or auricled at the base; stipes 18–36 cm. long, with vestigial pinnae; costae flattened on the under side; vein spaces 10–13 to 1 cm.; indusium dark, only occasionally lacerate to the base, not concavely hollowed on the sides of the lacerations. 21. *S. Underwoodiana.*

Rhizome scales broad, flaccid, without dark centers; vestigial pinnae * lacking; margins more or less serrate; membranous to rigid-herbaceous.†

Sterile pinnae with rounded to tapering bases.

Pinnae 2–5-jugate, 4–7.5 cm. long, ovate to ovate-lanceolate, with an acute apex. 13. *S. danaeacea.*

Pinnae 8–25-jugate, 9–26 cm. long, lanceolate to linear, with an acuminate apex.

Margins conspicuously and irregularly erose; stipes red-purple; lamina not reduced at the apex. 22. *S. varians.*

Margins entire to finely serrate; stipes shining straw-colored to dull, pale brown; lamina reduced at the apex in all except the smallest forms. 17. *S. Schiedeana.*

Sterile pinnae with cordate, or rarely subcordate, bases.

Stipes with vestigial pinnae, closely covered with peculiar, appressed, amorphous scales, ordinary scales lacking; viviparous near the apex of the rachis; lamina not reduced at the apex. 24. *S. vivipara.*

Stipes without vestigial pinnae, ordinary scales present, with or without fibrillose or somewhat formless appressed ones; not viviparous; lamina reduced at the apex (except in the smaller *S. striata* specimens).

With red-purple to black stipes; pinnae with an acute (or obtuse?) apex; lower fertile pinnae usually with spurlike protuberances. 23. *S. violacea.*

With straw-colored to chestnut stipes; pinnae with an acuminate apex; lower fertile pinnae usually without spurlike protuberances.

Margins never revolute, but sharply, finely, and regularly cartilaginously serrate throughout. 14. *S. falciformis.*

Margins irregularly or fully revolute, definitely serrate at the apex only.

Stipe scales narrow, short, 2–6 mm. long, projecting; appressed finer ones inconspicuous. 10. *S. chiriquana.*

---

[*] Except in *S. vivipara.*

[†] Except in the smaller specimens of *S. violacea* and one St. Vincent specimen of *S. striata.*

Stipe scales broad, 1–2 cm. long, flaccid and lying more or less crumpled along the stipe; appressed somewhat formless ones present and numerous in most species.

Sterile pinnae mainly straight; lamina usually 1.5 (rarely 2) times as long as wide; pinnae 6–24-jugate; lower surface with definitely raised veins; margins revolute.

Pinnae 20–24-jugate, the apex acuminate, the base subcordate; lower surface not araneous. 12. *S. costaricensis.*

Pinnae 6–23-jugate (averaging 10–18-jugate), the apex abruptly acuminate, the base fully cordate; lower surface usually finely araneous. 20. *S. striata.*

Sterile pinnae mainly falcate; lamina 2–4 times as long as broad; pinnae 21–70-jugate; veins not raised below (except irregularly so in *S. Christii*); margins rarely fully revolute.*

Sterile stipes chestnut; veins more or less raised below; fertile pinnae occasionally with spurlike protuberances. 11. *S. Christii.*

Sterile stipes straw-colored to brownish; veins not raised below; fertile pinnae without spurlike protuberances.

Sterile pinnae 20–40-jugate; fertile pinnae without a glandular, basal enlargement of the petiole. 15. *S. lineata.*

Sterile pinnae 60–70-jugate; fertile pinnae with a glandular, basal enlargement of the petiole. 18. *S. sessilifolia.*

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* Except possibly in *S. sessilifolia;* the condition of the type specimen seen makes it difficult to determine this.

10. **S. chiriquana** Broadh. sp. nov.

Plants terrestrial. Rhizome (not seen) evidently large, the scales lanceolate, 4–10 mm. long, snuff brown to tobacco brown. Sterile fronds 1.7–2.1 m. long; stipes 71–86 cm. long, 1–1.6 cm. thick at the base, angulate, reddish brown to purplish brown, the scales lanceolate, 2–6 mm. long, yellowish to purplish brown, projecting noticeably from the stipe and mixed with smaller, finer ones which are more or less appressed; lamina 106–123 cm. long, 38–45 cm. wide, oblong, slightly reduced at the base (between type B and C * in the normal frond seen, without vestigial pinnae), the apex gradually reduced, the terminal pinna 6.5–9 cm. long, the lower pinnae more or less opposite; pinnae 44–50-jugate, narrowly lanceolate, straight to slightly curved, the apex serrate, long-acuminate, the base subcordate to cordate, the upper pinnae adnate, the lower pinnae sometimes long-petioled (1 cm.), 19–25 cm. long, 2.3–3 cm. wide; margins narrowly revolute;† leaf tissue rigid-herbaceous, the under surface but slightly or not at all araneous, the costae almost naked; veins more or less raised below (not so distinctly as in most specimens of *S. striata*), the vein spaces 12–15 to 1 cm. Sporophyls 1.6 (in young plant)–2.4 m. long; stipes 64–112 cm. long, slightly lighter than the sterile, or yellowish and tinged with reddish brown; lamina 98–124 cm. long, rather gradually reduced at the apex, the base slightly or abruptly reduced; pinnae 49–52-jugate, 15 to 23 cm. long, 3–5 mm. wide, the apex with a sterile tip 3–5 mm. long, the base rounded; sporangia yellowish brown; indusium delicate, very early deciduous, and irregularly lacerate. [PLATE 26.]

Type in the U. S. National Herbarium, no. 676110 to 676114 inclusive, collected in humid forests of the upper Caldera watershed between "Camp I" and the Divide, Holcomb's trail, above El Boquete, Chiriqui; altitude 1650–1925 m., *William R. Maxon 5650*, March 23, 1911.

SPECIMENS INCLUDED: U. S. National Herbarium, no. 675825 to 675828 inclusive, collected in humid forests of Cuesta de Las Palmas, southern slope of Cerro de la Horqueta, Chiriqui, altitude 1700–2100 m., *Maxon 5442* (partly abnormal), March 18, 1911.

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* Bull. Torrey Club **39**: 264. *f. 1.* 10 Jl 1912.

† Irregularly revolute in the abnormal plant, *Maxon 5442*, included in this species. The revolute part is narrow when compared with that in *S. striata*, which has pinnae about equal in width.

Maxon's two plants vary in the bases of the sterile pinnae; in no. 5650 the base is gradually narrowed through a distance of about 2 cm.; in the other, no. 5442, the base is the widest part of the pinna. Excepting also the irregular character of the margin of the latter, the two plants are similar; there is nothing else from the mainland that approaches them in stipe characters, and only one plant (*Tonduz 10907*, the type of *S. sessilifolia*) with such long, numerous pinnae. *S. chiriquana* differs from *S. sessilifolia*, however, in having brightly colored, shining stipes, the upper pinnae partly adnate, straighter pinnae with practically naked costae, and much lighter colored fertile pinnae with very delicate, deciduous indusia.

11. **S. Christii** (C. Chr.) Broadh. comb. nov.

Lomaria spissa Christ, Bull. Boiss. II. 4: 1092. 1904. (Not *L. spissa* Fée.)

Blechnum Christii C. Chr. Ind. Fil. 152. 1905.

Lamina very large; "rachis" 1 cm. thick, red-brown; pinnae 20 cm. long, 2 cm. wide, the apex elongated, the base cordate and sessile, covering and extending beyond the rachis; margins finely dentate with regularly crisped undulations; costae scaly, the scales oval, appressed; veins prominently projecting below. (Sporophyls not described.)

TYPE: In Christ's herbarium; from Costa Rica.

DISTRIBUTION: Apparently limited to Costa Rica.

SPECIMENS INCLUDED: COSTA RICA: Tablaro, "1900 m. VII, '08," *Braveas 143* (N).

Christensen changed the specific name of Christ's *Lomaria spissa* to *Christii*, because Fée had earlier used *L. spissa* for an African species. The very incomplete description given above has been rearranged from Christ's description of *L. spissa*. Following are some additions based upon the sheet from Christ's herbarium mentioned above. The fertile frond is slightly abnormal, having broad sterile tips on some of the pinnae; the following additions have not been incorporated into the description, though a fragment kindly sent by Christ indicates that these smaller fronds are, except in size, decidedly like his specimen.

Sterile frond 52 cm. long; stipe 14 cm. long, and 1 cm. thick at the base, angulate, the scales numerous, deciduous, 1–2.5 cm.

long, yellowish brown, flaccid, loosely appressed, accompanied by small linear or araneous ones; lamina 39 cm. long, 19 cm. wide, ovate-lanceolate, not reduced at the base (type A, without vestigial pinnae), gradually reduced at the apex, the scales smaller on the costae, the under surface finely araneous; pinnae 21-jugate, narrowly lanceolate to linear-falcate, the apex acuminate, serrate, the base cordate, the lowest pinnae petioled; margins slightly and irregularly revolute and therefore appearing subentire; leaf tissue rigid-herbaceous; veins irregularly raised below, the vein spaces 10–12 to 1 cm. Sporophyl (not mature) 64 cm. long, including the stipe; stipe 26 cm. long, lighter in color, partly yellow-brown, otherwise as in the sterile; lamina 38 cm. long, abruptly or not at all reduced at the base, rather abruptly reduced at the apex; pinnae 21-jugate, 9–11 cm. long, 2–3 mm. wide, the base cordate (at least in the lower pinnae), occasionally with spurlike protuberances;* sporangia very dark brown; indusium delicate, narrow, deciduous, subentire, irregularly and not fully lacerate.

12. **S. costaricensis** (Christ) Broadh. comb. nov.

Lomaria costaricensis Christ, Bull. Boiss. II. 4: 1092. 1904.

Blechnum costaricensis C. Chr. Ind. Fil. 152. 1905.

Plants terrestrial. Sterile fronds 60–80 cm. long; stipes at least 30 cm. long, irregularly angulate, straw-colored, the scales lanceolate, 1.5 cm. long, 4 mm. broad, soft, deciduous, mixed with fibrillose ones; lamina at least 41 cm. long, 28 cm. wide, broadly oblong, the rachis somewhat rugose, otherwise like the stipe;† the costae soon becoming naked, leaf tissue rigid-herbaceous, brittle and yellowish green when dry; pinnae 20–22-jugate, straight or slightly curved near their apex, acuminate, the lower ones slightly petioled, and subcordate at the base, 11–22 cm. long, 1.6–2 cm. wide, margins finely serrate or subserrate and somewhat revolute;‡ veins indistinctly raised, the vein spaces 16–20 to 1 cm. Sporophyl § indusium smooth, 2 mm. wide, edge entire but wavy, brown-ochre.

TYPE: In Christ's herbarium.

DISTRIBUTION: Costa Rica and Guatemala.

SPECIMENS INCLUDED: GUATEMALA: Alta Verapaz, Coban, 1350 m., *von Türckheim 1384*, 1907 (Y). Alta Verapaz, "In paludosis prope Coban," altitude 4,300 ft., *von Türckheim 353*, 1879 (N).

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* See footnote under *S. violacea*, p. 380.

† But with some whitish, appressed scales in the Guatemalan specimens.

‡ Von Türckheim's specimens from Guatemala are irregularly revolute; so is a pinna sent by Christ. Neither specimen is serrate as in *S. falciformis;* nor so definitely serrate as in any of the species so described in this paper.

§ According to Christ.

The above incomplete description has been rearranged from Christ's with some few additions based on von Türckheim's specimens. The fertile frond forming part of von Türckheim's no. 353 is somewhat mutilated; the two specimens afford the following additions:

Fertile frond 130 cm. long; stipe 60–68 cm. long, light, blotched with brownish, the scales few, yellowish brown; lamina 65–80 cm. long, the pinnae distant; pinnae 16–24-jugate, 13–16 cm. long, 4–5 mm. wide, heavy, with a sterile apex 1–5 mm. long, the bases decidedly cordate; sporangia yellowish brown or dark brown; indusium wavy and entire or irregularly broken, less lacerate than in most of the petioled species.

Christ kindly sent one sterile pinna of *S. costaricensis*. It was evidently one of the upper ones, measuring 10 cm. by 13 mm.; the color is not yellow as in *S. Werckleana*, but a light gray-green characteristic of recent specimens of *S. polypodioides* and common to several of the heavier species of *Struthiopteris;* the vein spaces vary from 16 to 18 to 1 cm.

13. **S. danaeacea** (Kunze) Broadh. comb. nov.

Lomaria danaeacea Kunze, Linnaea **18**: 326. 1844.

Blechnum danaeaceum C. Chr. Ind. Fil. 153. 1905.

Rhizome oblique, very paleaceous with reddish scales. Sterile fronds 10–40 cm. long; stipes clustered, 4–15 cm. long, with appressed scales which are larger toward the rhizome; lamina 8–10 cm. wide, short ovate-oblong, not gradually reduced above, the terminal pinna largest, 6–9 cm. long, often with a basal lobe, shining, lighter below; pinnae 2–5-jugate, ovate-lanceclate to ovate-oblong, the apex serrate, the base rounded, unequally subcuneate, free throughout, sessile, the lower pinnae short-petioled, 4–7.5 cm. long, 1.5–2.5 cm. wide; margins revolute; leaf tissue coriaceous;* costae raised below and chaffy with appressed scales; veins close and distinct. Sporophyls with light-colored, sparsely chaffy stipes; pinnae curved, numerous, long (12–15 cm. in parts of the fertile laminae seen in Kew and Geneva), the apex short-acuminate.

TYPE: Herb. Roemer, no. 121 and 122, from Mexico.

DISTRIBUTION: Known from Mexico only.

SPECIMENS INCLUDED: *Siebold 125* (Delessert Herbarium, Geneva; tracing, N).

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* Coriaceous as used here by Kunze and by many of the earlier writers evidently corresponds to rigid-herbaceous as now used.

The incomplete description given above is a translation of the original by Kunze, changed only as to measurements to include some smaller but mature fronds in the Delessert Herbarium at Geneva. Siebold's specimen seen there bears Kunze's name and is evidently a cotype of *L. danaeacea.* Christensen makes *L. deflexa* Liebm. a synonym of *danaeacea;* this it certainly is not, as *deflexa* is described as having *numerous* sterile pinnae. The validity of *Lomaria deflexa* itself might well be questioned, as no type specimen is indicated, and it is founded on a single sterile leaf (a not uncommon practice with Liebmann).

14. **S. falciformis** (Liebm.) Broadh. comb. nov.

Lomaria falciformis Liebm. Vid. Selsk. Skr. V. 1: 234. 1849.

Blechnum falciforme C. Chr. Ind. Fil. 154. 1905.

Plants terrestrial. Rhizome (not seen), the scales lanceolate to ovate-lanceolate, 1–3 cm. long. Sterile fronds 70–150 cm. long; stipes 30–80 cm. long, often angulate, straw-colored to yellowish or reddish brown, varying greatly in the number and in the color of the deciduous scales, which range from straw, tan, and fawn to red-ochre; lamina 35–76 cm. long, 18–32 cm. wide, oblong, abruptly reduced at the base (type A, without vestigial pinnae), gradually reduced at the apex, the scales of the rachis like those of the stipe or darker; pinnae 18–32-jugate, linear or lanceolate, falcate to straight, the lower ones more curved than the upper, the apex acuminate, abruptly so in the widest forms, the base unequally and usually decidedly cordate, the lower pinnae distinctly petioled, 12–23 cm. long, 1.4–2.5 cm. wide; margins never revolute, finely, sharply, and regularly cartilaginously toothed, the teeth usually slanting forward, sometimes incurved; leaf tissue membranous to herbaceous; veins distinct, at least below, not heavy (often appearing as delicate dark lines), the vein spaces 12–15 to 1 cm. (9–12 in one very young frond and also in a single pinna, both determined by Liebmann). Sporophyls (incomplete) at least 65–80 cm. long; lamina 36–40 cm. long; pinnae 11–22 cm. long, 4–5 mm. wide, with a sterile apex 3–12 mm. long, the base cordate, usually petioled; sporangia dark brown; indusium lacerate.

TYPE: Cotypes (?) U. S. National Herbarium no. 474921 (an immature frond determined by Liebmann), "ad rivulos, Chiuautla,"* Mexico, May, 1841. Berlin herbarium (single pinna now in the New York Botanical Garden herbarium) *Liebmann 135*,

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* Elsewhere spelled Chiuautata and Chiautla.

Chiuautla, Mexico. In his description, Liebmann attributes this species also to Puebla and Oaxaca, Mexico.

DISTRIBUTION: Mexico and Guatemala.

SPECIMENS INCLUDED: MEXICO: Oaxaca, "Santa Ines del Monte, Zimatlan-Oaxaca Mts.," altitude 3,000 m., *Conzatti 1313* (N). Oaxaca, "Cerro de San Felipe," *Conzatti and Gonzalez 529*, altitude 3,000 m. (N). GUATEMALA: Dept. Chimaltenango, Volcano Acatenango, altitude 8,500 ft., *Kellerman 6481* (N).

Liebmann described *L. falciformis* without seeing the fertile leaf; he probably had a young specimen, for a single pinna of the cotype from Berlin measures 14 cm., and he gives the length of the pinnae as 10 cm. (4 in.). Liebmann speaks of the pinnae as sessile, meaning, apparently, compared with his *L. spectabilis*, for a single sterile frond (U. S. National Museum no. 474921) determined by Liebmann has distinctly petioled lower pinnae. The specimen is apparently very immature. It differs, however, from Liebmann's description in having rounded rather than "obliquely cuneate cordate" bases, elsewhere described by him as unequally angled cordate; the margin of this specimen is *not* fully serrate and is but *slightly* cartilaginous. Notwithstanding these inconsistencies, the very peculiar margin (which does fit the fragment of Liebmann's Berlin specimen) makes it possible to place in this species the plants mentioned above. The Kellerman plant has straighter and proportionately narrower pinnae than the Berlin fragment; it differs still more in this respect from the other specimens included above. More material might make possible its separation.

A plant recently collected in Panama, in "moist ravines above El Potrero camp, Chiriqui Volcano, altitude 2890–3025 m.," *Maxon 5335*, may belong here. The texture is much heavier and the pinnae are shorter and broader than in the other specimens placed in this species; the margin is not quite like that of *S. falciformis*.

15. **S. lineata** (Sw.) Broadh. comb. nov.

Osmunda lineata Sw. Prod. 127. 1788.

Onoclea lineata Sw. Jour. Bot. Schrad. **1800**^{2}: 73. 1801; Syn. Fil. 111. 1806.

Lomaria lineata Willd. Sp. Pl. **5**: 290. 1810.

Lomaria procera Spreng. (as used by Jenman and others).

Blechnum capense Diels (in part?) in E. & P. Nat. Pfl. 1^4: 249. 1899.

Blechnum lineatum C. Chr. Ind. Fil. 156. 1905.

Plants terrestrial. Rhizome erect, 10 cm. high (see discussion following this description), 3–5 cm. thick, the scales 1–2 cm. long, 2–6 mm. wide, burnt umber to tobacco brown. Sterile fronds 40–155 cm. long; stipes clustered, 18–90 cm. long, angulate, shining or dull, light-colored, or less often bicolored (with brown) or more rarely blotched with brown (purplish brown in some Cuban specimens), the scales numerous, brownish yellow, mixed with more or less fibrillose ones, very loosely appressed, at least toward the rhizome, more numerous than in *S. striata*, the attachment of the larger ones indicated by dark points or raised dots; lamina 28–74 cm. long, 8.5–36 cm. wide, oblong to narrowly lanceolate, slightly or not reduced at the base (type A, without vestigial pinnae), gradually reduced at the apex, the pinnae close to overlapping in the smaller plants; pinnae 18–40-jugate (usually 20–40), linear-oblong, falcate, the apex acuminate, serrate, the base cordate, often partly covering the rachis, often free throughout, the lowest pinnae petioled, 6.5–20 cm. long,* 0.9–2 cm. wide; margins subentire, somewhat cartilaginous, rarely revolute;† leaf tissue herbaceous to rigid-herbaceous, usually somewhat shining below, the costal scales smaller, usually numerous, tan, fawn, and buff, rarely araneous; veins rarely raised below, the vein spaces 13–18 to 1 cm. Sporophyls 92–146 cm. long; stipes 43–85 cm. long (one specimen has a chestnut cast, otherwise like the sterile); lamina 28–66 cm. long, slightly or not reduced at the base, somewhat reduced at the apex; pinnae 24–40-jugate, 8–18 cm. long, 3–4 mm. wide, with a sterile tip 5–10 mm. long, petioled, the lower bases rounded or cordate; sporangia very dark brown; indusium irregularly lacerate.

TYPE LOCALITY: Jamaica.

DISTRIBUTION: Cuba (?), Jamaica, Santo Domingo, and Porto Rico.

SPECIMENS INCLUDED: JAMAICA: Road from Cinchona to Morce's Gap, altitude 5,000 ft., *Underwood 258* (Y). Blue Moun-

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* But 5 cm. long in some immature (?) specimens from Cuba; see later discussion for other differences; a fragment from Jamaica consists of but two pinnae which are 42 cm. long. One abnormal specimen from Jamaica, *Underwood 2098*, has pinnae 2.4 cm. wide.

† Two growing plants of *S. lineata* now in the New York Botanical Garden conservatories have pinnae with non-revolute margins, which are narrowly cartilaginous and inconspicuously but sharply and finely serrate.

tain Peak, altitude 6,500–7,325 ft., *Underwood 1446* (Y). Lower slopes of Mt. Moses, moist shaded banks among bushes, altitude 2,000–2,500 ft., *Maxon 1049* (N). Cinchona, altitude 5,000 ft., *Clute 71* (Y, N).

Among these Jamaican plants, as in *S. violacea* and *S. striata*, there occur small but mature specimens differing mainly in size from the larger ones. These smaller plants have narrower laminae (3–4 times as long as broad instead of 2–2.5 times), the pinnae are closer and smaller (4.5–8 cm. long and 6–12 mm. wide as contrasted with pinnae 13–20 cm. long and 15–18 mm. wide); the leaf tissue is much heavier in these smaller forms. As indicated above, a similar range occurs in several other species, and it was not thought best to subdivide them. In this case, however, the rhizome may offer a real distinction. The smaller Underwood plant of *S. lineata* in the New York Botanical Garden conservatories already referred to in a footnote has an *erect* rhizome 10 cm. high and 4–5 cm. thick. The larger *S. lineata* plant incompletely labeled as from Jamaica, though larger in every other way, has a low spreading crown about 7 cm. broad and but slightly raised above the soil.*

Professor L. M. Underwood, who collected a great deal of *S. lineata* in Jamaica, stated that it is "very variable according to soil and light, and especially, age."

The two species, *S. lineata* and *S. striata*, have long been confused. The measurements given by Swartz indicate that in both cases he described small forms. He distinguished between them by describing *striata* (1) as having broader, almost entire, and sessile sterile pinnae, in which the whole apex is serrate; and (2) as having fertile pinnae with dilated cordate bases. A careful study of over thirty sheets from the type localities has shown (1) that many of the *S. lineata* group have fertile pinnae with cordate bases; (2) that the lower pinnae of *striata* are petioled; and (3) that the tips are serrate in most of the *lineata* group, also. Never-

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* Other differences, which correspond to those found in herbarium specimens, are as follows: the smaller plant has stipes 15–17 cm. long, laminae 25–35 cm. long and 13–14 cm. wide, close to overlapping pinnae, which are 16–20-jugate, with the terminal pinna 6–7 cm. long; the larger plant has stipes 45–60 cm. long, more or less blotched with brown, laminae 45–60 cm. long and 20 cm. wide, pinnae not close, 25–27-jugate, with a terminal pinna 9–11 cm. long.

theless it is easy to select single plants from these localities which will justify the distinctions made by Swartz. Abundant material from these localities separates readily according to distribution, showing the following differences, mainly relative but sufficient to separate them. *S. lineata* has narrower sterile laminae and narrower, more numerous pinnae, which are more curved, not abruptly but gradually acuminate, shining below, and less revolute. The scales in *S. lineata* are more numerous and more persistent; they are mixed with finer and shapeless ones, which are more or less appressed to the stem; the costae contrast markedly with the commonly naked ones of *S. striata*, as do the smoother, often shining, under surfaces of the pinnae with the finely araneous condition of the strongly raised veins on the under surface of *S. striata*. A plant from Santo Domingo (*Eggers 2041*, "monte Barrero," altitude 1,100 m.) has very heavy, more numerous (58-jugate), narrow, close pinnae with deeply cordate bases; the rachis is densely chaffy and also fibrillose, and the scales on the costae are numerous, more uniform, and heavier in texture. More material might make possible its separation from *S. lineata*.

Some recent material from Cuba, collected by J. A. Shafer at Oriente (no. 4150 and no. 9038), shows plants with very narrow fronds, and narrow pinnae which (when fully mature) are heavier than any of the *S. lineata* specimens seen, except the plants mentioned above collected by Eggers. Shafer's no. 8059, also from Oriente, is like *S. lineata* in the narrow lamina but has short and proportionately broad pinnae (suggesting *S. striata*, in proportion only); as in *S. lineata*, the margins are subentire to almost serrate, not revolute, and the veins are not raised below; the scales throughout are more like those of *striata;* the stipes are dark reddish brown and the rachises similar. More material from Cuba is most desirable; excepting *S. Shaferi* these are the only Cuban representatives of the petioled species.

16. **S. rufa** (Spreng.) Broadh. comb. nov.

Lomaria rufa Spreng. Nova Acta **10**: 230. 1821; Syst. **4**: 63. 1827.

Lomaria robusta Fée, Gen. Fil. 69. 1852.

Plants terrestrial. Rhizome subarboreous (in *Duss 4164*, 20 cm. long and 12 cm. thick), the scales 2.5–3.5 cm. long, linear, 1–2 mm. wide, rigidly erect, dark tobacco brown or burnt umber with definite lighter margins. Sterile fronds 30–58 cm. long; stipes 9–20 cm. long, more or less irregularly angulate, marked throughout by vestigial pinnae, dull brownish, not shining, the scales like those of the rhizome, but shorter, less numerous, and abruptly wider at the base, mixed with finer, soft, light brown to rufous ones, the position of the fallen scales plainly indicated as in *S. lineata;* lamina 28–40 cm. long, 13–20 cm. wide, elliptical to oblong, abruptly reduced at the base (type A, with vestigial pinnae) gradually reduced at the apex, terminal pinna 4–7 cm. long, the pinnae crowded to overlapping, the lower often deflexed (at least in dried specimens), the rachis scales mixed with more numerous, fine or fibrillose, matted scales; leaf tissue very heavy and coriaceous, becoming rolled and rufous below in drying, the costae more or less fibrillose, the under surface usually araneous with similar yellowish to rufous scales (the upper surface of the costae occasionally slightly fibrillose also); pinnae 12–25-jugate, elliptical to oblong, the apex obtuse, appearing acute in some "rolled" specimens, the base rounded, short-petioled in the lower pinnae, 6–10 cm. long, 17–27 mm. wide; margins revolute; veins not raised below, sometimes rather distinctly grooved above, the vein spaces 13–18 to 1 cm. Sporophyls taller, 67–114 cm. long; stipes 15–57 cm. long; lamina 33–60 cm. long, abruptly reduced at the base, slightly reduced at the apex; pinnae 20–35-jugate, thick or heavy, 15–16 cm. long, 5–6 mm. wide, the petioles heavy; sporangia dark brown; indusium quite regularly lacerate. [PLATE 28.]

TYPE LOCALITY: "Islands of the Caribbean."

DISTRIBUTION: Guadeloupe only, apparently.

SPECIMENS INCLUDED: GUADELOUPE: "Plateau de la Soufrière (autour du lac de soufre), 1895," altitude 1,420 m., *Duss 4164* (Y, N); U. S. National Museum no. 524499, *Duss*. *L'Herminier 27* (Geneva; tracing, Y).

Fée himself says that his *Lomaria robusta* is near *L. rufa* Spreng.; and the rufous, oblong, obtuse, coriaceous pinnae of Sprengel's description, described from the islands of the Caribbean, are so characteristic that there seems to be no reason for disregarding the older name of *rufa*.

17. **S. Schiedeana** (Presl) Broadh. comb. nov.

Lomaria Schiedeana Presl, Linnaea **5**: 613. 1830; Tent. 143. 1836.

Lomaria longifolia Schlecht. Mém. Acad. Brux. **15**: 49. 1842.

Lomaria spectabilis Liebm. Vid. Selsk. Skr. V. **1**: 235. 1849.

Lomaria acrodonta Fée (?), Mém. Foug. **8**: 70. 1857.

Blechnum ornifolium C. Chr. (in part). Ind. Fil. 157. 1905.

Plants terrestrial. Rhizome (not seen), the scales (in Guatemalan species at least) large, 2.5–3 cm. long, 5–10 mm. wide, more or less plicate, burnt umber. Sterile fronds 1.1–2 m. long; stipes 70–80 cm. long, irregularly angulate, light-colored (and shining in the Guatemalan species), the scales yellowish brown to snuff-colored, very deciduous; lamina 45–86 cm. long, 20–50 cm. wide, oblong, but slightly or not at all reduced at the base (type A, without vestigial pinnae), gradually reduced at the apex (except in the smallest forms which are not reduced),* the rachis with few scales and usually fibrillose in the channel; pinnae 18–25-jugate (8–15 in the smaller forms), lance-oblong, straight or somewhat curved (falcate in the smaller forms), the apex serrate, acuminate to long-acuminate, often abruptly so, the base rounded or even tapering (the pinnae all free in the smaller fronds), the lower pinnae long-petioled, 24–36 cm. long (9–15 in the smaller forms), 1.8–3 cm. wide; margins entire to finely serrate, more or less cartilaginous; leaf tissue membranous to herbaceous or barely rigid-herbaceous, the surface sometimes shining, the costae finely fibrillose or naked; veins† not raised, but distinct below, the vein spaces‡ 13–18 to 1 cm. Sporophyls 50–160 cm. long; lamina 38–100 cm. long, slightly or not at all reduced at the base, gradually reduced at the apex; pinnae 15–26-jugate, 8–20 cm. long, 3–5 mm. wide, with a sterile tip 2–5 mm. long, more or less petioled; sporangia dark brown; indusium delicate, narrow, and sparingly lacerate.

TYPES: 1. (*Lomaria Schiedeana*) Mexico, *Schiede 781* (Berlin; fragments and tracing, Y). 2. (*Lomaria longifolia*) Mexico, Cordilleras, Vera Cruz, altitude 4,000 ft., *H. Galeotti 6406*, 1840 (Kew and also Delessert Herbarium, Geneva; tracings, Y).

DISTRIBUTION: Apparently confined to Mexico and Guatemala.

SPECIMENS INCLUDED: MEXICO: Herb. Rovirosa, no. 846, Chiapas, "Habitat inter pago San Bartolo et Las Nubes," alti-

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* The type of *L. Schiedeana* is a small plant and is not reduced at the apex.

† The vein apices are so swollen in one Guatemalan plant that the true cartilaginous margin seems almost intramarginal.

‡ Vein spaces 14–16 in the type of *S. Schiedeana* and in all the larger specimens, except possibly the Galeotti specimens.

tude 1,400 m. (Y). Totutla, *Liebmann*, U. S. National Museum no. 591311. GUATEMALA: Guatemala (Dept.), altitude 4,500 ft., *J. D. Smith 2427* (N). Alta Verapaz, "Sumpfiger Boden bei Coban," altitude 4,300 ft., *von Türckheim 353** (N).

Liebmann published *L. spectabilis* to include the earlier *L. longifolia* Schlecht. and *L. Schiedeana* Presl. He considered *L. longifolia* † invalid because that specific name had been previously used for a twining species. The description consists merely of the name, the type number (*Galeotti 6406*), the height (5–6 ft.), and the habitat (borders of "ruisseaux"). *L. Schiedeana* was little more than a name, as Liebmann states. It, also, however, was accompanied by a type number, *Schiede 781* (herb. no. 19849), and the statement that it differed from *L. striata* in having an elliptical-obtuse instead of a subcordate base.

Galeotti's specimens, seen in Kew and Geneva, seem at first quite different from the fragments and partial tracings of the type of *Lomaria Schiedeana*. The latter is smaller, more membranous, and the pinnae are more curved. Liebmann says that Schiede found but fragments of the sterile frond. At all events the differences are no greater than in the plants included in *S. striata;* in fact, the range in the apical reduction of the frond and in the shape and number of the pinnae is about the same.

Our material representing *S. Schiedeana* is very scanty; Liebmann had the advantage of knowing this region, and there seems to be no strong reason for not accepting his conclusion that *Schiedeana* and *longifolia* should be united. Both names were based on numbered type specimens; *longifolia* is, as Liebmann points out, a homonym; *Schiedeana*, however, was published twelve years earlier and is therefore the rightful name of the species, and Liebmann's name *spectabilis* is reduced to a synonym of *S. Schiedeana.* Liebmann's own sheets of *spectabilis* (U. S. National Museum no. 591311 and 591312) do not have the shining surface mentioned in his description of *L. spectabilis*. Otherwise, except for their smaller size, they seem to be very like the larger specimens included in *S. Schiedeana*.

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* Not the same as *von Türckheim 353* under *S. costaricensis*.

† *Lomaria longifolia* Kaulf. 1824; since transferred to *Stenochlaena;* var. 2 of *S. sorbifolia*, according to Christensen.

Christensen makes these three names (*Schiedeana*, *longifolia*, and *spectabilis*) synonyms of *Lomaria ornifolia** Presl. Presl published *L. Schiedeana* five years after *L. ornifolia;* in comparing them he described *ornifolia*, thought to be from Peru, as differing in having obliquely cordate bases; *Schiedeana* he elsewhere described as having elliptical-obtuse, not subcordate, bases. There seems therefore no reason for adopting *S. ornifolia* as the specific name for these plants which possess rounded to almost tapering bases.

Fée's *L. acrodonta* has apparently an abnormal fertile frond; not having access to the type, *Schaffner 102*, 1854, I see no valid reason for separating it from *S. Schiedeana*, especially as the description contains contradictory statements as to size. In the Rovirosa specimen included in *S. Schiedeana*, the fertile frond has in two places a pair of fertile pinnae instead of the usual single pinna. Such abnormality has not been noticed in any other species of *Struthiopteris*.†

18. **S. sessilifolia** (Klotzsch) Broadh. comb. nov.

Lomaria sessilifolia Klotzsch; Christ, Bull. Boiss. II. 4: 1092. 1904.

Blechnum sessilifolia[*um*] C. Chr. Ind. Fil. 159. 1905.

Plants‡ terrestrial. Rhizome (not seen). Sterile fronds 1.5 m. long; stipes 50–82 cm. long, angulate, dull brownish, the scales lanceolate, 1.5–2 cm. long, 2–4 mm. broad, dull brownish, ragged (according to Christ, reddish straw-colored, very soft, and thread-like); lamina 96 cm. long, 29 cm. wide, oblong, not at all or but slightly reduced at the base (type A, without vestigial pinnae), very gradually reduced at the apex, the pinnae crowded, often opposite, the rachis grayish brown, with dull brownish, fibrillose, more or less appressed, and deciduous scales; pinnae 58–70-jugate, linear-oblong, mostly falcate, the apex attenuate, serrate, the base cordate, free throughout, and partly covering the rachis, 13–15 cm. long, 20 mm. wide; margins irregularly revolute; leaf tissue herbaceous (much rolled in the poorly preserved cotype seen), not araneous below, the costal scales lanceolate or ovate-lanceolate, light brown, rather numerous;

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* Rel. Haenk. 1: 51. 1825.

† See the discussion under *S. violacea* of spurlike growths at the bases of the fertile pinnae in some species of *Struthiopteris*, p. 380.

‡ This description is chiefly from the U. S. National Museum cotype of *L. sessilifolia*.

veins slightly grooved above, appearing below as distinct, fine lines slightly but not definitely raised, the vein spaces 10–13 to 1 cm., the vein apices often marked by delicate, irregular, deciduous, scalelike growths. Sporophyls at least 100 cm. long; stipe over 22 cm. long (complete stipe not seen); lamina 80 cm. long; pinnae about 60-jugate, 12–15 cm. long, 3–4 mm. wide, the apex with a sterile tip 2–4 mm. long, the base distinctly cordate and petioled, the petioles bearing throughout glandular swellings at the upper side where they join the rachis;* sporangia dark brown; indusium not very heavy, irregularly but quite fully lacerate, apparently quite persistent.

Cotype in the U. S. National Museum, no. 472015, 472016, collected "Sommet du Volcan de Poas," 2,644 m., Costa Rica, *Tonduz 10710*, November 1896.

If not distinct, this could well be considered a mainland form of *S. lineata*. It differs as indicated in the key, and also in having many more pinnae. The only island specimens of *S. lineata* having more than 40 pinnae are the peculiar ones from Santo Domingo which were mentioned under *S. lineata* as quite different from the rest of that species; they, however, do not resemble this plant collected by Tonduz, as they are much heavier in texture and have much narrower laminae.

19. **S. Shaferi** Broadh. sp. nov.

Plants terrestrial. Rhizome evidently large, the scales 1.5–2 cm. long, tufted, rigidly erect, linear, broader at the base, often abruptly so, yellowish brown with a definite dark brown center. Sterile fronds 32–42 cm. long; stipes 3–10 cm. long, smooth to somewhat angulate, straw-colored to brownish, the scales much as on the rhizome, shorter, loosely arranged or disappearing with age; lamina 16–35 cm. long, 14–18 cm. wide, oblong or broadly elliptical (young oblanceolate), abruptly reduced at the base (type D, without vestigial pinnae), usually not reduced at the apex, the terminal pinna 7–11 cm. long, the rachis with much smaller scales or naked; pinnae 10–15-jugate, narrowly oblong to almost linear, straight to somewhat falcate, ascending, 8–11 cm. long, 10–15 mm. wide (through the dilation or auricle), the apex acuminate, entire, the base broadly dilated and fully adnate to the rachis in the upper pinnae, in the lower ones narrowed suddenly below the expansion or auricle on the lower side of the pinna and

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* Each petiole has therefore a peculiar shouldered appearance; a few of the lower sterile pinnae have the same glandular expansion of the petiole.

barely petioled; margins incompletely and very narrowly revolute, entire,[*] not cartilaginous, finely glandular with stalked glands;[†] leaf tissue coriaceous, gray-green or sometimes when dried yellowish brown, much as in *S. Werckleana*, the costal scales smaller or lacking; veins not raised, indistinct, not swollen at their apices, the vein spaces 15 or 16 to 1 cm. Sporophyls 67 cm. long;[‡] stipes 18 cm. long; lamina 47 cm. long, abruptly reduced at the base, not reduced at the apex; pinnae 19-jugate, with a sterile apex 1–2 mm. long, the base decurrently adnate in the upper pinnae, sessile in the lower ones and rounded to cordate, 9.5–11 cm. long, 2–3 mm. wide; sporangia brownish yellow; indusium cartilaginous, fully and regularly lacerate to the base, the sides of the lacerations concavely hollowed, the edges finely fimbriate. [PLATE 27.]

Type in the New York Botanical Garden herbarium, collected at Camp La Gloria, south of Sierra Moa, Oriente, Cuba, *J. A. Shafer 8106*, Dec. 24–30, 1910.

20. **S. striata** (Sw.) Broadh. comb. nov.

Onoclea striata Sw. Syn. Fil. 304; 422. 1806.

Lomaria striata Willd. Sp. Pl. **5**: 291. 1810.

Lomaria Ryani Kaulf. Enum. Fil. 155. 1824.

Lomaria brasiliensis Raddi (?), Pl. Bras. **1**: 50. *pl. 72, 72 bis.* 1825.

Lomaria tuberculata J. Sm.[§] Cat. Kew Ferns. 1856.

Blechnum capense Diels (in part), in E. & P. Nat. Pfl. 1^4: 249. 1899.

Blechnum striatum C. Chr. Ind. Fil. 160. 1905.

Plants terrestrial. Rhizome at least 2.5 cm. thick, the scales 2–3 cm. long, 2–4 mm. wide, varying from dark fawn to burnt umber. Sterile fronds 35–125 cm. long; stipes 15–74 cm. long, clustered, angulate, usually light-colored, dull to shining, the scales lighter, otherwise as on the rhizome, very deciduous, fewer shapeless ones among them than in *S. lineata* or none at all, the

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[*] Wholly entire; not even subserrately margined by the swollen vein apices. In this *S. Shaferi* affords a marked contrast to all the petioled species previously described.

[†] Numerous, tiny, stalked glands are found on the revolute margin. Nothing of the kind has been observed in any other specimens included in this paper. This material is fresher than any other seen (collected in 1911), and this fact may account for the presence of the glands. Conservatory specimens of *S. Underwoodiana*, to which *S. Shaferi* is most nearly related, do not possess similar glands.

[‡] All of the following measurements refer to the single fertile frond seen.

[§] According to Smith himself; Cat. Ferns Br. Gard. 40. 1857.

position of the fallen ones marked by points as in *S. lineata*; lamina 22–71 cm. long, 12–35 cm. wide, broadly lanceolate to broadly oblong (broadly ovate or elliptical in the smaller plants), not at all or slightly reduced at the base (type A, without vestigial pinnae), usually reduced gradually at the apex, not reduced in the smaller forms; pinnae 7–20-jugate, lanceolate to lance-oblong, straight or slightly curved in the outer half or near their apex (falcate in some of the smaller fronds only), 8–20 cm. long, 1.8–3 cm. wide, tapering gradually, if slightly, to the abruptly acuminate, serrate apex, the lower pinnae petioled, the base decidedly cordate; margins revolute; leaf tissue rigid-herbaceous to coriaceous,[*] the costae scaly, fibrillose, or naked, the under surface delicately but often fully araneous on the raised veins; veins distinct, definitely raised below, the vein spaces 12–16 to 1 cm. Sporophyls 40–175 cm. long; stipes 24–118 cm. long; lamina 48–64 cm. long (16–23 in the smaller forms), reduced at the apex, but slightly reduced at the base; pinnae 15–27-jugate (7–15 in the smaller forms) with a sterile tip 5–10 mm. long which is often serrate, the lower petioled and cordate at the base, 7–18 cm. long, 3–6 mm. wide; often whitish-knobbed at the vein ends as in *S. vivipara;* sporangia yellowish brown to dark brown; indusium irregularly lacerate, often to the base.

TYPE LOCALITY: Martinique, St. Kitts (St. Christopher).

DISTRIBUTION: St. Kitts, Montserrat, Guadeloupe, Dominica, Martinique, St. Vincent, and Grenada.

SPECIMENS INCLUDED: ST. KITTS: Forest slopes of Mt. Misery, *Britton & Cowell 511*. GUADELOUPE: (Definite locality not given), altitude 700–900 m., *Duss 4353* (N, no. 524250; Y). DOMINICA: Laudat, *Lloyd 190* (small form, Y). MARTINIQUE: "Bois de la montagne," Pelée, altitude 600–1,000 m., *Duss 1555* (N, no. 524242, 524243; Y). GRENADA: *Sherring 137* (small form, Y, N).

In this as in *S. lineata* there are large and small forms. In both these species the field notes are too scanty to help explain these differences. Small forms have been seen from Guadeloupe, Dominica, Martinique, and Grenada. The Elliott and the Sherring specimens from Grenada have broadly elliptical-oblong to almost square laminae, with curved lower pinnae. These

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[*] Markedly coriaceous in but one plant from St. Vincent ("Souffrière," 2,200 ft. in lava, *Eggers 6911* N), which differs also in having crowded overlapping pinnae which are deeply cordate; the wide fertile pinnae are somewhat abnormal, having cordate, sterile bases. (See also footnote under *S. violacea*, p. 380.)

specimens are not at all reduced at the apex of the lamina; the other smaller forms are but slightly reduced at the apex.

Kaulfuss described *L. Ryani* from Montserrat Island, saying he had seen only young specimens. Despite the reddish woolly character of both surfaces, it probably belongs with *striata*, from which he separates it because of oblong, smooth tubercles on the rachis at the base of the petioles; the lower, bipinnatifid, fertile pinnae suggest that he had an abnormal frond.* Raddi describes his *L. brasiliensis* as intermediate between *lineata* and *striata*. In the shape of the blade and in the small number of pinnae it seems nearer the smaller *S. striata* plants.

21. **S. Underwoodiana** Broadh. nom. nov.

Lomaria Boryana of American authors, not of Swartz.

Blechnum tubulare Diels (in part), in E. & P. Nat. Pfl. 1^4: 249. 1899.

Plants terrestrial. Rhizome "a pronounced trunk,† though mostly underground," the scales 3–3.5 cm. long, linear, rigid, erect, shining, dark brown with a light margin, the whole appearing tobacco brown. Sterile fronds 85–100 cm. long; stipes 18–36 cm. long, often angulate, marked almost throughout by vestigial pinnae, the scales smaller, soon deciduous, suddenly broadened at the base, and mixed with tangled fibrillose deciduous ones, the position of the fallen ones marked by fine points as in *S. rufa;* lamina 58–70 cm. long, 25–32 cm. wide, oblong or broadly elliptical, abruptly reduced at the base (the lower pinnae 4–8 cm. long, type D, with vestigial pinnae), but little reduced toward the apex, the terminal pinna 10–12 cm. long; pinnae 20–30-jugate, narrowly lanceolate to narrowly oblong, straight or slightly curved near their apices, the apex gradually acute to acuminate, the upper pinnae broadly adnate or dilated on the lower side at their bases, the lower ones free in at least half the lamina, the bases never auricled, rounded, sessile to very short-petioled, 15–20 cm. long, 18–24 mm. wide; margins entire, not revolute; leaf tissue rigid-herbaceous,

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* It is possible that the bipinnatifid character may refer to such an abnormality as that mentioned under *S. Schiedeana;* the whole genus *Struthiopteris* does not contain a single species with a bipinnatifid *sterile* frond.

† According to Professor Underwood; Jenman says it is one or more feet high. Professor Underwood thought that Jenman had modified this statement to include *L. Boryana* Sw., which has a caudex 2–3 feet high. A plant now growing at the New York Botanical Garden, which was brought back by Professor Underwood in 1903, has (January 1912) a densely scaly crown 3 cm. high and about 3 cm. broad.

smooth to shining below; costae* flattened on the under side, naked or with reduced scales, the surface never araneous; veins not raised below, the vein spaces 10–14 to 1 cm. Sporophyls (in the only complete one seen) 110 cm. long; stipes 30–40 cm. long, marked at least part way by vestigial pinnae; lamina about 67 cm. long, abruptly reduced at the base, somewhat reduced at the apex; pinnae about 30-jugate, 16–30 cm. long, 3–4 mm. wide, heavy, the upper ones decurrent on the lower side, the lower with occasional basal protuberances;† sporangia dark brown; indusium quite regularly lacerate, and occasionally so to the base. [PLATE 28. This illustration includes a tracing from one of Jenman's unnumbered specimens, showing the usual reduction of the basal pinnae in the sterile lamina.]

Type in the New York Botanical Garden herbarium, collected at New Haven Gap, Jamaica, altitude 5,500 feet, *L. M. Underwood 985*, February 4, 1903.

SPECIMENS INCLUDED: JAMAICA: Base of John Crow Peak, altitude 5,000–5,500 ft., *Underwood 2431* (Y). "Morse's Gap," *Harris 7598* (Y).

This species has long been confused with the species *Boryana* (*Onoclea Boryana* Sw.), originally described from Africa. The original illustration‡ shows a very different plant with fewer, short, elliptical, distant pinnae; the original description mentions an arboreous stem, four feet high, and ovate-oblong pinnae which are obtuse and 5–10 cm. long. Even the descriptions of this species by American authors have been influenced by those of the African *Boryana;* e. g., Jenman describes the Jamaican plant as having an arboreous trunk. It has therefore been necessary to describe the Jamaican species, giving it a new name, *S. Underwoodiana*, for Professor L. M. Underwood, who collected

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* In the other species the costae are definitely raised on the lower side; in this the shining costae look as if smoothed or ironed down.

† See the footnote under *S. violacea*, p. 380.

‡ Bory de St. Vincent, Voy. 2, p. 194, *pl. 32;* a copy is in the Astor Library, New York City; a tracing has been placed in the New York Botanical Garden herbarium.

A small plant, probably *S. Underwoodiana*, was brought to the New York Botanical Garden conservatories by Professor F. S. Earle from Jamaica in 1902. It lived about nine years but never seemed vigorous. In 1911 it had a rhizome 3–5 cm. in diameter, 3 cm. high, and 7 sterile fronds less than 30 cm. high, which were 5–10-jugate only. There were no fertile fronds. The plant in size and number of the pinnae suggested *S. Shaferi;* the laminae were less reduced at the base than in *S. Shaferi*, and the pinnae could hardly be called auricled on the lower side.

the plant in Jamaica. The stem description given above is quoted from a letter by Professor Underwood. He brought back a specimen of the rhizome, but it could not be found during the writing of this paper. He mentioned it as growing "on the summit of the higher ridges, above 5,000 feet, and not common."

22. **S. varians** (Fourn.) Broadh. comb. nov.

Lomaria varians Fourn. Mex. Pl. **1**: 113. 1872.

Blechnum varians C. Chr. Ind. Fil. 161. 1905.

Plants terrestrial. Rhizome (not seen). Sterile fronds 60–90 cm. long; stipes 12 cm. or more (incomplete in the cotype at the New York Botanical Garden), apparently not angulate, maroon, the scales yellowish, early deciduous, narrowly triangular to linear, mixed with fibrillose ones; lamina 48–50 cm. long, 25–28 cm. wide, oblong, the base not reduced (type A, without vestigial pinnae), but slightly or not reduced at the apex, the terminal pinna almost as long as the lateral ones,* the rachis soon becoming naked; pinnae 15–20-jugate, straight, long-lanceolate to narrowly oblong, the apex serrate, rather abruptly long-acuminate, the base subequally rounded, free throughout, petioled, 19 cm. long, 2 cm. wide; margins cartilaginous, irregularly erose-crispate and not revolute; leaf tissue rigid-herbaceous, smooth; veins not raised, the vein spaces 15–18 to 1 cm. Sporophyls,† the stipes 15 cm. long, the "base densely chaffy with long scales," pinnae 25-jugate, with a sterile apex.

TYPE: *Bourgeau 1826;* Herb. von Heurck, no. 1420, Mexico, "Vallée de Cordoba," February 4, 1866 (Y).

DISTRIBUTION: Known from the type locality only.

23. **S. violacea** (Fée) Broadh. comb. nov.

Lomaria violacea Fée, Mém. Foug. **11**: 11. *pl. 5*. 1866.

Blechnum violaceum C. Chr. Ind. Fil. 161. 1905.

Plants terrestrial. Rhizome 2–4 cm. thick (seen only in small specimens), the scales short (5 mm. or less) umber or brown-maroon. Sterile fronds of two types, (1) short and ovate or broadly lanceolate, and (2) larger and oblong, 18–100 cm. long;‡

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* Abnormal in the New York Botanical Garden type number; not reduced, however, in the type number seen either at Kew or Geneva.

† As given in Fournier's incomplete description. They are lacking in the New York Botanical Garden sheets.

‡ Fée says the length may reach 100 cm.; he figures one of the "smaller" specimens which measures 118 cm.; no scale is given, however.

stipes 4–50 cm. long, clustered, somewhat angulate, the color varying from black and reddish black to dark violet, shining where naked, the younger, at least, having scales which are seemingly viscid and which dry as straight or hooked projections (appressed in one large specimen); lamina 13–44 cm. long, 7–25 cm. wide, abruptly reduced at the base (type A, without vestigial pinnae), gradually reduced at the apex, the rachis soon becoming naked and shining; pinnae 12–50-jugate, oblong and lanceolate to narrowly oblong, often opposite below, 4–10 cm. long, 8–16 mm. wide, the apex acute,[*] obtuse or only apparently so in the thicker forms with rolled pinnae, the bases subcordate to cordate or unequally cordate, but 1–4 of the upper pinnae adnate, the rest free, and the lower petioled; margins usually revolute,[†] the pinnae themselves rolled in the heavier forms; leaf tissue coriaceous in the smaller forms, membranous to rigid-herbaceous in the larger ones, costae more or less scaly, under surface smooth;[‡] veins raised below, sunken above in the coriaceous plants, the vein spaces 14–16 to 1 cm. Sporophyls 40–85 cm. long, but taller than the sterile in all complete specimens seen; lamina 20–37 cm. long; pinnae 11–25-jugate, 4–5 mm. wide, the apex obtuse or with a sterile tip 3–7 mm. long, the bases cordate, the lower pinnae distinctly petioled with spurlike protuberances;[§] the margins of the very dark and heavy pinnae often with whitish spots corresponding to the vein apices; sporangia very dark brown; indusium irregularly lacerate.

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[*] Fée says "*tunc obtusiusculis, tunc acuminatis*." Only the smaller specimens seen show the blunt tips.

[†] Irregularly so and serrate in a young, membranous plant from Dominica, *Lloyd 315*.

[‡] Slightly araneous below in *Duss 3710*.

[§] All the fertile fronds of *S. violacea* bear curious spurlike protuberances in or near the axils of most of the lower pinnae. They are plainly discernible to the naked eye and usually 2–5 mm. long. Similar spurs are found with some of the lower pinnae in a few of the petioled species: *S. vivipara*, *S. Christii* (very small), *S. chiriquana* (apparently brittle and deciduous), *S. Schiedeana* (few, but interesting in connection with the twin pinnae seen in one specimen), *S. striata* (in the peculiar volcanic specimen from St. Vincent only, and as flattish glandular areas), and in *S. Underwoodiana*. Fertile fronds of *S. danaeacea* and *S. varians* were not accessible after this character was noted. It does not occur in any of the non-petioled species. (It is present in the fertile lamina of U. S. National Herbarium no. 575235, but there are indications that it does not belong with the sterile one on that sheet.) Hooker (Spec. Fil. 3: 26. 1860) in speaking of the sterile frond of *L. spectabilis* remarks upon a "remarkable, rather large, and distinct black glossy *gland* exactly resembling except in color a very common scale insect. Were it more constant," he adds, "I would consider this a distinct species." No other reference to similar growths on the rachis, either fertile or sterile, has been found; the somewhat abnormal Panama plant included in *S. chiriquana* shows occasional, elongated, glandular areas on the sterile rachis.

TYPE: Fée, Mém. Foug. 11: *pl. 5.* 1866; from Guadeloupe.

DISTRIBUTION: Known from Guadeloupe, Dominica, and Martinique.

SPECIMENS INCLUDED: GUADELOUPE: *Duss 4165* (Y), *Duss 3710* (Y). DOMINICA: Laudat, *Lloyd 315* (Y, N). MARTINIQUE: Montagne Pelée, *Duss 4163* (Y).

This species shows great variation in size, texture, and in the length and apices of the pinnae; most of the smaller coriaceous ones bear legends indicating that they are from high altitudes and the sides of volcanoes. Parallel information is wanting, however, for the larger specimens. The colored stipes and the heavy, lacerate, whitish-dotted fertile pinnae are apparently common to all mature specimens. Fée describes the sterile stipes as bearing short, remote spines, which are not present on our specimens or in his figure; the numerous projections figured on it resemble the dried, viscid scales described above.

24. **Struthiopteris vivipara** Broadh. sp. nov.

Plants terrestrial. Rhizome 3 cm. thick in the fragment seen, the scales very few, 2–2.5 cm. long, 4–6 mm. broad, brown umber, more or less plicate. Sterile fronds 85–90 cm. long; stipes 24–25 cm. long, angulate, vestigial pinnae present throughout, shining mahogany, the scales light brownish yellow, deciduous, shapeless and wholly appressed to the stipe, their attachment indicated as in *S. lineata;* lamina 64–66 cm. long, 28–30 cm. wide, oblong, abruptly reduced at the base (type A, with vestigial pinnae), not reduced at the apex, the terminal pinna 12–15 cm. long, viviparous at or very near the apex of the rachis; pinnae 15–16-jugate, oblong-lanceolate but broadest at the cordate base, straight or occasionally very slightly curved near the apex, the apex acute, never long-acuminate, the base cordate and free throughout, mostly sessile and the rachis covered by the bases of the pinnae, the lower pinnae petioled, 15 cm. long, 3–3.5 cm. wide; margins serrate, slightly or not at all revolute; leaf tissue rigid-herbaceous, the costae much like the stipe but also finely chaffy or fibrillose, the lower surface of the pinnae decidedly and finely araneous over the once forked veins; veins distinctly grooved above, raised below and more perpendicular than in most species of the genus (except the wider *S. striata* specimens), the vein spaces 12–14 to 1 cm. Sporophyls 115–125 cm. long; stipes 34–45 cm. long, vestigial pinnae barely visible; lamina 68–78 cm. long, abruptly reduced at the base, not gradually reduced at the apex; pinnae 15–17-

jugate, 15–17 cm. long, the terminal pinna 11–16 cm. long, 5–7 mm. wide, heavy, sometimes with a sterile apex 2–5 mm. long, the base cordate, petioled (lower 5 mm.), occasionally with spur-like protuberances;* the margins of the pinnae have whitish glands marking many of the vein apices as in *S. violacea;* sporangia very dark brown; indusium narrow, early deciduous, brittle, and very irregularly lacerate. [PLATE 29.]

Type in the U. S. National Herbarium, no. 575810, 575811, and in the New York Botanical Garden, collected on moist banks on the trail in the vicinity of La Palma, Costa Rica, altitude 1,450–1,550 m., *William R. Maxon 435*, May 6–8, 1906.

The type of *S. Christii* is from Costa Rica, but *S. vivipara* is evidently a very different plant. The following differences between the specimen mentioned under *S. Christii* (from Christ's herbarium) and *S. vivipara* may be noted: *S. vivipara* is oblong in shape and not reduced at the tip, the single specimen of *S. Christii* is ovate-lanceolate and gradually reduced at the tip; in *S. vivipara* the stipe and rachis are almost scurfy in appearance, owing to the fine, amorphous character of the wholly appressed scales; in Christ's sheet the scales are mainly definite, at least 1 cm. long, and appressed only at their bases, the stipes looking much like very scaly *S. lineata* stipes. The viviparous character may not prove constant, but it appears in each of the five fronds seen.

25. S. **Werckleana** (Christ) Broadh. comb. nov.

Lomaria Werckleana Christ, Bull. Boiss. II. 4: 1091. 1904.

Blechnum Werckleanum C. Chr. Ind. Fil. 161. 1905.

Plants terrestrial. Rhizome apparently subarboreous, the scales linear, 2.5–3 cm. long, shining, rigid, erect, with a darker center, tobacco brown to umber. Sterile fronds 115–140 cm. long; stipes† 58 cm. long, but slightly angulate, usually marked to the base with vestigial pinnae, the scales like those of the rhizome but smaller and soon deciduous; lamina 83–110 cm. long, 15–25 cm. wide, narrowly oblong, the base abruptly reduced (type A, with vestigial pinnae), gradually reduced at the apex, the rachis "spangled by scales" which are narrow, fibrillose, and mixed with *hoary* ones, forming fine, webbed masses on the rachis;

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* See footnote under *S. violacea*, p. 380.

† All the following figures are the measurements of the only complete fronds seen: two sterile fronds and one fertile one; they are Wercklé's own specimens and from Christ's herbarium.

pinnae 35–50-jugate, narrowly oblong, the apex abruptly acuminate, slightly curved, not serrate, the base cuneate to somewhat rounded, petioled in all the lower ones, 12–15 cm. long, 13–17 mm. wide; margins entire, not revolute; leaf tissue coriaceous, yellowish below when dried; lower surface deciduously araneous with yellowish fibrillose scales, the costae also with fibrillose scales; veins not prominent yet distinct, the vein spaces 18–20 to 1 cm. Sporophyls 143 cm. long; stipes 66 cm. long; lamina abruptly reduced at the base; somewhat reduced at the apex; pinnae 40–50-jugate, 22–26 cm. long, 3–4 mm. wide, curved or twisted, heavy, very much reflexed in drying, the sterile (ventral) surface not visible; sporangia brownish yellow; indusium delicate, fawn to light tan, quite regularly lacerate to the base, the margin finely fimbriate.

TYPE: *Wercklé 169*, from Costa Rica.

DISTRIBUTION: Known from Costa Rica only.

SPECIMENS INCLUDED: Several sheets without collection number from Costa Rica collected by Wercklé, now in the U. S. National Museum (no. 575241, 575242, and 575243) and in the New York Botanical Garden.

This species is conspicuously different from any other species, both the sterile and the fertile fronds. Among the several characters given in the description the white or hoary, fibrillose scales of the rachis are perhaps the most peculiar, while the long, curved, fertile pinnae, very much lighter in color (sporangia and indusia) than in any other North American species, are the most striking.

Many foreign species have been incorrectly attributed to North America; e. g., even American writers have included in their local flora *Lomaria attenuata* Willd., *L. procera* Spreng., and *L. Schomburgkii* Klotzsch. The tonguelike tips and bases of the pinnatifid leaves of *attenuata* Willd. differentiate it from *S. polypodioides* with which it has been confused. Under *Lomaria procera*, Sprengel cites *Osmunda procera* Forst. The name was first used for a New Zealand species with remote or distant pinnae, which were ovate-oblong in shape. An early picture in Labillardière gives two forms of pinnae, neither of which resembles *S. lineata* or *S. striata* with which it is most commonly confused. A fragment of the type of *L. Schomburgkii* has such characteristic pinnae that it should not be made synonymous with any North American species; under it, however, Christensen places the species *L. rufa* Spreng. and *L. Ryani* Kaulf.

There is much need of more material from Central America;

except a few specimens from Guatemala there is very little from the region between Costa Rica and Mexico. Seven of the above twenty-five species have Costa Rica or Panama as type locality; for none of these, however, have we a sufficient number of specimens to be sure that our descriptions indicate the variation that might reasonably be expected. Much that we have is worth little because of its fragmentary condition; several of the specimens given under INQUIRENDAE are from this region.

The collections recently made by J. A. Shafer indicate that Cuba offers similar rewards and difficulties.

INQUIRENDAE*

1. One sheet from Costa Rica, *Pittier 1921*, "Forêts du Barba, versant Pacifique," 2,500–2,700 m., 1890 (N), with broad elliptical pinnae a little like *S. rufa* in shape, but differing in size, coloring, and in the serrate margin with definitely marked vein apices. A young specimen, U. S. National Museum no. 834094 ("Volcan de Poas, Alfaro, San José," Costa Rica, altitude 2,300 m., 1902), may belong with this.

2. One sheet from Costa Rica collected by J. J. Cooper, U. S. National Museum no. 154303, November 1886; the slender, fertile pinnae are 25–28 cm. long, and the sori are continued on the dilated, non-petioled, *decurrent* bases of the pinnae. No petioled species has such fertile fronds.

3. One sheet from Costa Rica collected by Wercklé 1901–1905; (the specimen is an unnumbered one from Christ's herbarium and bears the name *Lomaria procera*, below which is written Lysr.). The fibrillose midribs and rachis separate it from *S. costaricensis*, *S. lineata*, and *S. striata*, to which it is nearest. The fertile leaf is lacking, though I strongly suspect it is the one mounted with the sterile frond on the U. S. National Museum sheet no. 575235.

4. One sheet (part of a sterile leaf) from Costa Rica, collected by Wercklé, U. S. National Museum no. 575240, is wrongly labeled *B. Werckleana;* it differs from the description and Christ's other specimens in texture, color, proportion, the margin, the bases of the pinnae, and in size. A pinna was sent to Christ, but he

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* This section includes only the unplaced material not already discussed in connection with the various species.

found the material too incomplete to name satisfactorily. With this might be placed another fragment (one pinna) from Costa Rica, *Hoffman 36*.

5. Two sheets from Guatemala, *Cook & Griggs 161* and *578*, near the Finca Sepacuite, Alta Verapaz (N); the long terminal pinnae suggest the smaller forms of *S. Schiedeana*, but they are heavier in texture and the bases of the pinnae are subcordate to cordate.

6. Two sheets (fragments) from St. Vincent, *H. H. & G. W. Smith 1023* (Y). Their coloring, their flattened, shining costae, which resemble those of *S. Underwoodiana*, and their falcate pinnae distinguish them from *S. striata*, which they otherwise suggest. They are not at all like the deeply cordate, coriaceous specimen from St. Vincent discussed under *S. striata*.

TEACHERS COLLEGE,
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Contributions to the Mesozoic flora of the Atlantic coastal plain—
VIII. Texas*

EDWARD W. BERRY

(WITH PLATES 30–32)

The following annotated list of fossil plants is based on a small collection from the Woodbine formation, made at Arthurs Bluff on the Red River in Lamar County, Texas, by Doctors T. W. Stanton and L. W. Stephenson in 1911 for the U. S. Geological Survey.

The presence of fossil plants in the Cretaceous strata of Lamar County has been known for half a century as is shown by a letter from Dr. B. F. Shumard, dated Oct. 2, 1860, read before the Academy of Science of St. Louis at its session of Nov. 5, 1860, and quoted on page 140 of the printed Transactions.† Dr. B. F. Shumard, at that time state geologist of Texas, states that his brother Dr. G. G. Shumard discovered numerous dicotyledonous leaves resembling the modern leaves of *Salix*, *Ilex*, *Laurus*, etc., in the Cretaceous yellowish sandstones of Lamar County near the Red River. These were undoubtedly from the locality now known as Arthurs Bluff, which has furnished the subsequent collections. Dr. Shumard further states that these plants were sent to Leo Lesquereux for determination, but if sent they were apparently lost in transit.‡

When R. T. Hill took up the study of the Texas Cretaceous, new collections were made between 1880 and 1885 at Arthurs Bluff and at Denison, the latter a locality originally discovered by Dr. Shumard. These collections were, according to Hill, sent to the U. S. National Museum and lost in storage. Finally in Hill's great work on the Texas Cretaceous§ Dr. F. H. Knowlton furnished a report on collections of fossil plants from the Woodbine formation

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* Published with the permission of the Director of the U. S. Geological Survey.

† Trans. Acad. Sci. St. Louis **2**: 140. 1868.

‡ Lesquereux, Cretaceous Flora, U. S. Geol. Surv. Terr. **6**: 11. 1874.

§ Hill, Geography and Geology of the Black and Grand Prairies, Ann. Rep. U. S. Geol. Surv. **21**^{7}: 314–318. *pl. 39.* 1901.

at Arthurs Bluff, Lamar County; Woodbine, Cooke County; and Denison, Grayson County.

The largest of these collections is the one from Arthurs Bluff, which was made in 1894 by Dr. T. Wayland Vaughan. The plants are preserved in a fragmentary state in a yellowish sandy clay or loose sandstone. Dr. Knowlton identified the following species from this locality:

Aralia Wellingtoniana Vaughanii Knowlton
Benzoin venustum (Lesq.) Knowlton
Diospyros primaeva Heer
Ficus glascoeana Lesq.?
Liriodendron pinnatifidum Lesq.?
Myrica longa (Heer) Heer
Phyllites rhomboideus Lesq.
Platanus primaeva Lesq.
Sapindus Morrisoni Heer?
Salix deleta Lesq.
Viburnum robustum Lesq.

The collection from Woodbine in Cooke County was made by G. H. Ragsdale and is reported as containing:

Andromeda Pfaffiana Heer
Cinnamomum ellipsoideum Sap. & Mar.
Cinnamomum sp.?
Diospyros primaeva Heer
Eugenia primaeva Lesq.
Phyllites aristolochiaeformis Lesq.?

The collection from Denison, Grayson County, was made by T. V. Munson from two outcrops in that town, Munson Hill, from which Dr. Knowlton is unable to identify any forms specifically, and Rhamey Hill, from which the following are recorded:

Cinnamomum Heerii Lesq.
Diospyros Steenstrupi Heer
Inga cretacea Lesq.
Laurus proteaefolia Lesq.
Liquidambar integrifolium Lesq.
Magnolia Boulayana Lesq.
Magnolia speciosa Heer
Populus sp.?
Salix sp.?

Confining any comments to the collection studied by the writer we may note that out of a total of 27 species, three species and one variety of which are new, seventeen are forms either described or recorded from the Dakota group. It is greatly to be regretted that no very precise stratigraphic significance can be attached to any particular units of the Dakota group flora, since the Dakota group materials have been recognized over a very wide area in a more or less unscientific way and no careful stratigraphic-paleobotanic work has ever been carried out.

Since the Woodbine formation of northeastern Texas undoubtedly represents deposits laid down during a part of Dakota group time, they should naturally contain this large Dakota group element. If we judge by the range of the Woodbine species that occur in the Cretaceous of the Atlantic coastal plain as shown in the appended table, the Woodbine represents an earlier rather than a later part of the Dakota interval. Eleven Woodbine species are found in the lower Raritan, eleven in the upper Raritan, eleven in the Magothy, and fifteen in the lower Tuscaloosa of western Alabama. From extensive studies of this large lower Tuscaloosa flora it seems probable that its basal portion represents the time equivalent of the uppermost Raritan, and there are sixteen species from these two horizons represented in the Woodbine collection. The small representation in the upper Tuscaloosa is without chronologic significance, since it merely reflects our present lack of knowledge of the constituents of this upper Tuscaloosa flora. The presence of only five of these species in the Black Creek-Middendorf beds of the Carolinas, while it probably indicates that the latter are in the main younger than the Woodbine,* would be more impressive if all five were not extremely abundant and wide-ranging forms, all being present in either the lower Raritan or the lower Tuscaloosa. Only two species are found in the lower Eutaw, the older character of the Woodbine flora being particularly emphasized by the absence of the characteristic gymnosperms, such as *Araucaria bladenensis* Berry, *Araucaria Jeffreyi* Berry, *Sequoia*, *Cunninghamites*, *Tumion*, the two species of *Androvettia*, etc. In fact, the Woodbine flora is remarkable by reason of the almost total absence of gymnosperms, only two forms, *Brachyphyllum macrocarpum formosum* and *Podozamites lanceolatus*, being represented in the present collection, and none being recorded in the previous collections studied by Knowlton.

Our knowledge of the Woodbine flora is much too limited for any positive conclusions regarding the botanical or physical conditions that attended its development; and larger collections are much to be desired, since the small collections studied by the writer and by Dr. Knowlton indicate the presence in these beds of a large and varied, even if fragmentarily preserved, flora. This, when collected and studied, may be expected to show the relation between the Dakota flora and that from the Cheyenne sandstone of

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* I regard the Middendorf as the equivalent of a part of the Tuscaloosa and the typical Black Creek as representing the upper Tuscaloosa and lower Eutaw.

southern Kansas, so that eventually we will know what are the older and what the younger elements in the Dakota flora.

Seven species in the Arthurs Bluff collection extend northward along the Atlantic coastal plain to western Greenland, and four additional species in the lists of Woodbine plants quoted from Knowlton's report have a like distribution. These are sufficient to indicate that climatic conditions at this time in the Upper Cretaceous were much more uniform than they are at the present time. A consideration of the large collections from the Tuscaloosa formation of Alabama shows that the latter, when compared with the contemporaneous Greenland flora, while essentially similar, contains additional elements that may legitimately be regarded as tropical or subtropical. It seems evident that while the differences in climate between Greenland and Texas were infinitely less in Woodbine time than they are today, there was a distinct

	Dakota group	Lower Tuscaloosa	Upper Tuscaloosa	Lower Raritan	Upper Raritan	Magothy	Black Creek-Middendorf	Lower Eutaw
Andromeda Novae-caesareae Hollick	....	×	....	....	×	×	×	×
Andromeda Snowii Lesq	×	....	....	....	....	....	....	....
Aralia Wellingtoniana Lesq	×	....	....	×	....	....	....	....
Benzoin venustum (Lesq.) Kn.?	×	....	....	....	....	....	....	....
Brachyphyllum macrocarpum formosum var. nov	....	×	....	....	....	×	×	×
Cinnamomum membranaceum (Lesq.) Hollick	×	....	....	....	....	×	....	....
Colutea primordialis Heer	....	....	....	×	×	....	....	....
Cornophyllum vetustum Newb	....	×	....	×	....	....	....	....
Eucalyptus Geinitzi (Heer) Heer	×	×	×	×	×	×	×	....
Ficus daphnogenoides (Heer) Berry	×	×	....	×	×	×	×	....
Laurophyllum minus Newb	....	....	....	....	×	....	....	....
Laurus plutonia Heer	×	×	....	×	×	×	×	....
Liriodendron quercifolium Newb	....	....	....	×	....	....	....	....
Magnolia speciosa Heer	×	×	....	×	....	×	....	....
Malapoenna falcifolia (Lesq.) Kn.?	×	×	....	....	....	×	....	....
Myrica emarginata Heer	×	×	....	×	×	....	....	....
Oreodaphne alabamensis sp. nov	....	×	....	....	....	....	....	....
Palaeocassia laurinea Lesq	×	×	....	....	....	....	....	....
Podozamites lanceolatus (L. & H.) Braun	×	....	....	×	×	×	....	....
Populus harkeriana Lesq	×	....	....	....	×	....	....	....
Rhamnus tenax Lesq	×	×	....	....	....	....	....	....
Rhus redditiformis sp. nov	....	....	....	....	....	....	....	....
Sapindus Morrisoni Lesq	×	×	....	....	×	×	....	....
Sterculia lugubris Lesq.?	×	....	....	....	....	....	....	....
Tricalycites papyraceus Newb	....	×	....	×	×	?	....	....
Viburnum robustum Lesq.?	×	....	....	....	....	....	....	....
Zizyphus lamarensis sp. nov	....	×	....	....	....	....	....	....

increase in mean annual temperatures in proceeding southward from the latitude of Greenland.

Conditions comparable to those of Woodbine time occur in those areas where the tropical flora extends many degrees farther than its normal range to the north or south of the equator, becoming more or less mixed with temperate elements to form the flora typical of temperate rain forests like that of New Zealand, so often cited. The extension of the Upper Cretaceous flora southward across the present torrid zone indicates less torrid conditions during the Cretaceous than in the present day tropical belt, so that it will be extremely difficult, even if it ever becomes possible, to discriminate between subtropical and warm temperate Cretaceous climates, and to assert with any confidence that the imaginary line separating the two shall be placed in the South Atlantic or Middle Atlantic states or still farther to the northward.

The appended table shows the range in the United States of the species discussed in the following notes:

GYMNOSPERMAE

PODOZAMITES LANCEOLATUS (L. & H.) F. Braun

Zamia lanceolata Lind. & Hutton, Foss. Fl. **3**: 121. *pl. 194.* 1836.
Podozamites lanceolatus F. Braun, in Münster, Beitr. Petref. **2^6**: 33. 1843.

This form, described originally from the English Oolite, has a very wide recorded geological and geographical range. A large number of Jurassic varieties have been described, and indistinguishable forms occur in both the Lower and Upper Cretaceous of both America and Europe. In the Upper Cretaceous it occurs in the Raritan formation from Long Island to Maryland and in the Cenomanian of Bohemia, as well as in the Dakota group of Kansas.

While it is almost inconceivable that these similar detached leaflets from such various horizons represent a single botanical species, no criteria other than the unsafe one of stratigraphic position are available for their discrimination. The Arthurs Bluff collection contains a single perfect and typical leaflet, and whether it is specifically identical with all of the other forms referred to this species or not, it is of great interest in showing the presence of a gymnosperm of this type in the Woodbine flora.

Brachyphyllum macrocarpum formosum var. nov.

Brachyphyllum macrocarpum Berry, Bull. Torrey Club **37**: 183. 1910; **38**: 420. 1911. (Not Newberry, 1896.)

DESCRIPTION: Slender elongated twigs, pinnately branched, covered with medium-sized, crowded, appressed leaves, spirally arranged. Leaves bluntly pointed, relatively smooth, thick. (PLATE 30.)

In the consideration of the various specimens that have been referred to *Brachyphyllum macrocarpum* Newberry, a very considerable variation within certain fixed limits is at once obvious. This variation is usually one of size, the more slender specimens being at the same time more elongated and smoother. This has been frequently noted by the writer and is commented upon in print by Dr. F. H. Knowlton,* who in discussing the later forms (from Wyoming) suggests that the species on the verge of extinction became smaller in its proportions.

In studying the material from the South Atlantic and Gulf States a constant difference in size was noticed by the writer. This may reflect a slight difference in climatic conditions, and all of the forms may be interpreted as the variations of a single species, in fact, one of Newberry's figures† of a Raritan specimen is approximately the same size as the forms from the Montana group of the West and is associated with the normal, stout, club-shaped type. That the variety has no particular stratigraphic significance is indicated by its abundance at a horizon as old as the basal Tuscaloosa formation in Alabama and its presence in the Woodbine formation. In general, however, it occurs at later and more southern horizons than the type. This might be ascribed to the fact that only the slender and more elongated terminal twigs are preserved at these localities; but such an explanation is regarded as improbable, since the same reasoning should hold good for the areas where only the thicker twigs have been found.

The remains are usually much macerated and broken, and this is eminently true of the three specimens from Arthurs Bluff. The warrant for describing them as a new variety is furnished by the

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* Knowlton, Bull. U. S. Geol. Surv. 163. 29. *pl. 4. f. 5, 6.* 1900.

† Newberry, Mon. U. S. Geol. Surv. 26: 51. *pl. 7. f. 1–7.* 1896 (see *f. 7*).

discovery of a large and rather complete specimen in the Magothy formation of Maryland. The latter shows the terminal part of two approximately parallel and curved twigs, about 12 cm. in length, united proximad. These in their thickest portion are only 6 mm. in diameter. At intervals of from 3 mm. to 5 mm., subopposite lateral branches are given off in a pinnate manner. These are relatively much elongated, curved, and slender, averaging about 4 cm. in length by 2 mm. in diameter, bluntly pointed and not tapering to any appreciable extent. These have been infrequently observed to fork pseudo-dichotomously, and at times they give off toward their distal ends tiny lateral branchlets less than a centimeter in length and about one millimeter in diameter. The general proportions are thus decidedly different from the parent type. The leaves are slightly smaller and smoother and somewhat more elongated in their relative proportions, at the same time lacking the apical papillae and the convergent striae. The new variety is much more graceful than the type in appearance, and in its general aspect suggests the Lower Cretaceous genus *Arthrotaxopsis*. The most closely allied form appears to be one from the Albian of Portugal, described by Saporta* as *Brachyphyllum obesiforme elongatum*. There is also considerable resemblance to *Brachyphyllum crassicaule* Fontaine of the Patapsco formation in Maryland and Virginia. Remains of this new variety are associated with the type in Maryland; they are abundant throughout the Tuscaloosa of Alabama, ranging upward into the basal part of the Eutaw formation in both Alabama and western Georgia.

MYRICALES (?)

MYRICA EMARGINATA Heer

Myrica emarginata Heer, Fl. Foss. Arct. **6**^{2}: 66. *pl. 4. f. 2.* 1882. —Lesquereux, Mon. U. S. Geol. Surv. **17**: 67. *pl. 12. f. 1.* 1892.—Newberry, Mon. U. S. Geol. Surv. **26**: 62. *pl. 41. f. 10, 11.* 1896.—Berry, Bull. N. J. Geol. Surv. **3**: 104. *pl. 10. f. 5.* 1911.

Leaves obovate in outline, widest at the rounded-truncate and more or less emarginate apex. Margins entire, narrowing to the cuneate base. Midrib medium stout, inclined to be somewhat

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*Saporta, Fl. Foss. Portugal 176. *pl. 31. f. 14.* 1894.

flexuous. Secondaries about five thin subopposite pairs, diverging from the midrib at angles of about 45 degrees, camptodrome.

A single but entirely typical leaf of this species is contained in the collection. It is identical with the remains of this species as they occur in the basal part of the Tuscaloosa formation in Alabama and in the Dakota sandstone of Kansas. It is relatively wider and more robust than the type material from the Atane beds of Greenland, being intermediate in character between the type material and that referred to this species from the Raritan formation of New Jersey. Its reference to the genus *Myrica* is entirely problematical.

SALICALES

POPULUS HARKERIANA Lesq.

Populus harkeriana Lesq. Fl. Dakota Group 44. *pl. 46. f. 4.* 1892. —Hollick, Mon. U. S. Geol. Surv. **50**: 49. *pl. 7. f. 31.* 1907.

This species was described by Lesquereux from the Dakota group at Fort Harker, Kansas, and was subsequently recorded by Hollick from the Cretaceous material (Raritan or Magothy) in the terminal moraine near Tottenville, Staten Island. The Arthurs Bluff collection contains a single specimen and its counterpart showing half of a large typical leaf of this species. There is also an undeterminable species of the *Populus* type in the collection.

URTICALES

FICUS DAPHNOGENOIDES (Heer) Berry

Proteoides daphnogenoides Heer, Phyll. Crét. Nebr. 17. *pl. 4. f. 9, 10.* 1866.

Ficus daphnogenoides Berry, Bull. Torrey Club **32**: 327. *pl. 21.* 1905.

This species was described originally from the Dakota group of Nebraska by Heer. It is a widespread and common Upper Cretaceous form ranging from Marthas Vineyard to Alabama in the Atlantic coastal plain and from Northwest Territory to Kansas and Nebraska in the western interior. It is abundant in the lower part of the Tuscaloosa formation in western Alabama. The Arthurs Bluff collection contains three fragmentary specimens showing the characteristic attenuated tip of this species.

Figs are apparently much less abundant in the Woodbine than in the Tuscaloosa formation on the eastern shore of the Cretaceous Mississippi embayment.

RANALES

MAGNOLIA SPECIOSA Heer

Magnolia speciosa Heer, Neue Denks. Schw. Gesell. **23**: 20. *pl. 6. f. 1; pl. 9. f. 2; pl. 10. f. 1.* 1869.—Knowlton, Ann. Rep. U. S. Geol. Surv. **21**^{7}: 318. 1901.

A single small leaf of this species is contained in the collections from Arthurs Bluff. *Magnolia speciosa* was described by Heer from the Cenomanian of Moravia, and subsequently it has been found to have a wide range in North America, being recorded from the Dakota group and from the Raritan and Magothy formations along the Atlantic coast. In Alabama it is confined to the lower part of the Tuscaloosa formation, where it is abundant. It was reported by Knowlton (loc. cit.) in 1901 in a small collection from the Woodbine formation at Rhamey Hill, Denison, Texas, made by T. V. Munson of Denison.

LIRIODENDRON QUERCIFOLIUM Newberry

Liriodendron quercifolium Newb. Bull. Torrey Club **14**: 6. *pl. 62. f. 1.* 1887; Fl. Amboy Clays 81. *pl. 51. f. 1–6.* 1896.—Berry, Bull. N. J. Geol. Surv. **3**: 138. *pl. 17. f. 1.* 1911.

This species was described a quarter of a century ago by Newberry from the middle Raritan of Woodbridge, N. J., to which locality it has been hitherto confined. It is a very characteristic leaf with a broadly emarginate summit and three or four pointed laterally directed lobes on each side, separated by relatively narrow sinuses. The venation is of the *Liriodendron* type with strong secondaries.

While the present determination is based upon a single incomplete specimen, it is undoubtedly a fragment of this species and is about as complete, as well as similar in outline and size, as Newberry's *fig. 2.* It shows the two upper lateral lobes of one side of a leaf, separated by a sharp, not deep sinus, separated from a larger but similar basal lateral lobe by a deeper and broader sinus, and is absolutely characteristic.

Knowlton (loc. cit.) has recorded *Liriodendron pinnatifidum* Lesq., doubtfully, and *Liriodendron Snowii* Lesq., positively, from

Arthurs Bluff, but neither of these species is represented in the present collection. Both are characteristic forms and so different that there is no possibility of confusing them with the species just discussed.

ROSALES

PALAEOCASSIA LAURINEA Lesq.

Palaeocassia laurinea Lesq. Fl. Dakota Group 147. *pl. 64. f. 12.* 1892.

This species was described from the Dakota group of Kansas, to which it has been hitherto confined. As interpreted by Lesquereux, its describer, the remains represented leaflets of a *Cassia*-like plant, although so far as I know, all have been found detached, the only basis for considering them leaflets rather than leaves being their slight inequilateral form.

A single entire leaf is contained in the collection from Arthurs Bluff. It is identical with the type material from Kansas in size, outline, and venation, with the exception that it is slightly wider (2–5 mm.) with a consequently somewhat fuller and more rounded base. It has recently been detected in the lower Tuscaloosa of Alabama.

COLUTEA PRIMORDIALIS Heer

Colutea primordialis Heer, Fl. Foss. Arct. **6**^{2}: 99. *pl. 27. f. 7–11; pl. 43. f. 7, 8.* 1882.

This well-marked little species was described from the Atane beds of Greenland. It occurs in strata at least as old as the upper Raritan in New Jersey and is present in both the Dakota and Magothy floras.

The collection from Arthurs Bluff contains a single complete and in every way typical leaf of this species.

SAPINDALES

SAPINDUS MORRISONI Lesquereux

Sapindus Morrisoni Lesq.; Heer, Fl. Foss. Arct. **6**^{2}: 96. *pl. 40. f. 1; pl. 41. f. 3; pl. 43. f. 1a, b; pl. 44. f. 7, 8.* 1882.—Knowlton, Ann. Rep. U. S. Geol. Surv. **21**^{7}: 317. 1901.

This species was described by Heer from the Atane beds of west Greenland and identified with the manuscript species of the same name which Lesquereux had given to a Dakota group plant from Morrison, Colorado. It is a common Dakota group form occurring also in the Raritan, Tuscaloosa, and Magothy formations of the Atlantic coastal plain. Fragmentary specimens occur in the collection from Arthurs Bluff, where it was also recorded by Knowlton in 1901 (loc. cit.).

Rhus redditiformis sp. nov.

DESCRIPTION: Leaves compound, probably trifoliate. Leaflets petiolate, ovate in outline, with bluntly pointed tips, cuneate bases, and entire or undulate margins forming occasional distal shallow broadly rounded lobules separated by broad shallow sinuses. Terminal leaflet nearly equilateral, about ⅓ larger than the lateral leaflets, about 4 cm. in length by 2 cm. in maximum width, which is about midway between the apex and the base; petiolule 5 mm. long; midrib stout, prominent; secondaries thin, 5 or 6 alternate pairs, branching from the midrib at angles of about 50°, curving slightly upward, anastomosing close to the entire margin. Lateral leaflets inequilateral, the outer limb of the lamina being slightly wider and fuller than the inner limb; petioles shorter than that of the terminal leaflet, 2–3 mm. in length, diverging from the latter at angles of about 70°; in outline and venation similar to the terminal leaflet, but smaller and showing a tendency to develop slight irregularities in the margin, especially toward their tips. (PLATE 31, FIG. 2.)

This species is obviously new and is named from its rather striking resemblance to the European early Tertiary species *Rhus reddita* Saporta* from Aix in southeastern France. Several Cretaceous species of *Rhus* have been described from horizons as old as the Woodbine, the Dakota group of Kansas furnishing three well-marked species with pinnate leaves, one of which *Rhus Uddeni* Lesquereux† is reported by Ward from the so-called Cheyenne sandstone at Belvidere, Kansas. A small toothed species has been described by Velenovsky‡ from the Cenomanian sandstone of Bohemia as *Rhus cretacea*, although this name was already in use for a very different Cretaceous species described by Heer§ from the Senonian of Quedlinburg in Saxony and recorded by Hollick‖ from the Upper Cretaceous of Long Island. The Woodbine

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* Saporta, Études 1: 124. *pl. 13. f. 2, a, b.* 1862.

† Lesquereux, Mon. U. S. Geol. Surv. 17: 154. *pl. 57. f. 2.* 1892.

‡ Velenovsky, Fl. Böhm. Kreidef. 4: 7. *pl. 4. f. 7–12.* 1885.

§ Heer, Fl. Quedlinburg 14. *pl. 3. f. 11.* 1872.

‖ Hollick, Mon. U. S. Geol. Surv. 50: 87. *pl. 33. f. 2.* 1907.

species is readily distinguishable from all of the foregoing and adds a well-marked and probably trifoliate Cretaceous form to this genus, which is so largely developed during Tertiary times. In the existing flora *Rhus* is a prominent element with upwards of 150 species, which are for the most part natives of warm temperate and tropical regions. A modern species with almost identical foliage is *Rhus villosa* L., a south African form.

OCCURRENCE: Woodbine formation, Arthurs Bluff, Red River, Lamar County, Texas.

COLLECTION: U. S. National Museum.

Zizyphus lamarensis sp. nov.

DESCRIPTION: Leaves elliptical in outline, 4.5 cm. to 5 cm. in length by 3 cm. in maximum width about midway between the apex and the base, slightly nearer the latter; base full and rounded; lateral margins full and rounded; apex rounded, slightly less full than the base; margin with regular but shallow crenate teeth becoming less prominent toward the base. Midrib slender but prominent, straight. Lateral primaries one on each side, diverging from the midrib at its extreme base at an acute angle (about 10°), thin, slightly curved inward above their middle, joining a secondary in the apical part of the leaf. Secondaries from the midrib two or three alternate thin pairs in the apical region, camptodrome; secondaries from the lateral primaries five or six in number, on the outside, curved, camptodrome; the lowest secondary is longest and branches at the most acute angle (about 10°) and from the extreme base, each successively higher secondary subtending a slightly larger angle and following a somewhat shorter course. Internal tertiaries more or less percurrent, marginal ones similar to the secondaries from the primaries in their arrangement and course, thin and camptodrome. (PLATE 31, FIG. 1.)

This handsome species of an undoubted *Zizyphus* is unfortunately represented by very scant material. It is entirely distinct from any described Cretaceous species and is much closer to various Tertiary and still existing forms. It has recently been detected in the lower Tuscaloosa of Alabama.

RHAMNALES

RHAMNUS TENAX Lesquereux

Rhamnus tenax Lesq. Am. Jour. Sci. **46**: 101. 1868; Fl. Dakota Group 170. *pl. 38. f. 6.* 1892.

This species was described many years ago by Lesquereux from the Dakota sandstone of southern Kansas and subsequently reported by Bartsch from the same horizon in Iowa. It is abundant in the lower Tuscaloosa of western Alabama, and a single characteristic specimen is contained in the Arthurs Bluff collection.

MALVALES

STERCULIA LUGUBRIS Lesquereux?

Sterculia lugubris Lesq. Cret. and Tert. Fl. 81. *pl. 6. f. 1–3.* 1883.

This species is apparently represented at Arthurs Bluff by the single specimen figured, which agrees very well with the Dakota group forms of *Sterculia lugubris.* It is queried since it may represent a slender almost parallel-margined form of *Aralia Wellingtoniana Vaughanii* Knowlton, which is so common at this locality. (PLATE 31, FIG. 3.)

THYMELEALES

BENZOIN VENUSTUM (Lesq.) Knowlton

Lindera venusta Lesq. Fl. Dakota Group 95. *pl. 16. f. 1, 2.* 1892.

Benzoin venustum (Lesq.) Knowlton, Bull. U. S. Geol. Surv. **152**: 47. 1898; Ann. Rep. U. S. Geol. Surv. **21**: 317. *pl. 39. f. 2.* 1901.

This is a trilobate Dakota group species, described originally from Kansas and identified by Knowlton in 1901, in a collection made at Arthurs Bluff by T. W. Vaughan.

The present collection contains two fragmentary specimens which I have little hesitancy in referring to this species, especially as it has already been reported from this locality.

MALAPOENNA FALCIFOLIA (Lesq.) Knowlton?

Litsea falcifolia Lesq. Fl. Dakota Group 97. *pl. 11. f. 5.* 1892.

Malapoenna falcifolia (Lesq.) Knowlton, Bull. U. S. Geol. Surv. 182: 142. 1898.

This species was described from the Dakota group of Kansas by Lesquereux and recorded by the writer from the Magothy formation in New Jersey. The Arthurs Bluff collection contains a single specimen of the lower half of a leaf which is doubtfully identified as this species. It is clearly distinguishable from

Malapoenna horrellensis Berry,* of the Black Creek formation in North Carolina, by its suprabasilar primaries and cuneate base but may possibly be a fragment of *Cinnamomum Newberryi* Berry.†

Oreodaphne alabamensis sp nov.

DESCRIPTION: Leaves of large size, ovate in general outline, ranging from 13 cm. to 20 cm. in length, and from 4.75 cm. to 7 cm. in maximum width, which is at a point about midway between the apex and the base. From the point of greatest width the margins curve, both distad and proximad, in a very full curve, narrowing rather abruptly to the acuminate tip and also to the more or less decurrent base. Midrib stout, curved. Lateral primaries opposite, one on each side, branching from the midrib at an acute angle a considerable distance above its base, rather straight in their course, thinner than the midrib. Above the primaries there is an interval, and then about six pairs of thin, curved, approximately parallel, camptodrome secondaries branch from the midrib at acute angles. The lateral primaries give off on the outside numerous regularly spaced and approximately parallel curved camptodrome secondaries, the latter feature serving to distinguish this species from other fossil species of this genus, and from *Cinnamomum*, *Cocculus*, or other genera with somewhat similar leaves with which it might be compared. Texture coriaceous. (PLATE 32.)

This fine large species is represented at Arthurs Bluff by fragmentary but characteristic specimens. The foregoing description and the figure are drawn from abundant and complete material collected by the writer from the lower Tuscaloosa of western Alabama. It shows considerable variation in size and some in outline, the latter dependent on whether the leaf is widest nearer to or farther from the base. In the latter case the distal part is more fully rounded and abruptly contracted to the acuminate tip, while the base is more gradually narrowed and finally cuneate rather than decurrent. In the former case the apical portion is more gradually narrowed and the base is full and rounded abruptly, decurring to the petiole.

This species is markedly different from previously described fossil forms but may be matched by several modern tropical American species of *Oreodaphne*. The genus *Oreodaphne* of Nees,

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* Berry, Bull. Torrey Club 37: 198. *pl. 24. f. 1–9.* 1910.

† Berry, loc. cit. 38: 423. 1911.

which is exclusively American in the existing flora, is made a subgenus of *Ocotea* Aublet by Pax in Engler and Prantl's Die Natürlichen Pflanzenfamilien. The latter genus, which for paleobotanical purposes may be considered as composite, has about two hundred modern species, occurring chiefly in the American tropics and ranging from southern Florida to Brazil and Peru, but with some representation (subgenus *Mespilodaphne* Nees) in the Canary Islands, South Africa, Madagascar, and the Mascarene Islands.

The single existing American species reaching the United States, whose habit and environment may be taken as typical for the whole genus, is found in Florida, southward from capes Canaveral and Romano along the shores and islands with the exception of some of the western keys, making its best growth in the rich, moist, hammock lands near the coast.

CINNAMOMUM MEMBRANACEUM (Lesq.) Hollick

Paliurus membranaceus Lesq. Am. Jour. Sci. **46**: 101. 1868.
Cinnamomum membranaceum Hollick, Mon. U. S. Geol. Surv. **50**: 75. *pl. 29. f. 5, 6.* 1907.

Two leaves of this species, identical with Hollick's *fig. 6*, except that one is slightly smaller, were found at Arthurs Bluff. The previous occurrences are the Dakota group and Glen Cove, Long Island (Raritan or Magothy formations).

LAURUS PLUTONIA Heer

Laurus plutonia Heer, Fl. Foss. Arct. **6**^{2}: 75. *pl. 19. f. 1d, 2–4; pl. 20. f. 3a, 4–5; pl. 28. f. 10, 11; pl. 42. f. 4b.* 1882.

This species was described by Heer from the Atane beds of west Greenland and a large number of somewhat variable and fragmentary specimens were figured. Subsequently it was recorded from a very large number of Cretaceous plant beds, so that its range, both geographical and geological, is rather extensive. A number of these records are not entirely above suspicion, and this appears to be especially true of the forms from the Cenomanian of Bohemia identified by Velenovsky.

Laurus plutonia is rare in the Raritan, the writer having found it only near the top of that formation. It is abundant in the overlying Magothy formation from New Jersey to Maryland. In the southern coastal plain it occurs in the Middendorf beds of South Carolina and ranged from the base of the Tuscaloosa formation upward into the Eutaw formation in the Alabama area.

A single complete and characteristic leaf and several fragments are contained in the Arthurs Bluff collections.

LAUROPHYLLUM MINUS Newberry

Laurophyllum minus Newb. Fl. Amboy Clays 86. *pl. 16. f. 7-9.* 1896.

This species was described from the Raritan formation of New Jersey and found by the writer in the upper part of that formation only. In the absence of venation characters in both the type and later collected material its identification is always more or less uncertain; and it may represent a variety of *Laurus plutonia* Heer or some of the forms that have been referred to *Myrica longa* Heer, although in general it is wider than the latter and more elongated and less symmetrical than the former. A single specimen is present in the collection from Arthurs Bluff.

MYRTALES

EUCALYPTUS GEINITZI (Heer) Heer

Eucalyptus Geinitzi Heer, Fl. Foss. Arct. 6^2: 93. *pl. 19. f. 1c; pl. 4. f. 1, 13.* 1885.

This widespread and characteristic Upper Cretaceous species is found from the base of the Raritan formation of New Jersey upward into the Black Creek and Middendorf beds of the Carolinas. The type locality is the Cenomanian of Moravia, but it has also been recorded from the Atane beds of west Greenland and from the Dakota group of the West. In the Alabama Cretaceous it has been collected from only the lower part of the Tuscaloosa formation.

A single characteristic leaf is present in the collections from Arthurs Bluff.

UMBELLALES

ARALIA WELLINGTONIANA Lesq. emend.

Aralia Wellingtoniana Lesq. Fl. Dakota Group 131. (in part) *pl. 21. f. 1.* 1892 (not *pl. 22. f. 2, 3,* which are referred to *Aralia*

Saportana).—Newberry, Fl. Amboy Clays 114. *pl. 26. f. 1.* 1896.—Berry, Bull. N. J. Geol. Surv. 3: 202. *pl. 25. f. 7.* 1911 (not Smith, Geol. Coastal Plain Ala. 348. 1894).

This handsome species is characterized by its describer as being palmately 3- to 5-lobed, but it certainly seems significant that all of the forms from the Raritan formation are invariably 3-lobed and that the 5-lobed forms from the Dakota sandstone which Lesquereux referred to this species are indistinguishable from his species *Aralia Saportana*, which occurs at the same horizon and, in part at least, at the same locality.

This is the most abundant form collected at Arthurs Bluff, there being fifteen specimens in the one small collection, several nearly complete leaves being present. These are all trilobate with toothed margins and agree exactly with the Raritan leaves of this species and with the trilobate leaves from the Dakota sandstone like the one figured by Lesquereux on *pl. 21. fig. 1.*

In the light of our present knowledge *Aralia Wellingtoniana* may be recharacterized in the following terms:

Leaves variable in size, 10–20 cm. in length by 8 to 15 cm. in maximum width from tip to tip of the lateral lobes, average size about 15 cm. in length by 11 cm. in width; coriaceous, palmately deeply trilobate, with a rapidly narrowed and more or less extended decurrent base; lobes long, lanceolate, widest in the middle and narrowing below, somewhat abruptly acuminate, the median slightly the longest, diverging at an angle of about 30°, separated by sinuses extending more than halfway to the base, narrowly rounded; margins entire below and for varying distances upward, passing gradually into dentate-serrate teeth, one to each secondary or sometimes less in number, prominent in some specimens where they are more or less extended and directed upward, separated by wide shallow sinuses. Primaries stout, suprabasilar, the median slightly larger than the laterals. Secondaries numerous, thin, regular, subparallel, ascending, since the angle of their divergence from the primaries averages about 33°, but slightly curved in their course, ultimately craspedodrome in distal parts of leaf, where the margin is toothed, and camptodrome in the basal half of the leaf, where the margin is entire. Areolation indistinct, reticulate, of quadragonal or polygonal meshes. The smaller leaves are relatively shorter and broader, with less extended lobes and more open and less deep sinuses.

The present species may be distinguished from *Aralia cotton-*

dalensis Berry of the Tuscaloosa formation, with which it was confused by Ward (in Smith, Geol. Coastal Plain Ala. 348. 1894), by the shorter more conical lobes of the latter, its broadly rounded base and more crenate marginal teeth.

Aralia Saportana as here restricted to the 5- or 6-lobed forms is very close to *Aralia Wellingtoniana* and may be regarded as an offshoot from it. The fact that the two are associated in the Dakota group only and not in New Jersey or Texas rather controverts regarding them as the variants of a single species; and suggests that at least geographic varieties are represented, particularly as the trilobate form is so abundant at Arthurs Bluff that it is hard to conceive of trees with 5-lobed leaves growing in the vicinity whose foliage failed to be preserved. Furthermore, as the writer correlates the deposits, both the New Jersey Raritan and the Texas Woodbine at Arthurs Bluff are older than the Dakota sandstone in that area in Kansas from which Lesquereux described the 5-lobed forms, so that there is every reason for regarding *Aralia Saportana* as the direct descendant of *Aralia Wellingtoniana*.

The present species is also very similar to *Aralia decurrens* Velenovksy* from the Cenomanian of Bohemia, which, however, has relatively narrower and more elongated lobes, with coarser teeth and deeper sinuses.

In reporting on a collection made by Vaughan at Arthurs Bluff and now in the U. S. National Museum, Knowlton† mentions *Aralia Wellingtoniana Vaughanii* var. nov. as the most abundant form observed. This variety was distinguished from the type by its trilobate form, more slender lobes and entire margins. This variety is not contained in the present collection.

CORNOPHYLLUM VETUSTUM Newberry

Cornophyllum vetustum Newb. Fl. Amboy Clays 119. *pl. 19. f. 10.* 1896.—Berry, Bull. N. J. Geol. Surv. 3: 196. 1911.

This species has heretofore been known only in the lower and middle Raritan beds in the New Jersey area, although it is present in undescribed collections from the lower Tuscaloosa made by

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* Velenovsky, Fl. Böhm. Kreidef. 3: 11. *pl. 4. f. 5–7.* 1884.

† Knowlton, in Hill, Ann. Rep. U. S. Geol. Surv. 21^7: 317. 1901.

the writer near Glen Allen, Ala. It is very similar to species of *Cornus* described from the Dakota group, the Atane beds of west Greenland, and the Magothy formation of Maryland. It is represented in the collection from Arthurs Bluff by one good specimen.

VIBURNUM ROBUSTUM Lesq.?

Viburnum robustum Lesq. Fl. Dakota Group 120. *pl. 20. f. 4–6.* 1892.—Knowlton, Ann. Rep. U. S. Geol. Surv. **21**^{7}: 317. 1901.

Knowlton records a single nearly perfect leaf of this Dakota group species from Arthurs Bluff. The same species is represented by fragments in the present collection.

ERICALES (?)

ANDROMEDA NOVAE-CAESAREAE Hollick

Andromeda Novae-caesareae Hollick in Newb. Fl. Amboy Clays 121. *pl. 42. f. 9–12, 28–31.* 1896.

This well marked species, which appears in the upper Raritan formation of New Jersey and is so abundant at somewhat later horizons in the coastal plain southward as far as Alabama, is represented by three complete leaves in the collections from Arthurs Bluff. These Texas leaves are of the type with a rounded apex so common in the Black Creek beds of North Carolina.

While the species is found in both the Black Creek beds of North Carolina and in the Middendorf beds of South Carolina, both horizons considerably younger than the Raritan, it appears to be confined to the basal part of the Tuscaloosa formation in western Alabama.

ANDROMEDA SNOWII Lesquereux

Andromeda Snowii Lesq. Fl. Dakota Group 117. *pl. 17. f. 16.* 1892.

This Dakota group species, previously recorded from Kansas, is represented by a single specimen from Arthurs Bluff. It resembles the lanceolate leaves of the preceding species but is broader with less numerous and much less ascending secondaries.

INCERTAE SEDIS

TRICALYCITES PAPYRACEUS Hollick

Tricalycites papyraceus Hollick, Bull. Torrey Club **21**: 63. *pl. 180. f. 8.* 1894.

This very characteristic tri-alate fossil is abundant in the middle and upper Raritan formation of New Jersey. It occurs sparingly in the overlying Magothy formation and is very common in the lower part of the Tuscaloosa formation in western Alabama. It is abundant at Arthurs Bluff, the present collection containing eight typical specimens, some of them complete. They are in exact agreement with the Tuscaloosa forms and demonstrate what is discussed at length in my manuscript of the Tuscaloosa flora that the approximately parallel longitudinal venation of the wings is really a more or less forked and anastomosing venation, thus allying these fossils in a remote way with such modern genera as *Vatica* of the Dipterocarpaceae.

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Explanation of plates 30-32

PLATE 30

Brachyphyllum macrocarpum formosum Berry var. nov., Sullivans Cove, Maryland.

PLATE 31

FIG. 1. *Zizyphus lamarensis* Berry sp. nov., Arthurs Bluff, Texas.
FIG. 2. *Rhus redditiformis* Berry sp. nov., Arthurs Bluff, Texas.
FIG. 3. *Sterculia lugubris* Lesquereux, Arthurs Bluff, Texas.

PLATE 32

Oreodaphne alabamensis Berry sp. nov., Cottondale, Ala.

Mitosis in living cells

CHESTER ARTHUR DARLING

Practically all of the work done on the phenomena of cell division has been done with material that has been fixed, imbedded in paraffin, sectioned, and finally stained; this method has been subjected to various criticisms and it has been maintained that figures observed in the fixed and stained cells are artifacts, stages that do not exist in nature. Although these criticisms have been squarely met in many cases, undoubtedly much valuable data might be obtained by devoting more time to the study of the living cell.

Very favorable material for studying cells in the living condition has been found in the young anthers of some of the maples. Twigs of the red maple, *Acer rubrum*, with flower buds were gathered on February 10 before any swelling of the buds had taken place. Twigs about 6–10 inches long were brought into the laboratory, placed in a glass of water and kept near the window, the water was changed every day or two and the base of the stem often cut afresh. To examine the pollen mother cells the bud scales were removed and the young flowers placed on a slide and mounted in water; if the anthers are long enough it is best to cut them crosswise with a sharp knife; by pressing down on the cover glass the mass of spore mother cells are forced out of the anther and are then readily observed. In the case of the red maple the mother cells began to divide on February 17, one week from the time they were picked from the tree, whereas those left on the tree did not divide until one week later; the advantage of bringing them into the laboratory is that one may examine them every day and so determine in what stage of growth or division the cells may be. I was able to observe the chromosomes in the equatorial plate, and in polar view was able to count as many as 40, fixed and stained material showing practically the same number. An advantage in the living cell at this stage is that the chromosomes are placed about equally distant from each other and not drawn close together as is often the case when fixed and stained. The spindle was clearly marked and the spindle fibers distinguishable; anaphase and telophase stages could be readily observed; in fact practically all of the division figures to be found in fixed and stained material were observed in these living cells. The spireme is rather thin in this form, so that it could not be detected in the living cell; the nucleolus with a budlike attachment was plainly seen. The cytoplasm in *Acer rubrum* is not so dense as to obstruct or confuse the view of the nucleus as it is in some forms.

Various stages in the division of the daughter nuclei were as clearly seen as were those of the mother cell; these daughter nuclei divide very soon after the first division of the mother cell, without the formation of the new cell wall. Within twenty-four hours after the first cells were seen to have begun division practically all of the mother cells in the material had formed the four distinct spores, showing that these stages go on rapidly.

Attempts were made to induce the cells to complete their divisions by placing them in sugar solutions of various strengths from 2 per cent to 15 per cent, but in no case did a cell continue to divide after being forced out of the anther.

Twigs of the silver maple, *Acer saccharinum*, were brought into the laboratory on the same dates as those of the red maple; although the cytoplasm is denser and although the division figures were not so clearly marked, yet practically all of the stages observed in the red maple were seen in the pollen mother cells of this species. In the Norway maple, *Acer platanoides*, the division of the pollen mother cells takes place much later in the season. On March 20 twigs were brought into the laboratory, and on March 23 the mother cells divided. Various division figures were observed in this species together with a very conspicuous budlike process on the large nucleolus. The cytoplasm in this species is more dense and more granular than that in *Acer rubrum*, so that the chromosomes and spindle fibers were not so clearly seen. The mass of spore mother cells does not force out of the anther until the cells are nearly ready to divide, usually within a day or two, whereas in the red maple the tapetal cells become detached from the endothecium of the anther at least two weeks before division.

In the European larch, *Larix decidua*, I have observed the pollen mother cells in stages of division, although the presence of numerous starch grains and of granules in the cytoplasm often obscures the definiteness of the figures.

Because of the simplicity of the means any one interested in seeing the chromosomes, nucleoli, and stages in the division of the living cell may do so with an ordinary compound microscope with a 1/6 in. objective. The only difficulties that may arise are: to obtain the flower buds before division of the pollen mother cells has taken place, which may be four weeks or more before the flowers open, as was the case in the maples this year; the other difficulty may be in the density of the cytoplasm, but this varies with different species and with different anthers of the same species.

These few observations are recorded to emphasize the fact that many of the phenomena presented in fixed and stained material can easily be verified as existing in the living cell.

COLUMBIA UNIVERSITY.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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Bitter, G. Weitere Untersuchungen über die Gattung *Acaena.* Repert. Sp. Nov. **10**: 489–501. 5 My 1912.

Discusses several species from Central and South America.

Blake, S. F. The forms of *Peltandra virginica.* Rhodora **14**: 102–106. *pl. 94.* 14 Je 1912.

Bragg, L. M. The museum herbaria. Bull. Charleston Mus. **8**: 43–49. My 1912.

Brown, P. E. Some bacteriological effects of liming. Centralb. Bakt. Zweite Abt. **34**: 148–172. 15 My 1912.

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Coker, W. C. The plant life of Hartsville, S. C. Jour. Elisha Mitchell Sci. Soc. **27**: 169–205. *pl. 1–15.* 16 F 1912.

East, E. M. Inheritance of color in the aleurone cells of maize. Am. Nat. **46**: 363–365. Je 1912.

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Evans, A. W. *Hepaticae* of Puerto Rico—XI. *Diplasiolejeunea.* Bull. Torrey Club **39**: 209–225. *pl. 16, 17* + *f. 1, 2.* 8 Je 1912.

Faull, J. H. The cytology of *Laboulbenia chaetophora* and *L. Gyrinidarum.* Ann. Bot. **26**: 325–355. *pl. 37–40.* Ap 1912.

Fawcett, W., & Rendle, A. B. New plants from Jamaica. Jour. Bot. **50**: 177–182. *pl. 518.* Je 1912.

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Fedde, F. *Corydalis Allenii,* eine neue Art aus der Verwandtschaft der *Corydalis Scouleri,* von Washington. Repert. Sp. Nov. **10**: 478, 479. 5 My 1912.

Fedde, F. Neue Arten aus der Verwandtschaft der *Corydalis aurea* Willd., von Nord-Amerika—V. Repert. Sp. Nov. **10**: 479, 480. 5 My 1912.

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"A descriptive account of the ferns and flowering plants, including the trees, of the Yosemite National Park."

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Harris, J. A. A first study of the influence of the starvation of the ascendants upon the characteristics of the descendants—I. Am. Nat. **46**: 313–343. Je 1912.

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Heller, A. A. The flora of the Ruby Mountains—V. Muhlenbergia **8**: 49–58. *pl. 5 + f. 4, 5.* 31 My 1912.

Includes *Castilleja lapidicola* sp. nov. and *Siphonella* gen. nov.

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Contains some information relating to the fungi and other plants of these islands.

Hitchcock, A. S. *Gramineae.* In Jepson, W. L., A flora of California. 82–189. 30 Ap 1912.

Includes keys to the tribes, genera, and species; one new species each in *Aristida*, *Agrostis*, *Poa*, and *Glyceria; Notholcus* Nash, gen. nov.

Howe, M. A. The building of "coral" reefs. Science II. **35**: 837–842. 31 My 1912.

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Schlechter, R. *Orchidaceae* novae et criticae. Decas XXXIV. Repert. Sp. Nov. **10**: 480–486. 5 My 1912.

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Describes *Hapterophycus canaliculatus* Setchell & Gardner, *Besa papillaeformis* Setchell, *Baylesia plumosa* Setchell, gen. et spp. nov.; *Fauchea Fryeana* Setchell, *Dudresnaya bermudensis* Setchell, *Leptocladia conferta* Setchell, and *Weeksia Fryeana* Setchell, spp. nov.

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A translation of the descriptions of the seven species described by Britton and Rose in Torreya **12**: 13–16.

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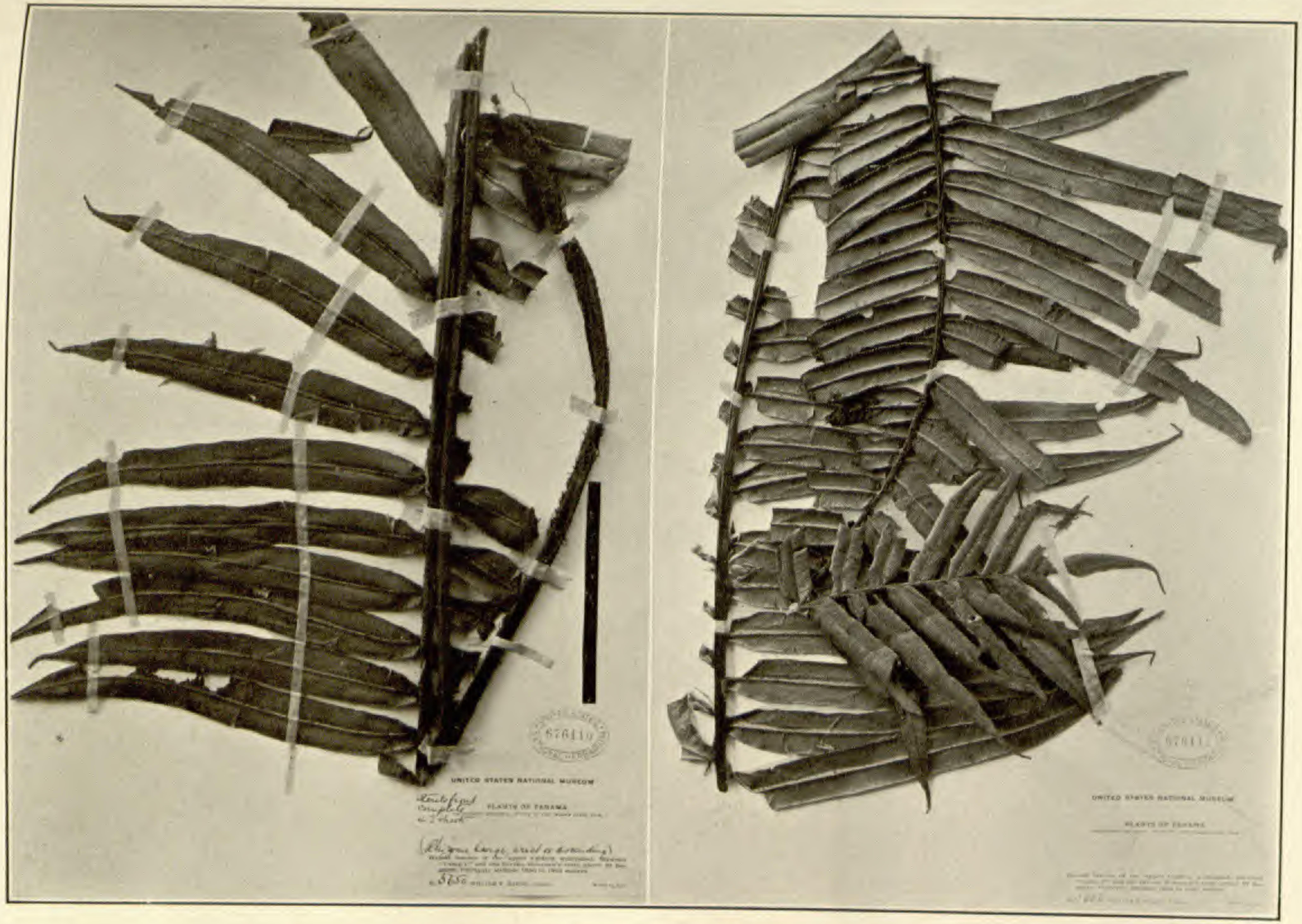
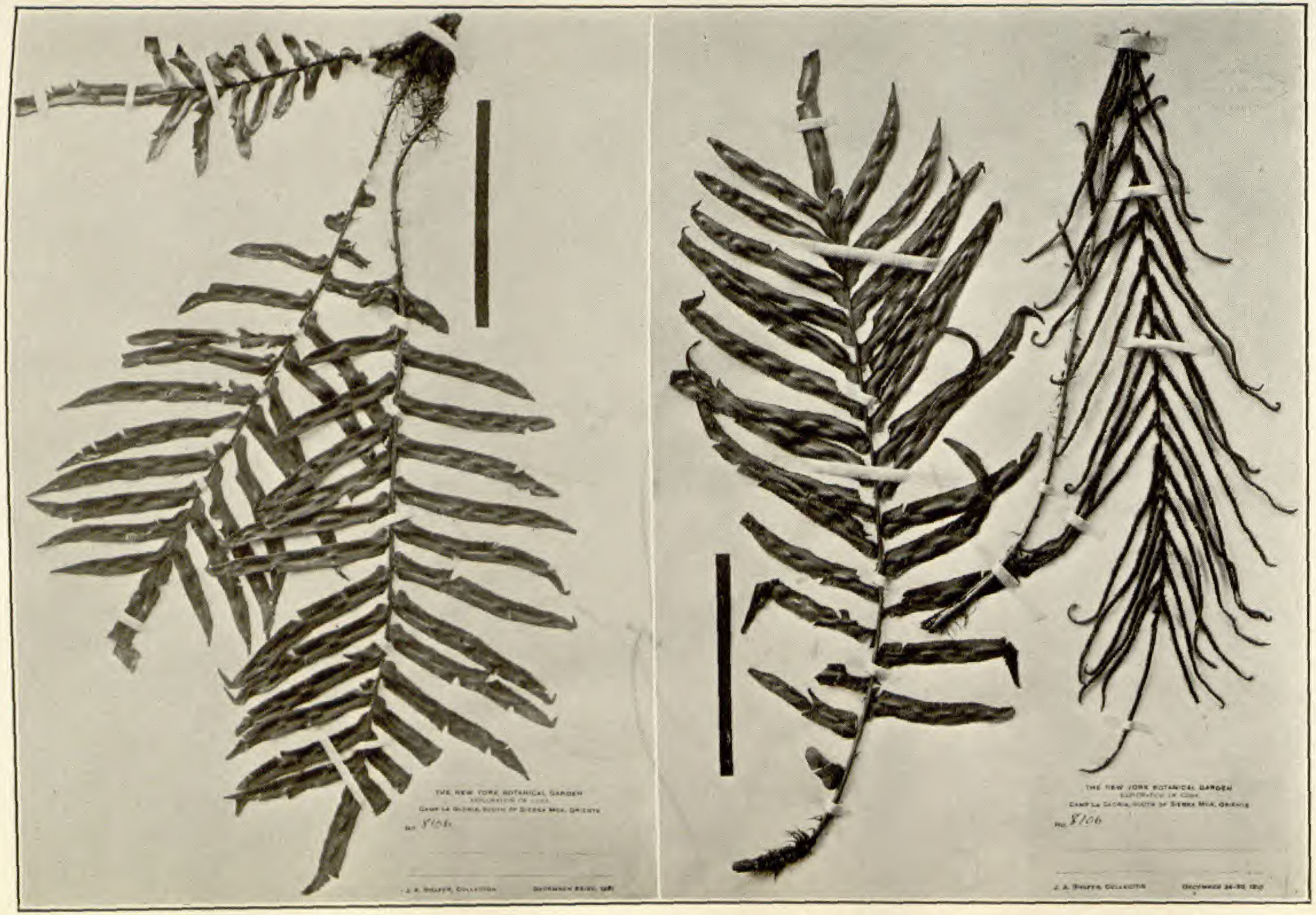


STRUTHIOPTERIS CHIRIQUANA Broadh. × ¼.

(A scale 10 cm. long is shown on the sheet to the left.)



STRUTHIOPTERIS SHAFERI Broadh. × ¼.

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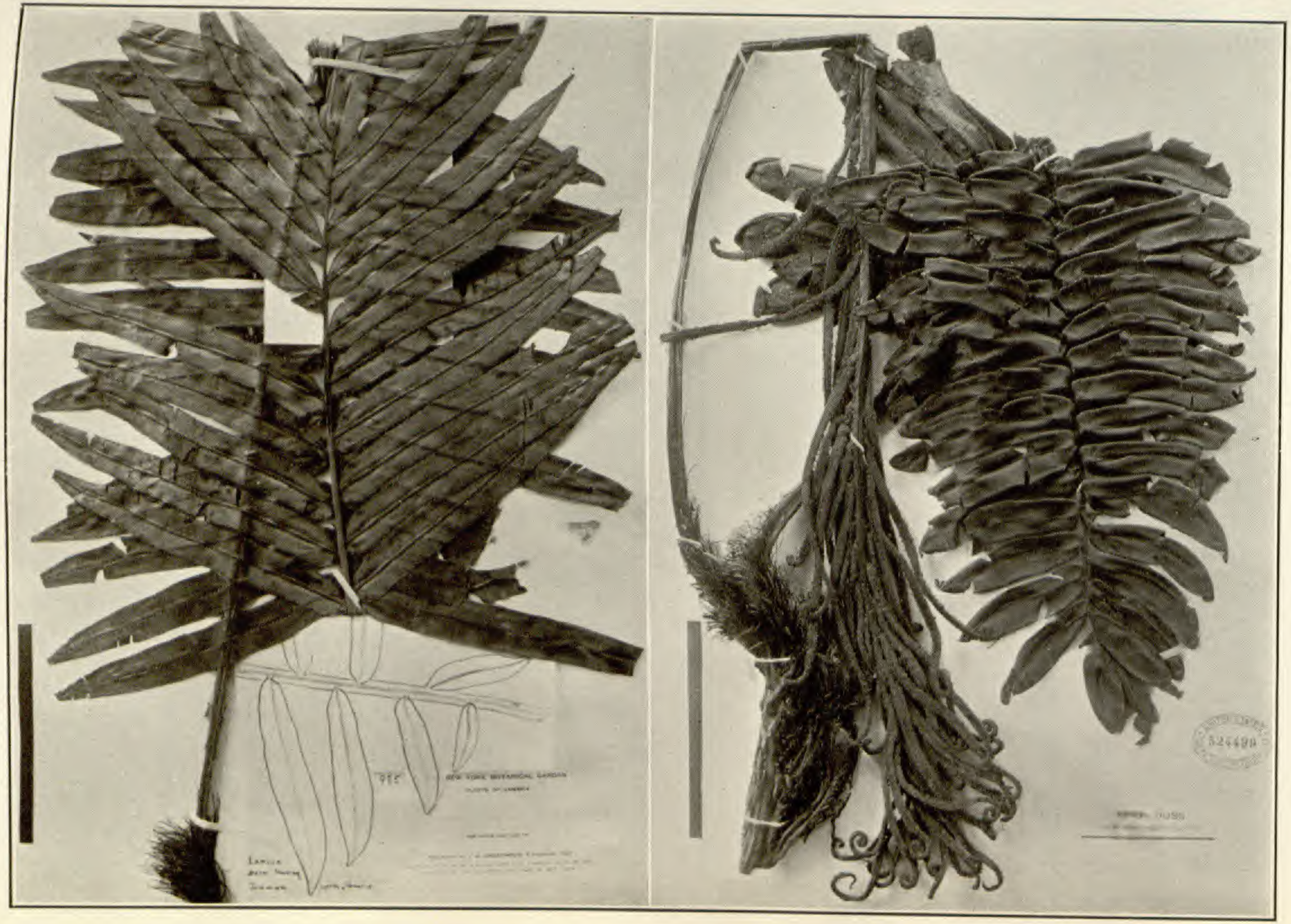
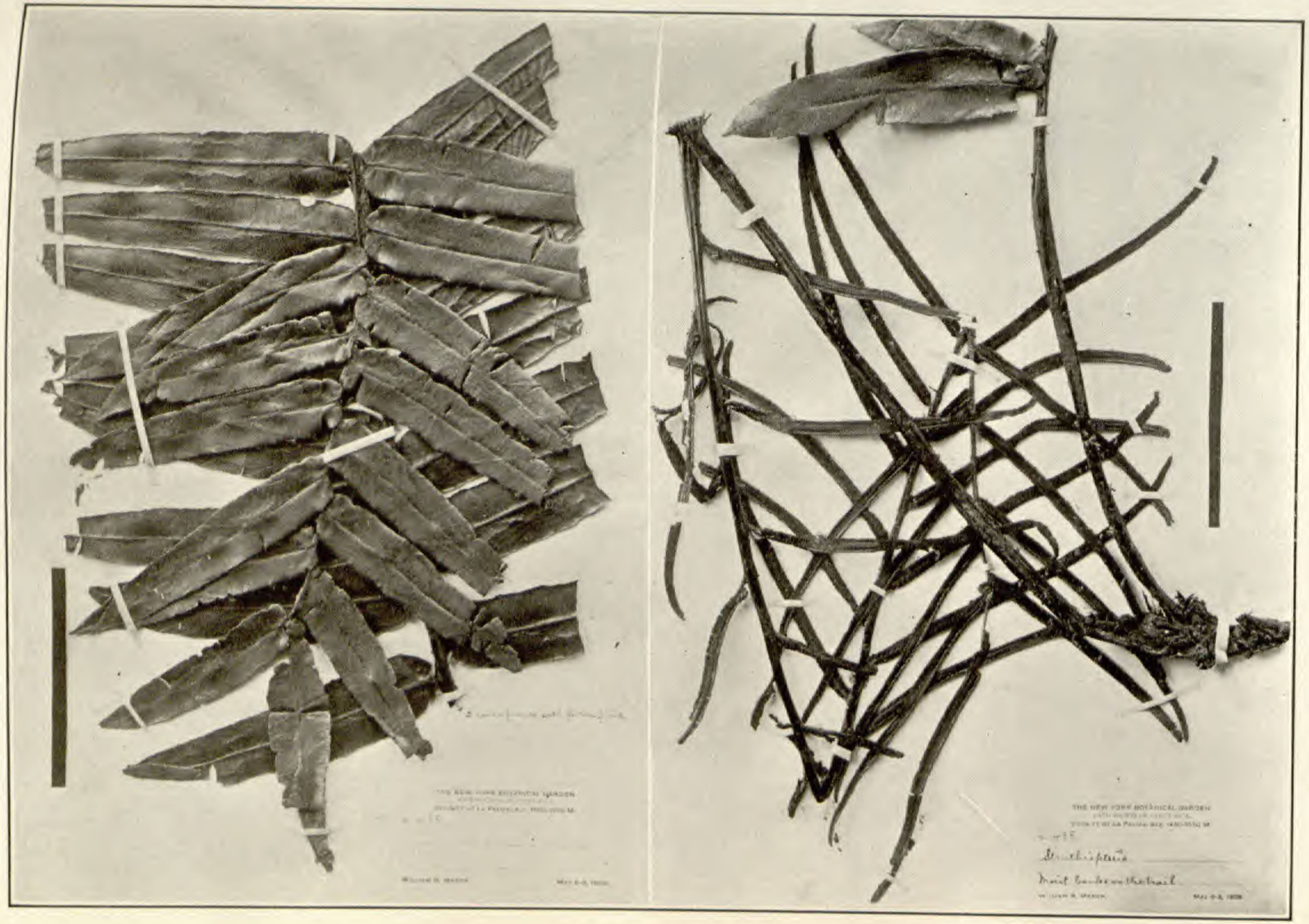


STRUTHIOPTERIS UNDERWOODIANA Broadh. STRUTHIOPTERIS RUFA (Spreng.) Broadh.

(Reduced to ¼ of the actual size. A scale 10 cm. long is shown on each sheet.)



STRUTHIOPTERIS VIVIPARA Broadh. × ¼.

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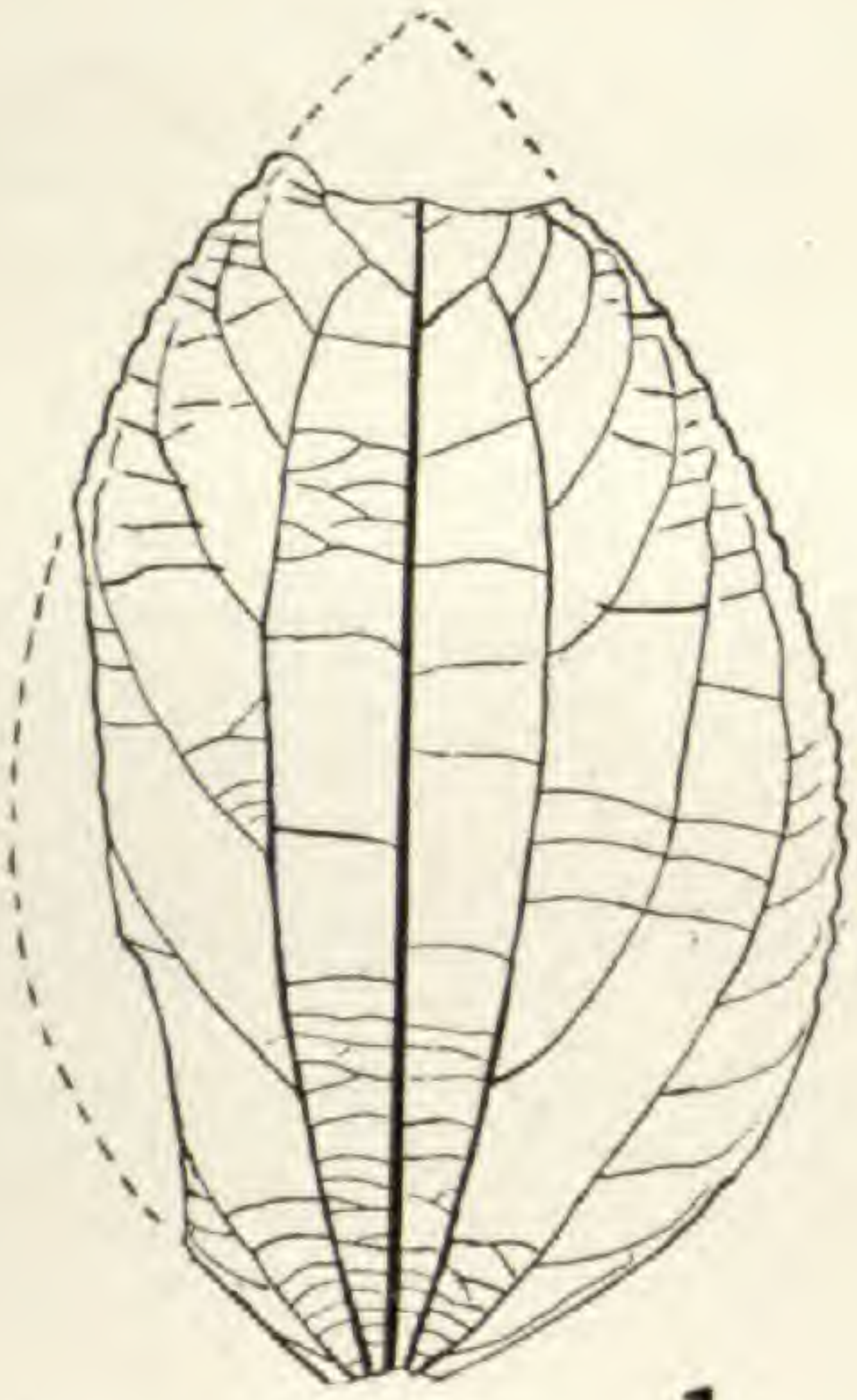
BRACHYPHYLLUM



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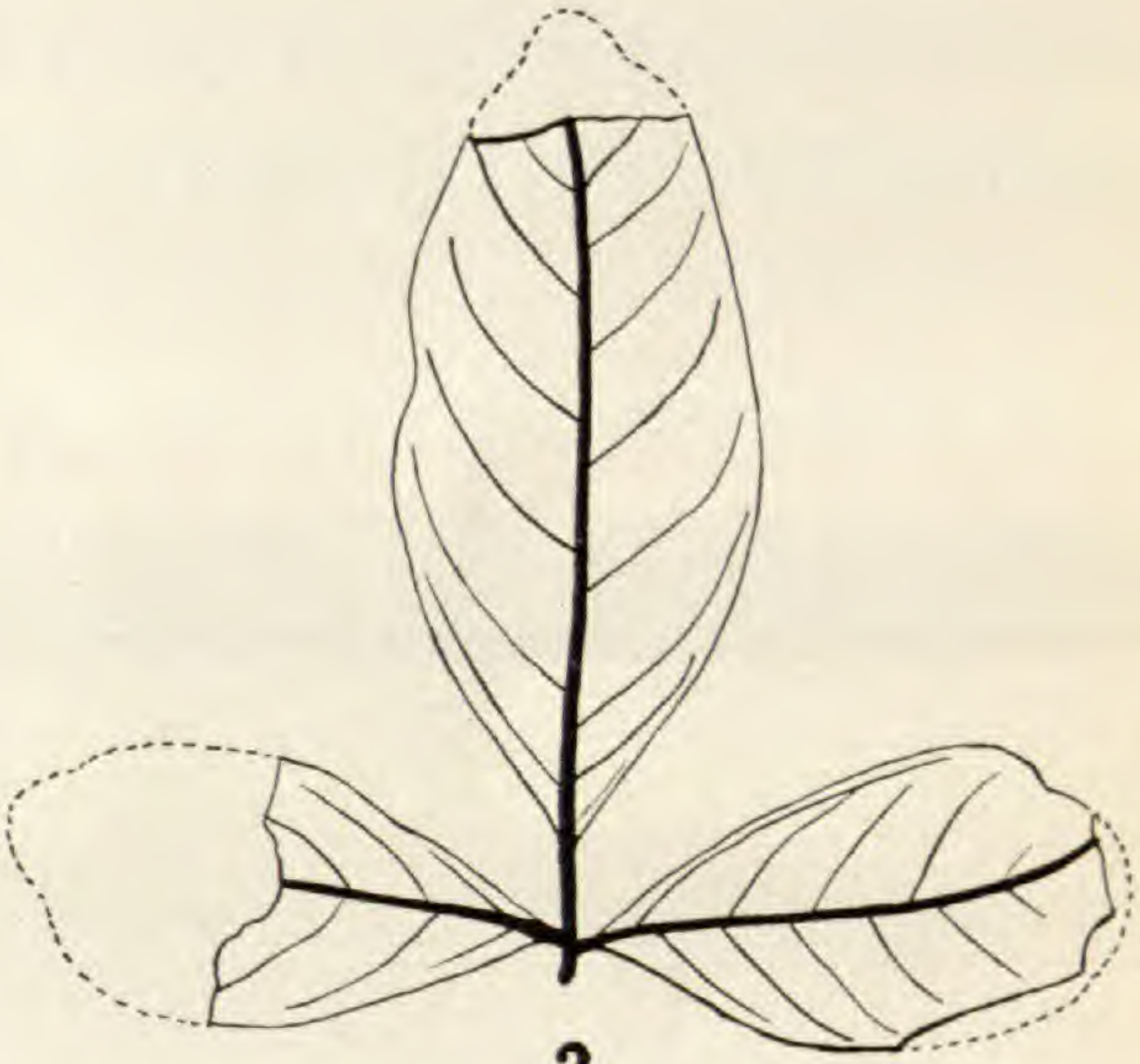

2

3

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OF THE

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Vol. 39 No. 9

BULLETIN

OF THE

TORREY BOTANICAL CLUB

SEPTEMBER 1912

The ferns and flowering plants of Nantucket — X

EUGENE P. BICKNELL

GERANIACEAE

GERANIUM MACULATUM L.

Common, but so retiring an inhabitant of dense thickets as to be little noticeable. Like other spring-flowering plants on Nantucket it comes into bloom much later than at more inland points in the same general latitude. In fresh flower May 30, 1910; just in bloom June 5, 1911; last flowers June 22, 1910.

GERANIUM ROBERTIANUM L.

This fragile plant of rocky woods and ravines is one of the surprises of Nantucket, where it has somehow found its way and hides under the cedars on Coatue, a narrow arm of sand, some five miles in length, which protects the harbor from Nantucket Sound. Long ago it was detected there by Mr. Dame—Mrs. Owen's record runs "Under red cedars near the head of the harbor." It probably occurs throughout the extent of Coatue, since I met with it near Second Point, Sept. 7, 1904, scattered here and there among the cedars and completely screened from view in the recesses beneath their low spreading branches. It remains well established there, where I observed it in full flower July 13, 1912.

A single plant was seen in the town, growing under a porch on Liberty Street, in 1909, and again June 16, 1910, then in full bloom.

GERANIUM CAROLINIANUM L.

Occasional as a weed in disturbed or once cultivated ground,

[The BULLETIN for August 1912 (39: 357–414. *pl. 26–32*) was issued 16 Au 1912.]

sometimes abounding but readily giving way and disappearing before conditions only slightly changed from those that enabled it to thrive. Mrs. Owen has told us that it was once found in abundance by Mr. Dame in a field near Sachacha, and Mr. Floyd has given me the following records: Gibbs Pond, 1901, and Monomoy, 1904, Mrs. Nellie F. Flynn; Pocomo, 1907, Mrs. Mabel P. Robinson. I did not myself meet with it until September 1907, a single tuft of basal leaves where soil had been upturned on the plains east of Miacomet Pond. Here the next year, on June 17, were a few plants in flower and fruit. On June 2, 1909, unusually widespreading plants in full flower were scattered through a once cultivated field at Shimmo Valley farm, where a year later not a plant was to be found. On June 4, 1911, a solitary plant just in flower was met with west of the town and an abundant growth in full flower June 10 in an old field at Quidnet. It seems to be spreading on the island and getting to be more common.

*GERANIUM PUSILLUM L.

Now not uncommon in waste ground in and near the town but evidently a newcomer within recent years. It appears to have been found first on Nantucket by Mrs. Flynn, "Pleasant Street, 1904," fide F. G. Floyd, who also collected it in Hillers Lane in 1906. I first met with it the same year, on Aug. 11, in flower and fruit in waste ground west of the town, where also it was flowering Sept. 20, 1907, but had disappeared the following year. In 1909 it was abundant and in full flower June 6 in a field west of the town and was also found a mile to the south. In June 1910, it was abundant and of unusually large size in a lot on Pleasant Street and was seen for the first time at Siasconset, growing by a fisherman's cottage below the bluff. In 1911 it had appeared in a lawn on the Cliff Road. It occurs also in Edgartown on Marthas Vineyard, where I observed it on a lawn, still in flower Oct. 10, 1911.

*GERANIUM MOLLE L.

A single cluster in a weedy place off Centre Street, near North Street, June 3, 1911, showing its first open flower. Meadow below Sea Cliff Inn, 1897, Mrs. Mabel P. Robinson, fide F. G. Floyd.

ERODIUM CICUTARIUM (L.) L'Her.

Mrs. Owen has recorded single plants found many years ago on three occasions in the town, one in 1850 and one in 1851. No recent collector seems to have met with it.

OXALIDACEAE

OXALIS STRICTA L.

Common in fields and open places in all quarters of the island, often thriving along sandy shores; especially common on sandy levels about the south shore ponds. Just in flower May 30, 1909; June 7, 1908; in full flower June 3, 1911; flowering during the summer and through September; capsules full size June 18, 1908.

For so delicate a plant this species is remarkably tenacious of life under hard conditions and accommodates itself as well to sterile and stony situations as to the rich soils of gardens and cultivated grounds. These adjustments are not without rather wide variations in habit and characters by which the species is marked off into several noteworthy forms. Heavy soils produce pale green canescent plants of large size, sometimes having a spread of 2.5 dm., and bearing large flowers and capsules. A greatly reduced form of brighter green color and with smaller flowers and capsules belongs to hard or gravelly soils; it is of contracted habit, often forming close mats only 5–10 cm. wide and bearing very small crowded leaves and prostrate or even procumbent and rooting stems. Another variety if, indeed, it be not of more moment, which I have met with only in the streets of the town, is of a dull green color, the comparatively few and large leaves purplish tinged or even deep purple throughout; the leaflets, often strongly declined, are more strongly ciliate than in the commoner forms and their lower surface less distinctly cellular-alveolate under a lens; the flowers are large, having rather broad and blunt sepals, which become 7 mm. long, and the dried corollas are often upborne on the apex of the capsule; the slender styles are twice the length of those found in associated forms of the plant and are much less spreading.

*OXALIS CYMOSA Small.

Seen only in the town, where it is frequent by streetsides and in old yards, appearing as if introduced. It develops much later than *Oxalis stricta* and may be seen with its earliest leaves only beginning to unfold when the other is in full bloom. First leaves appearing June 6, 1909; first flowers June 16, 1911; June 18, 1908; June 21, 1910; flowering through September.

LINACEAE

Linum usitatissimum L.

Casual and transient. It grew sparingly in an old field in 1899, but I have seen it since on Nantucket only in waste ground at Surfside, July 9, 1912, the most forward buds showing blue tips. It is included in Mrs. Owen's catalogue, and Mr. Floyd's notes report it as having been collected by Miss Nina K. Goddard, in 1895, and by Mrs. Mary A. Albertson.

Linum virginianum L.

Not uncommon on the eastern side of the island from Squam to Tom Never's Pond, especially at outlying points about Saul's Hills, growing in dry sandy soil. Elsewhere it was met with only at a single station in Trot's Hills. The young plants may be detected early in June and in some seasons are but a few inches high late in the month. The fruit is mature by the end of August, although flowering may continue until after the middle of September.

*Linum striatum Walt.

Border of Waqutuquaib Pond, Sept. 9, 1904, a small colony of well-fruited plants still bearing a few flowers. This is one of the rather numerous group of Nantucket plants that have been found only at a single station.

✓ ***Linum** (*Cathartolinum*) **intercursum** sp. nov.

Perennial, erect, slender, striate-angled, 1.5–3 dm. or even 5 dm. high, branched at the top, the branches 1–8 cm. long, erect or erectly ascending, simple or sparsely corymbose; leaves numerous, pale green, erect or ascending, oval-oblong to narrowly oblong and oblanceolate, acute, 7–18 cm. long, 1.5–5 mm. wide, the lowermost and those of the basal shoots oblong-obovate and rounded at the end; sepals ovate to lanceolate-oblong, acuminate, keeled, mostly three-nerved, 1.5–2.5 mm. long, the inner minutely glandular-ciliolate; corolla yellow, spreading 8–12 mm.; pedicels 1–4 mm. long; capsule greenish purple, ovoid-conic, usually broader than high, acute, 1.5–2 mm. long, readily dehiscent, the carpels cuspidate; false septa long-ciliate; seeds 1.5 mm. long.

East Massachusetts to southern New Jersey, Georgia, and Alabama. Type from Nantucket, Sept. 11, 1899, in Herb. N. Y. Botanical Garden. Flowers on Nantucket from July (July 8, 1912) until well into September.

This is the small, yellow-flowered *Linum* that is a characteristic plant of Nantucket, where it is scattered widely over the moorland and commons and is sometimes found about cranberry bogs in lower grounds. It was first collected by me in 1899 on the supposition that it was the then little known *Linum medium* (Planch.) Britton. Subsequently it proved to be not uncommon on Marthas Vineyard and on Long Island, where it is one of the noteworthy plants of the Hempstead Plains. Early Nantucket specimens submitted to Dr. J. K. Small were referred to *Linum floridanum* (Planch.) Trelease, which had not then been found north of South Carolina, and in the North American Flora the range of that species was extended north to Massachusetts. This disposition of the plant was also adopted in the seventh edition of Gray's Manual. I have seen much of this *Linum* since it was first collected and have learned in the field how distinct it is from *Linum medium*, and now a review of herbarium material leads me here to propose it as distinct from *Linum floridanum* also. If we examine a well-fruited specimen of the latter, say Curtiss' "North American Plants," no. 412, or his "Second Distribution," no. 6850, we find that the conspicuous yellow bony capsules are ovoid-subglobose to ovoid-oblong, 2.5–3.5 mm. high and rounded or even subtruncate at the top. In size and form as well as in color they are thus in marked contrast to the greenish purple conic and acute thinner-walled capsule of the more northern plant. They are also much more tardily dehiscent, the carpels not cuspidate and with non-ciliate septa; also, the false septum is more complete and the seeds, of a more reddish color, are one third larger. *Linum floridanum* is a taller and paler green plant than *Linum intercursum*, its leaves thicker and more rigid, narrower and more attenuate, and sharply cuspidate with pale hardened points; the flowers appear to be larger and the rootlets are fewer and less delicately fibrous. The leaves and the capsules of *Linum floridanum* conform closely to those of *Linum medium*. *Linum intercursum* in its angled branches and acute capsule with cilia-bearing septa, shows an approach to characters of *Linum sulcatum* Riddell, and its bracteal leaves sometimes show a submarginal thickening that recalls the trinerved leaves of that species. *Linum sulcatum* has been attributed to Nantucket, and I suppose there is no doubt at all that this species was mistaken for it.

In addition to numerous specimens collected on Nantucket, Marthas Vineyard, and Long Island the following collections may be cited: Georgia, Cobb County, dry woods, elevation 1,020 ft., July 12, 1900, *Roland M. Harper 213*. Alabama, Clay County, Sept. 24, 1897, *F. S. Earle 947;* Coosa County, Sept. 29, 1897, *F. S. Earle 1035*. These specimens are the only ones I have seen from south of New Jersey, where I collected the plant at Wildwood, Cape May County, May 31, 1897, just in flower, and where Mr. Norman Taylor has more recently collected it at New Brunswick, Middlesex County, and also in Monmouth County.

The purport of the evidence would seem to be that *Linum intercursum* is a plant of the coastal plain from Massachusetts to New Jersey, extending southwestward in the hilly country into Alabama, while *Linum floridanum* is a coastwise species of the southern states, passing inland at low elevations and ranging from North Carolina to Mississippi. The most northern specimens I have seen of the latter are from Craven County, North Carolina, collected at Newbern, Aug. 1, 1898, *Thos. H. Kearney, Jr., 1978*. Apparently it is a plant of wet pine barrens and low grounds, whereas *Linum intercursum* inhabits preferably dry sandy places.

SIMARUBACEAE

*AILANTHUS GLANDULOSA Desf.

In 1899 this tree had become established at several places in the neighborhood of the town. It has not since greatly increased its foothold and though slowly spreading scarcely strays away from places where it was originally planted. It is also spontaneous at Siasconset. It comes into leaf later in the season perhaps than any other Nantucket tree. As late as June 7, 1911, it appeared nearly naked, showing only small tufts of coppery red leaves at the tips of the branchlets.

POLYGALACEAE

POLYGALA CRUCIATA L.

One of the commonest plants of sandy open bogs, often abundant in sphagnum about the borders of ponds. In full flower in August and September.

POLYGALA VERTICILLATA L.

Dryish sandy places in low grounds, scarce. Little Neck; roadside at Eatfire; Coskaty. In full flower at the middle of September.

POLYGALA VIRIDESCENS L.

Low grounds, rare. Roadside along Trot's Swamp, Aug. 16, 1906, in full flower; near Bache's Harbor, in full flower, Sept. 17, 1907. This species is given in Mrs. Owen's catalogue without mention of any locality.

POLYGALA POLYGAMA Walt.

One of the characteristic plants of the island, widely disseminated over the moorland and commons and flowering from the middle of June until the middle of September. White flowers are not rare. Flower buds showing pink June 10, 1911, June 11, 1908; first flowers June 15, 1908, June 15, 1910; Tuckernuck, June 17, 1911.

EUPHORBIACEAE

EUPHORBIA POLYGONIFOLIA L.

In white sand along the beaches and back among the dunes; common. Plants very small but recognizable June 25, 1910; just in flower July 13, 1912; in full flower through September.

EUPHORBIA MACULATA L.

Not uncommon about the shores of Miacomet Pond; met with elsewhere only at a few stations not far from the town. Just in flower July 2, 1912. In full flower through September.

EUPHORBIA PRESLII Guss.

Reported by Mrs. Owen as having been found by Judge Churchill and Mr. Deane by the railroad track near the town—doubtless a casual introduction only, since no one else seems ever to have met with it.

EUPHORBIA CYPARISSIAS L.

Fence borders and about farmhouses and abandoned grounds. Just in flower May 30, 1909; in full flower June 3, 1911, June 15, 1910; passing out of bloom later in the month. No set fruit observed.

CALLITRICHACEAE

CALLITRICHE HETEROPHYLLA Pursh.

Common in brooks, pools, and springy places or on drying mud where the water has receded. Mature fruit June 3, 1911, Sept. 5, 1904.

EMPETRACEAE

COREMA CONRADII Torrey.

Locally abundant in the southeast quarter of the island, extending from north of the third milestone on the state road to Siasconset, within a quarter of a mile of the shore and into the South Pasture. This general area extends in a northwest and southeast direction south of Saul's Hills for a distance of about four miles and is two miles or more in greatest breadth. It is a territory of level or gently rolling plains and open barrens of scrub oak and affords conditions that manifestly meet well the needs of this very local species. Where most abundant it grows in widespread profusion, covering the ground with a springy heathlike carpet for rods together, perhaps even acres, or when of more interrupted growth forming firm cushionlike masses several yards across. Here and there it has extended its growth thickly along old wagon trails on the moors, which have opened a way for it through the dense carpeting of bearberry with which its more lively green makes striking contrast. Parts of these long unused roadways have thus been almost completely obliterated, the old wagon ruts once deeply scored in the sandy soil being marked only by shallow parallel grooves along the dense masses of this diminutive compact shrub cushioned up between them. I have not myself met with it outside of the general area indicated except near Tawpaushas Swamp, about two miles from the town. Mrs. Owen, however, mentions what may be still another locality, "Road from town to Polpis," her authority being Miss Tallant, 1867. It is still abundant in low places bordering Tom Never's

Swamp, just as it there grew long ago as reported to Mrs. Owen by Mr. Dame. Extensive growths of this plant are undoubtedly destroyed from time to time by fires which pass over the moors. I have noticed wide areas so devastated where the railroad traverses its general habitat, the fires having been started by sparks from passing trains.

Green fruit June 13, 1908; fruit mature and readily falling June 24, 1910; scarcely mature July 2, 1912.

ANACARDIACEAE

RHUS COPALLINA L.

Common, mainly on the eastern side of the island. Leaves only beginning to unfold June 7, 1911; in full flower Sept. 15, 1907.

*RHUS HIRTA (L.) Sudworth.

It may be open to doubt whether the staghorn sumac is native to Nantucket. A scattered growth has long occupied a field along an old cemetery south of the town, and a few rather ill-favored shrubs grow along a field border by the Surfside road in the suburbs, where they were first seen in 1899. But there is no certainty that these are of native origin, since the species has been used as an ornamental shrub in several yards in the town and also about a distant farmhouse in Squam. Better evidence that it belongs to the island's natural flora is afforded by a strong colony of full tree stature along a steep bank between Union and Orange streets. Although now pent in in the midtown and forming part of the back yards of buildings that abut on either street, this bank must have once formed a prominent bluff corresponding to the "Cliff" on the north side of the town. The evident age of these sumacs and their position on the side of the bluff allow strong presumption that they are a relic of its native vegetation. The larger trees are certainly not less than twenty-two feet in height, and one measured in 1909 was twenty-eight inches in circumference one foot above the base. This sumac occurs on Marthas Vineyard on a bank at Tashmoo Pond, where it is clearly native.

RHUS GLABRA L.

Frequent in dry ground about the borders of thickets in the northeastern section of the island from Shawkemo to Pocomo, Squam, and Sachacha. Elsewhere seen only among the Miacomet Pines, a few small plants, 1909, and west of Reed Pond, a single sprout, 1908. Close panicles of green buds July 11, 1912. On Nantucket this sumac is not ordinarily over two to four feet high, only exceptionally reaching a stature of five or six feet, and it is often the merest dwarf. The smallest fruiting plant seen was only six inches high, including a fruiting panicle 2½ inches long and 1¼ inches thick. The largest fruiting panicle observed was 3¾ inches long by 2½ inches thick.

Much variation in the leaves is shown even among plants of the same colony. The more common type of leaflet is lanceolate, sharply serrate, and the color of the upper surface rather a dull green. Side by side with plants so characterized occur others having much broader, subentire leaflets, dark shining green above and unusually whitened beneath.

TOXICODENDRON VERNIX (L.) Shafer.

Frequent, or rather common, in bogs throughout. Leaves beginning to appear June 1, 1909; leaves very small and undeveloped June 10, 1911.

TOXICODENDRON VULGARE Mill.

Abundant and of wide variation, quite probably including more than one species. Dr. E. L. Greene, who has kindly looked over my series of specimens, is rather definitely of this opinion, but points out to me that no pronouncement should be made in the absence of mature fruit. My collections, all made in June, bear panicles of buds or freshly opened flowers and clusters of the weathered fruit left over from the year before and having little or nothing remaining of the pericarp. The most abundant form on Nantucket is the common erect shrubby plant of low grounds, with ovate, often subcordate, shining leaflets, more or less rusty pubescent on the veins beneath, and globose or depressed globose, pubescent fruit. Very similar but taller and sometimes high-climbing forms have thinner, less shining leaves, often cuneate at the base, and differ further in their more diffuse inflorescence and rather larger flowers. A form with essentially similar inflorescence keeps to the ground in pine groves, running among the beds of pine needles and putting up short erect branchlets from its procumbent stems. All of these forms have essentially entire leaflets, but a low-climbing form found on Coskaty has thin leaflets mostly cuneate at the base and coarsely dentate. Most distinct of all is a plant of compact and clustered small foliage and prostrate and rooting stems, which thrives in the driest and most exposed reaches of pure white sand. By comparison in the field with freer-growing larger-leaved forms this showed marked differences in the inflorescence, which was sparser and much more contracted, even congested, with considerably smaller flowers, the anthers especially being less than half the size, by actual measurement 0.5–0.75 mm. as against 1.5–1.75 mm. The small fruit is densely pubescent.

ILICACEAE

ILEX OPACA Ait.

Twenty-four years ago Mrs. Owen wrote that the holly was becoming rare on Nantucket, having been cut for firewood, but that it still grew in swamps at the eastern end of the island. It is indeed regrettably rare at the present day, and I have met with it only in secluded spots in Beechwood, and a single tree farther west, in Polpis. At the main Beechwood locality there was still in 1910 a scattered growth of strong trees, the largest 10–15 feet in height, with trunks of 10–12 inches in circumference. The Polpis tree, in 1900, was about 10 feet high, the trunk 14 inches around, one foot above the base.

In July 1912 it was found that most of the fine trees in Beechwood had been severely mutilated, presumably for Christmas decorations, the entire tops of most of them having been cut away.

ILEX GLABRA (L.) A. Gray.

A characteristic shrub of the eastern and the western sides of the island, ornamenting low thickets or fringing the borders of ponds with its masses of dark lustrous green. It is one of the few species of Nantucket which is common on both sides of the island but is almost wanting in the intervening territory, in which I have seen it at only a few stations: Pout Ponds, Tawpaushas Swamp, Shimmo Ponds, a single cluster, and a small patch among pines on the Surfside road—an unusual situation. It is common at Long Pond, at the western end of the island, and especially so about ponds and bogs in Polpis, on the eastern side, and occurs in Saul's Hills, in Squam, and about the borders of Tom Never's Swamp. Small flower buds June 10, 1908; first flowers July 2, 1912, generally in full blossom July 6; green fruit at the middle of September 1899.

ILEX BRONXENSIS Britton.

Wet thickets and low grounds, either strongly typical or varying toward the next. The most pronounced examples, collected in Shawkemo, bore broadly obovate or obovate-oblong leaves 2.5–5 cm. wide and 5–8 cm. in length of blade. First flowers July 4, 1912.

As here understood, this is our common northern winterberry, which is replaced southward by true *Ilex verticillata* (L.) A. Gray (*I. verticillata* var. *padifolia* Watson, *Prinos padifolius* Willd.). The latter, although common near New York City and frequent on Long Island, appears not to extend eastward beyond southern New England.

***Ilex fastigiata** sp. (?) nov.

A closely much branched shrub similar to *Ilex bronxensis* but of more compact habit, the numerous ascending branchlets usually crowded and often closely fastigiate, the young bark pale, becoming dull bluish or brownish gray; leaves glabrous, or loosely pubescent on the veins beneath, very numerous, much smaller, narrower and more attenuate than those of *I. bronxensis*, dark green and shining as if polished or often dull bluish green with a subglaucous bloom, becoming coriaceous, slender-petioled; blades narrowly lanceolate to oblong-lanceolate or oblong, tapering to base and apex, often abruptly attenuate or short-caudate, commonly 2–4 cm. long (1–5 cm.) by 1–1.5 cm. wide (0.7–2 cm.), or sometimes much larger on the new shoots; serrulate to finely serrate with narrow-pointed, often outcurved, rigid teeth, or incised-serrate with the teeth almost spinescent, the margins undulate-revolute when dry; flowers on slender pedicels 1.5–4 mm. long, the corolla spreading 5–8 mm.; calyx lobes ciliate, mostly obtuse or rounded; fruit commonly smaller, more clustered, and deeper red in color than in *I. bronxensis*.

Common on Nantucket in low grounds, often clustered along wet thickets, and not infrequent in dry barrens. Ordinarily it is from five to eight feet in height but becomes fifteen feet high, with stems seventeen inches in basal girth. Nearly in flower June 18, 1908; first flowers July 1, 1912, everywhere in full flower July 10. The fruit remains green as late as the middle of September, maturing later in that month and in October. Type from near Long Pond, July 10, 1912, in full flower, in Herb. N. Y. Botanical Garden.

In color of bark and form of leaf this winterberry often calls to mind *Ilex verticillata* (L.) A. Gray rather than *I. bronxensis*, notwithstanding its nearer relationship with the latter. Like each of them it has a parallel thin-leaved shade form and a broader-leaved *cyclophylla* form.

This well-arisen scion of *I. bronxensis* largely replaces that species on Nantucket and to a less extent supplants it on Marthas Vineyard, but I have never seen it on Long Island. In its authentic pattern it bears a contrast to *I. bronxensis* that is altogether striking in plants so nearly related. Not any doubt need be entertained that it is no mere casual variation of that species. It is too well declared in the Nantucket flora to have had other cause than some broadly operating influence that has drawn it strongly away from the ordinary mainland type, albeit without having effected a wholly secure detachment. Connecting forms denote well enough its immediate parent, yet everywhere among such confusing intermediates it reports its own individual claim and bears a regional and insular stamp that may well be approved by a name. It is perhaps of no importance at all to classification whether this name be of trinomial or of binomial structure. The status of a plant once understood, it neither adds to nor detracts from the taxonomic facts it stands for, whether it be called by a name made up of two factors or of three. The really important question would seem rather to be, how far a third symbol may needlessly encumber speech and writing and err still further in overweighting nomenclature by leading straightway, and logically, to the polynomial. Here assuredly has taken its source that revived polynomialism already upon us which proceeds unmindful that a name is not a classification; and this notwithstanding that the efficient binomial ever perfectly denotes its object, whether in point of distinction small or great, provided only that it be worthy to be named at all. Its function is nominative, not classificatory. It stands opposed to the false precision of the multiple name now fast falling into incoherency in its pursuit of impossible distinctions—varieties, large type varieties, small type varieties, states, conditions, and forms. Held to its simple appellative function, the binomial should presently come upon a fair stability undisturbed by those problems of definition and relationship that, because they must continue to trouble our classifications, need not greatly disturb the names of the things we seek to classify.

Effect of asparagin on absorption and growth in wheat*

J. J. SKINNER AND J. H. BEATTIE

(WITH PLATE 33)

For the past few years a survey of the organic matter of the soil from the standpoint of biochemistry, has been under way in the Laboratory of Soil Fertility Investigations. As many as 25 different organic compounds have been isolated and identified. The definite recognition of these compounds has led to a fuller understanding of the chemistry of the organic matter of soils and of the biological changes taking place therein. The compounds isolated cover a wide range of chemical substances of biological origin. They are represented by the hydrocarbons, consisting of carbon and hydrogen only; by the acids, fats, resins, alcohols, esters, waxes, consisting of carbon, hydrogen, and oxygen; as well as by a large group of nitrogenous compounds, which consist of carbon, hydrogen, oxygen, and nitrogen.

The nitrogenous soil constituents isolated are creatinin,† with the probability that creatin also exists, hypoxanthin, xanthin, guanin, adenin, cholin, histidin, arginin,‡ nucleic acid,§ and picolin carboxylic acid.|| A number of these have been studied in regard to their effect on plant growth. Some of the soil constituents have been found to be harmful as for instance, picolin

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* Contribution from the Laboratory of Soil Fertility Investigations. Published by permission of the Secretary of Agriculture.

† Shorey, Edmund C. The isolation of creatinine from soils. Jour. Amer. Chem. Soc. **34**: 99. 1912; also U. S. Dept. Agr. Bur. Soils Bull. 83^1: 11–22. 1912.

‡ Schreiner, O., and Shorey, Edmund C. Chemical nature of soil organic matter. U. S. Dept. Agr. Bur. Soils Bull. 74: 34–36. 1910; The presence of arginine and histidine in soils. Jour. Biol. Chem. **8**: 381. 1910; Pyrimidine derivatives and purine bases in soils. Jour. Biol. Chem. **8**: 385. 1910.

§ Shorey, Edmund C. Nucleic acid in soils. Science II. **35**: 390. 1912; Biochemical Bull. **1**: 104. 1911.

|| Schreiner, O., and Shorey, Edmund C. The isolation of picoline carboxylic acid from soils and its relation to soil fertility. Jour. Amer. Chem. Soc. **30**: 1295. 1908; The isolation of harmful organic substances from soil. U. S. Dept. Agr. Bur. Soils Bull. 53: 1–53. 1909.

carboxylic acid[||] and dihydroxystearic acid,[*] while others are beneficial to growth. Creatinin, one of the nitrogenous soil constituents, has a beneficial effect on growth.[†] An extended study has been reported on, with this compound. Plants grown in solution cultures containing only potash and phosphate show greatly increased growth when creatinin is added. When large amounts of nitrate are present in the culture solutions, creatinin produced no appreciable effect on the growth. Plants growing in nitrate cultures, whether low or high in nitrate, showed a greatly diminished absorption of this ingredient when creatinin was present, whereas the removal of potash and phosphate was practically normal. It seems that creatinin was absorbed by the plants, replacing the effect of nitrates. Creatin, nucleic acid,[‡] hypoxanthin, and xanthin are also beneficial and have a similar action.

Many observations have been made with nitrogenous compounds not yet isolated from soils, although allied to the compounds which have been found to exist in soils. In this connection asparagin has been studied.

Asparagin is a water-soluble form of organic material which is relatively abundant in plants. It was first found in the young shoots of asparagus and subsequently in a large number of other plants representing many different families.

A number of investigators have worked with asparagin. Baessler[§] found it to be beneficial to maize, Prianischnikoff and Lebedeff[||] secured beneficial results, working with oats; Hansteen[¶]

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[*] Schreiner, O., and Shorey, Edmund C. The isolation of dihydroxystearic acid from soils. Jour. Amer. Chem. Soc. **30**: 1599. 1908. Schreiner, O., and Skinner, J. J. Some effects of a harmful organic soil constituent. Bot. Gaz. **50**: 161. 1910; U. S. Dept. Agr. Bur. Soils Bull. 70: 1–98. 1910.

[†] Skinner, J. J. Effects of creatinine on growth and absorption. U. S. Dept. Agr. Bur. Soils Bull. 83^3: 33–41. 1911; Beneficial effect of creatinine and creatine on growth. Bot. Gaz. **54**: 152–163. *f. 1.* 16 Au 1912.

[‡] Schreiner, O., and Skinner, J. J. The action of nucleic acid and its decomposition products on soils and plants. Science II. **35**: 390. 1912.

[§] Baessler, P. Assimilation des Asparagins durch die Pflanze. Landw. Vers. Stat. **33**: 231. 1887.

[||] Prianischnikoff, D., and Lebedeff, A. N. Assimilation of the nitrogen of some compounds in sterilized media. Tzv. Moscow Selskokhar Inst. **3**: 56. 1897; Abst. Exp. Sta. Rec. **9**: 820. 1907–8.

[¶] Hansteen, B. Om aeggehvidesynthese i den grönne phanerogame plante. Vid. Selsk. Skrifter No. 3. 1898; Über Eiweissynthese in grünen Phanerogamen. Jahrb. Bot. **33**: 417. 1899.

found it was beneficial to *Lemna;* Brown[*] found it beneficial to the barley embryo; Nakamura[†] secured beneficial results, working with the barley plant, and also found it beneficial to onions; and Molliard[‡] secured beneficial results with radish. All of these tests were made in water cultures.

EXPERIMENTAL METHODS

In studying the effect of asparagin on growth, wheat seedlings were grown in aqueous culture solutions containing the nutrient salts, calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained each of the salts singly, others were composed of a mixture of two salts, sodium nitrate and calcium acid phosphate, sodium nitrate and potassium sulphate, and calcium acid phosphate and potassium sulphate. Still other solutions had all three constituents in various proportions. In all there were 66 different cultures of nutrient solutions. The scheme of the experiment and manner of preparing the nutrient cultures was similar to that described in Bulletin 70 of the Bureau of Soils and other publications.[§] The concentration of all these solutions was 80 parts per million of the fertilizer ingredients, P_2O_5, NH_3, and K_2O. In cultures containing only one nutrient salt, for instance calcium acid phosphate, the concentration was 80 parts per million of P_2O_5. If two salts were present, for instance calcium acid phosphate and sodium nitrate, the concentration was 80 parts per million of $P_2O_5 + NH_3$. If all three salts were present the concentration was 80 parts per million of $P_2O_5 + NH_3 + K_2O$. The ratios of these concentrations varied in 10 per cent stages, making in all 66 different cultures. Distilled water treated with carbon was used in preparing the culture solutions. The culture solutions

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[*] Brown, H. T. On the culture of excised embryos of barley on nutrient solutions containing nitrogen in different forms. Trans. Guinness Research Lab. 1: 288. 1906.

[†] Nakamura, T. Relative value of asparagin as a nutrient for phanerogams. Bull. Coll. Agr. Tokyo 2: 465. 1894.

[‡] Molliard, M. Recherches sur l'utilisation par les plantes supérieures de diverses substances organiques azotées. Bull. Soc. Bot. France IV. 10: 541. 1910.

[§] Schreiner, O., and Skinner, J. J. Some effects of a harmful organic soil constituent. U. S. Dept. Agr. Bur. Soils Bull. 70: 1–98. 1910; Bot. Gaz. 50: 161. 1910; Ratio of phosphate, nitrate and potassium on absorption and growth. Bot. Gaz. 50: 1. 1910.

were contained in wide-mouth bottles holding 250 c.c., and 10 wheat plants were grown in each. The wheat plants when used for the experiment were about 2 cm. high; they had been previously germinated on aluminum disks floated upon the surface of a tank of water. When large enough to use in the experiment, seedlings of uniform size were selected for the test. The culture solutions were changed every three days, four changes being made during the course of the experiment. The solutions were analyzed for nitrates immediately after each change. The phosphate and potash were determined in a composite of the four changes. By this means the effect of asparagin upon the absorption of nutrients by the seedlings could be studied during the course of the experiment.

EFFECT OF ASPARAGIN ON GROWTH

Two sets of cultures were prepared: to one set were added merely the nutrient salts; to a similar set 50 parts per million of asparagin were added in each culture, in addition to the nutrient salts. The wheat seedlings grew in the culture solutions from November 13 to November 25.

When the plants had grown for several days it was noticeable that the asparagin cultures were better developed, these seedlings having broader leaves and longer and better developed roots. This was more pronounced in some of the fertilizer mixtures than in others. The beneficial effect became more decided as the experiment progressed. The weight of the plants taken at the end of the experiment shows the beneficial effect produced by the asparagin. The total green weight of the 66 cultures containing asparagin was 148.2 grams against 134.9 grams for the 66 control cultures, an increase of 9 per cent, as an average of all the asparagin cultures.

EFFECT OF ASPARAGIN ON GROWTH IN CULTURES CONTAINING NO NITRATE

The effect of the asparagin was more marked in the cultures containing potash and phosphate than in those which contained potash, phosphate, and nitrate. The green weight of the cultures composed of potash and phosphate with and without asparagin, taken at the termination of the experiment, are given in TABLE I. The first column gives the number of the culture; the second, third, and fourth the amount of the fertilizer ingredient in the culture solution. Calcium acid phosphate, sodium nitrate, and potassium sulphate were the nutrient salts used. The fifth column gives the green weight of the plant without asparagin, and the sixth column the green weight with 50 parts per million of asparagin in the solution.

TABLE I

EFFECT OF ASPARAGIN ON GROWTH IN CULTURE SOLUTIONS CONTAINING NO NITRATE

Culture no.	Fertilizer ingredients in culture solution			Green weight of cultures	
	P_2O_5, parts per million	NH_3, parts per million	K_2O, parts per million	Without asparagin, grams	With 50 p. p. m. asparagin, gms.
56	0	0	80	1.385	1.832
46	8	0	72	1.368	1.644
37	16	0	64	1.382	1.742
29	24	0	56	1.119	1.825
22	32	0	48	1.393	2.145
16	40	0	40	1.223	2.199
11	48	0	32	1.167	1.932
7	56	0	24	1.243	2.199
4	64	0	16	1.313	1.909
2	72	0	8	1.311	1.775
1	80	0	0	0.811	0.975

All of the cultures with asparagin present show a marked increase in weight. Culture no. 37 containing 16 parts per million of phosphate and 64 parts per million of potash gave 1.382 grams green weight without asparagin and 1.742 grams with asparagin; culture no. 16, which contained 40 parts per million both of phosphate and of potash gave 1.223 grams weight without asparagin and 2.199 grams with asparagin. Culture no. 4, composed of 64 parts per million phosphate and 16 parts per million potash, gave 1.313 grams green weight without asparagin and 1.909 with asparagin. The total weight of the 11 cultures without asparagin was 13.714 grams against 20.478 grams with asparagin, thus showing an increase of 47 per cent as an average effect in the various cultures without nitrate. This series of cultures is reproduced in PLATE 33. Cultures marked with the same number, for instance 56 and 56*A*, have the same proportion of potash and phosphate. Cultures marked with the number alone contain no asparagin, the cultures with the letter *A* have 50 parts per million of asparagin. The composition of the culture solution is given in TABLE I. It will be seen that each culture containing asparagin, no matter what the proportion of phosphate and potash may be, is larger than the culture growing in a similar solution without the asparagin.

EFFECT OF ASPARAGIN IN CULTURES CONTAINING NITRATE

In TABLE II are given the green weights obtained in the series of cultures, all of which contain the uniform amount of 8 parts per million NH_3 as nitrate, with varying amounts of potash and phosphate. The effect of asparagin is still noticeable in these green weight figures, as it was while the plants were growing, but the additional effect is much less marked than in the absence of nitrate as shown in TABLE I. The total growth in this series with-

TABLE II

EFFECT OF ASPARAGIN ON GROWTH IN CULTURE SOLUTIONS CONTAINING 8 PARTS PER MILLION NH_3 AS NITRATE

Culture no.	Fertilizer ingredients in culture solution			Green weight of cultures	
	P_2O_5, parts per million	NH_3, parts per million	K_2O, parts per million	Without asparagin, grams	With 50 p. p. m. asparagin, gms.
57	0	8	72	1.880	1.830
47	8	8	64	1.912	2.275
38	16	8	56	2.234	2.184
30	24	8	48	2.244	2.580
23	32	8	40	2.027	2.665
17	40	8	32	1.839	2.433
12	48	8	24	1.961	2.545
8	56	8	16	2.073	2.240
5	64	8	8	1.863	2.068
3	72	8	0	1.265	1.255

TABLE III

EFFECT OF ASPARAGIN ON GROWTH IN CULTURE SOLUTIONS CONTAINING 16 PARTS PER MILLION NH_3 AS NITRATE

Culture no.	Fertilizer ingredients in culture solution			Green weight of cultures	
	P_2O_5, parts per million	NH_3, parts per million	K_2O, parts per million	Without asparagin, grams	With 50 p. p. m. asparagin, gms.
58	0	16	64	1.905	2.379
48	8	16	56	2.270	2.489
39	16	16	48	2.510	2.255
31	24	16	40	2.518	2.795
24	32	16	32	2.289	2.660
18	40	16	24	2.633	2.566
13	48	16	16	2.256	2.545
9	56	16	8	2.219	2.245
6	64	16	0	1.317	1.319

out asparagin was 19.298 grams against 22.075 grams with asparagin, an additional increase of 14 per cent due to asparagin. When no nitrate was present this additional effect of the asparagin was 47 per cent.

In TABLE III the green weight for the series of cultures containing 16 parts per million NH_3 as nitrate, is given. Without the asparagin the total weight of these cultures is 19.917 grams; with asparagin it is 21.253 grams, or only an increase of 7 per cent. The additional effect of asparagin was still less in the 24 parts per million NH_3 cultures, and with the higher amounts of nitrate this effect became even uncertain.

The effect of asparagin was much more pronounced in those fertilizer combinations that contained no nitrate and those low in nitrate. From this it appears that asparagin, like creatinin, creatin, hypoxanthin, xanthin, and a number of other nitrogenous compounds, can replace the effect of nitrate in producing plant growth.

INFLUENCE OF ASPARAGIN ON ABSORPTION OF FERTILIZER SALTS

The foregoing discussion shows clearly the influence of asparagin on growth and its effect in cultures containing no nitrate. There remains to be discussed the removal of nutrients from the solution during the growth of the plant. As already mentioned, the absorption of nutrients was determined by making an analysis for nitrate at the termination of every three-day change, and of the phosphate and potassium on a composite of the solution from the four changes. It is thus possible to compare the results obtained under the controlled conditions, without the asparagin and under the conditions where 50 parts per million of asparagin were present in the solution.

The total phosphate, potash, and nitrate removed from the cultures was 1,109.6 milligrams for the normal and 1,117 milligrams for the cultures containing asparagin. The examination of the results, when considered for the three constituents separately as given below, shows that the phosphate and potash absorption were somewhat greater in the asparagin cultures, as is demanded by the larger growth, whereas the nitrate removal is considerablv less than in the normal cultures.

The amount of phosphate stated as P_2O_5 removed from the solutions during the experiment was 201.2 milligrams for the normal cultures and 326 milligrams for the cultures containing asparagin, a difference of 124.8 milligrams in favor of the asparagin cultures.

The amount of potash stated as K_2O removed from the solutions was 471.2 milligrams for the normal cultures and 485.6 milligrams for the asparagin cultures. As with the phosphate the asparagin cultures removed slightly more potash than the normal cultures, 14.4 milligrams.

The amount of nitrate removed during the course of the experiment was 437.2 milligrams by the normal and 305.4 milligrams for the asparagin cultures. The asparagin cultures, though making a larger growth, used 131.8 milligrams less nitrate. It seems that the plants absorb and use asparagin whether nitrate be present or not, the effect on growth being much more marked in the limiting case where no nitrate was present, and that in the other cases the compounds replaced the effect of nitrate.

The culture work was throughout under strict chemical control, so as to establish as definitely as possible that the effects on the plants noted were produced by the absorption of the compound as such. Nitrite, nitrate, and ammonia were tested for and found to be absent, or, in the case of ammonia, present in traces only. Although neither nitrate, nitrite, nor ammonia was found, the plants, nevertheless, grew remarkably well, and the only conclusion justified by this experimental evidence is that this compound is directly absorbed and assimilated. With the strict chemical control exercised, all possibility of any extended action by bacterial or other external biological agencies seems excluded. If such effects were produced in these experiments, they were of only minor significance in the results obtained. Bacteria and other microorganisms were excluded so far as possible, but no special effort was made to maintain absolutely sterile conditions, inasmuch as this would have been a practical impossibility in experiments on so large a scale, involving over a thousand plants in a single test. Moreover, it may even appear questionable whether absolute sterility, as being too artificial a condition for the determination of the effect of soil constituents on plants, would be desirable.

It would seem that chemical control under as normal conditions as a cultural experiment will allow, is better than conducting the experiment under the artificial condition of sterility, which, after all, is made only so that biochemical changes may be excluded. In these experiments the bottles were sterilized before being used in making culture solutions for the various changes, the pans and other apparatus used in germinating the seed were sterilized from time to time, and corks used for the cultures were always clean and sterilized before use. Although all of these precautions were taken, it was of course not possible to exclude some microorganisms in such work, as the solutions were exposed from time to time to the air. There was no excessive microorganic life noticeable. While bacteria and other micrcorganisms were present in the solutions to a slight extent, it can hardly be said that their influence could have been large; that is, such influence as they had was probably so slight as to be negligible so far as the general and larger tendencies which are shown to exist are concerned.

While the effect of the asparagin decreased with increasing nitrate so far as additional effect on growth is concerned, it had nevertheless a conserving effect upon the amount of nitrate left in the solution during the time the plants were growing, as is shown by the analysis of the solution. It appears, therefore, that the plant can utilize this nitrogenous compound for plant synthesis.

BUREAU OF SOILS,
WASHINGTON, D. C.

Explanation of plate 33

Wheat plants growing in culture solutions with and without asparagin, and containing various proportions of potash and phosphate but no nitrate. Cultures with the letter *A* following the number contain asparagin.

A contribution to the life history of Uvularia sessilifolia

ISABEL ALDEN

(WITH PLATES 34, 35)

INTRODUCTION

That the seasonal development of any plant, especially with reference to the unfavorable winter season, should be of interest and of some significance is undoubted. Such a study has been begun here with *Uvularia sessilifolia* and includes field observations as to growth of rhizome and aerial shoot as well as a more detailed study of the development of the megasporangium and microsporangium. The chronological development of these latter organs has received some attention, but the actual number of cases is meager, and what the significance of the history of these organs of reproduction may prove to be can be shown only after a considerable number of plants, particularly of related genera, have been studied. The variations thus far brought to light show the need of an even wider range of investigations in this line than at first would seem necessary. The plants that have been thus studied so far show a wide range of variation. *Symplocarpus foetidus* (Duggar[1]) showed the nuclei of the definitive archesporium in a resting condition about October first, with the divisions of the pollen mother cells taking place the first warm days of April. In *Trillium* (Smith[2]) the microspores were found in the mother cell stage in April together with the four potential megaspores. In *Hepatica* (Chamberlain[3]), however, the early spring, that is while the ground was still frozen, showed pollen grains fully formed and the embryo sac ready for fertilization. The same investigator[4] claimed that *Salix* passed the winter in the microspore mother cell stage with no megaspore defined till after the renewal of growth in the spring. This condition of the microsporangium has been challenged, for *Salix fragilis* (Moore[5]) showed the cells of the anther still homogeneous without differentiation of tissue in November. Perhaps *Corylus* and *Alnus*[3] gave the most extreme condition, for here the midwinter catkins showed pollen grains in which the tube nucleus and generative nucleus were distinct.

At first thought it would seem that that point which marks the end of the sporophyte generation would mark the end of the growing season. This has been made a generalization.[6] Chamberlain[3] suggests further that since the mother cell stage appears as a common halting place for the winter, this may be the condition most capable of withstanding the unfavorableness of winter. However, even the few instances given above show enough variety to lead one to suspect that perhaps the mother cell stage in winter is not to be found in a high enough majority of cases to warrant such an interpretation. The particular plant taken for this study, *Uvularia sessilifolia*, is one in which neither microspore nor megaspore passes the winter in that turning point of sporophyte and gametophyte phases.

The study is but a preliminary one and intended largely to indicate the time at which the various stages in the life history are to be sought. A cytological study of the stages here given is in progress.

COLLECTING AND METHODS

The buds of the rhizome of *Uvularia sessilifolia* were taken at intervals during the year as given below in detail. In the earlier stages the tips of the rhizome were put directly into the fixing agent, while in the later material from one to several of the bud scales were first removed. In the spring material the bud was dissected and the flower alone fixed. The fixing fluid used was chrom-acetic acid; time, twenty-four hours. The material was then washed and run through successive grades of alcohol, beginning with 15 per cent and changing the final absolute alcohol once. The infiltration was with cedar oil, 33 per cent cedar oil and absolute alcohol, 66 per cent cedar oil and absolute alcohol, and two changes of pure cedar oil. The paraffin was gradually introduced into the cedar oil and the material finally imbedded in pure paraffin melting at 54° C. The sections were cut about 7 mm. thick and mounted serially. Delafield's hematoxylin was used in staining, as only the general stages were sought.

FIELD OBSERVATIONS

Uvularia sessilifolia grows in rather close colonies, a fact correlated, of course, with the rhizome habit. The season's elongation of the rhizome appears first about the middle of April as a tiny protuberance at the base of the spring's leafy shoot. This quickly pushes out, elongating so rapidly that by the first of May the length of the new growth is one half to one inch. The growth continues very rapidly so that by the first of June the increase is from two to four inches. This is apparently almost the limit of increase. The bud at the end is at this time but slightly larger in diameter than the rhizome itself. No attempt has been made in this study to get at the contents of the buds borne at the base of the flowering and the non-flowering branches. The tip end becomes curved upward slightly and is usually at depths varying from one to three inches below the surface of the ground. The size of the bud increases mostly during the latter part of August and the month of September. From October through to March the size is practically the same. With the renewal of growth in the spring, however, the portion just back of the bud again elongates rapidly and the buds increase greatly in diameter and length so that they appear above ground about the middle of April, those containing flowers being about one fourth of an inch in diameter. The flowers appear the first week of May.

An interesting and probably very significant fact is noticed in connection with those plants having flowers. In all the plants observed the flowering plant is seen to branch once, the flower being borne at the first or second node of one of the branches. Conversely, no plant was found branched that did not blossom. This reminds one of similar occurrences in *Erythronium* and in *Podophyllum*, where the flowering plant bears in every instance two leaves, the non-flowering ones a single leaf.

DEVELOPMENT OF THE MICROSPORANGIUM

The development of the microsporangium is the usual one throughout, as will be seen in the stages here given. The first stage which I obtained for the microsporangium is that seen August 8, in which the inner whorl of stamens shows the differentiation of the hypodermal cell with beginnings of divisions into primary wall and primary sporogenous cell, FIG. 1, while the outer whorl of stamens has advanced to show several divisions of the primitive sporogenous cells as well as of the wall cells, FIG. 2. The general four-lobed appearance of the younger set is seen by reference to FIG. 3, and the comparative advance of the outer whorl noted in FIG. 4. (The crowding of the stamens is particularly noticeable at this time, which would account for the irregularity of outline in FIG. 4.) This earlier development of the outer set of stamens is noted in the history of the development until at the time of tetrad formation, the two are very nearly synchronous. The stages of the individual cells throughout any single anther are practically simultaneous.

The differentiation of the hypodermal cell is the usual one, namely, the increased size and denser cytoplasm, FIG. 5. The number of primary archesporial cells may be from three to six, FIG. 1, 2. In the young sporogenous cells the chromatic material is apparently very abundant, irregularly distributed in the fine linin mesh with prominent knots at the crossings. Two nucleoli are noted as of frequent occurrence, a condition that persists up to the mother cell stage, FIG. 5. The tapetal cells were not differentiated at this stage.

The primary wall cells divide to form five layers, the three outermost making up the permanent wall of the sporangium, FIG. 6, the innermost functioning as tapetum, while the intervening one breaks down at the time of maturity of the microspore mother cells. The tapetal jacket cells round off with the sporogenous mass, and at the time just preceding synapsis are usually elongated, the nuclei all in the end next the sporogenous tissue, FIG. 7. The nuclei of the tapetum are apparently at this time about to disorganize, staining diffusely and appearing as dark masses.

The mature spore mother cells, seen about the middle of September, have so increased in size that the prominent nucleus is now the size of the original hypodermal cell. The linin network of the nucleus is finer and the chromatin more evenly distributed, although still prominently knotted, than in the primitive sporogenous cells. The nucleolus (frequently two appear) is prominent. By the latter part of September the spore mother cells of the outer whorl of stamens show synapsis.

The material collected October 21, 1910, and that collected October 27, 1909, show the formation of tetrads, the phases varying from the equatorial plate stage of the heterotypic division to the complete organization of the four daughter nuclei. The usual large thick chromosomes that characterize the reducing division are seen. At the end of this division a resting nucleus is formed in each of the daughter cells, but no wall separates the two. The homoeotypic division, however, is not long delayed, as in the same anther all these stages may be found including the completed tetrads.

The spores round off and increase in size; it is at this point that the approach of winter is met. With the renewal of growth in the spring the pollen grains found in early March show the outer and inner walls differentiated and apparently mature in size. In this early spring condition the nucleolus is prominent, and the linin mesh fine and close with small chromatic granules. The division of the pollen grain nucleus into tube and generative nuclei is noted in the late April material, in which the generative nucleus appears not fully organized but showing traces of the spireme condition, and the tube nucleus is characterized by a large nucleolus but poorly organized reticulum, FIG. 8. The generative nucleus is rich in chromatic material staining deeply, and the tube nucleus has but little. I have not found the division of the generative nucleus, which evidently takes place after the shedding of the pollen.

DEVELOPMENT OF THE MEGASPORANGIUM

Turning to the study of the megasporangium, we find that its development is as tardy as that of the microsporangium is early. At the time when the archesporium of the microsporangium is formed, the ovary is a homogeneous mass. In September the carpelary cavities have appeared, and in each a pair of nucelli are protruding. The number of these cell masses destined to develop the megasporangia varies from two to three pairs for each cavity. In general each of a pair is on the same plane. In October and even as late as December the uniformity of the nucellar tissue is unchanged, and very little change in size is noted, FIG. 9 and 10. In early March the outline of the nucellus is such as to suggest an enlarging hypodermal cell at the side next the carpel wall, FIG. 11. The cells of the hypodermal layer, however, do not show the characteristics of the usual archesporial tissue, for the cells are only slightly enlarged, the cytoplasm not dense, and the chromatic network not prominent. Moreover, more than one of the hypodermal cells show a slight increase in size, perhaps indicating the archesporial potentiality of several hypodermal cells, FIG. 12. This is indicative of a primitive condition. A single cell, however, increases more rapidly than the others, getting a start over the others, for in the material of March 14 this greater increase is noted in the cell destined to develop the embryo sac, FIG. 13.

By the first of April this enlarging cell has become quite prominent, giving the cell mass a decidedly one-sided appearance. The nucleus is large but still with inconspicuous reticulum. This cell continues to increase in size, FIG. 14, and toward the end of April projects strongly, and the inner integument has begun to develop. The nucleus at this stage shows synapsis, indicating that the hypodermal cell does not divide to cut off a primary wall cell but functions directly as the megaspore mother cell, FIG. 15.

Five days later, April 30, the turning of the ovule, which was slight on April 25, is now almost complete and the ovule typically anatropous. The integuments have grown rapidly and almost surround the embryo sac. Owing to the twisting of the ovule at this time, it has been found difficult to obtain a longitudinal section of the developing mother cell. However, in material collected May 7 the division of the mother cell, which was in synapsis one week earlier, is complete, and two cells, which may be called megaspores, are seen. Vesque[7] has stated that each develops an embryo sac to the four-nucleate stage.

SUMMARY

1. The archesporium of the microsporangium, consisting of from 3 to 6 hypodermal cells, becomes differentiated the first of August.

2. The hypodermal cells divide at this time forming the primary sporogenous and the primary parietal cells.

3. The primary parietal cells divide several times, giving rise to the permanent wall of the sporangium and to the tapetum.

4. The primary sporogenous cells give rise to several microspore mother cells which are found mature in the middle of September.

5. The divisions of the microspore mother cells take place in October and show the usual tetrads. The winter is thus passed with microspores fully formed.

6. In the latter part of April the microspore divides to form the generative and the tube nuclei. The division of the former probably occurs after the shedding of the pollen.

7. The archesporium of the megasporangium is not differentiated till early March and consists of a single hypodermal cell, the adjacent cells showing gradations in size and characteristics of potential archesporial cells.

8. The archesporium does not divide to form a primary wall cell and primary sporogenous cell but functions directly as the megaspore mother cell. It reaches maturity about the middle of April.

9. The reduction division of the megaspore mother cell takes place the last week of April.

10. Two megaspores are found about one week later.

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Explanation of plates 34, 35

Uvularia sessilifolia

All drawings have been made with the aid of a Bausch and Lomb microscope and camera lucida.

PLATE 34

FIG. 1. Portion of cross section of anther of inner stamen of flower on August 8. (× 310.) *H*, hypodermal cell. *D*, hypodermal cell dividing into primary sporogenous and primary wall cell. Three hypodermal cells apparently give rise to archesporium.

FIG. 2. Portion of cross section of anther of outer stamen of flower on August 8. (× 310.) *D*, derivatives of primary wall cell. *P*, primitive archesporium. Five hypodermal cells apparently divided.

FIG. 3. Outline of cross section of inner anther of flower on August 8. (× 70.)

FIG. 4. Outline of cross section of outer anther of flower on August 8. (× 70.)

FIG. 5. Single hypodermal cell of anther on August 8. (× 720.) Note two nucleoli.

FIG. 6. Portion of cross section of anther on September 21. (× 70.) *W*, wall cells, 3 layers. *M*, middle layer, disappearing. *T*, tapetum. *S*, microspore mother cells.

FIG. 7. Portion of cross section of anther, September 27. (× 310.) *S*, microspore mother cell. *T*, tapetum cells elongated, nuclei close to spore mother cells. *M*, middle layer disorganized. *W*, wall.

FIG. 8. Cross section of pollen grain, April 25. (× 720.) *G*, generative nucleus. *T*, tube nucleus: note the prominent nucleolus and poor reticulum.

FIG. 9. Outline of portion of cross section of ovary showing two nucelli, Oct. 21. (× 70, material somewhat shrunken.)

PLATE 35

FIG. 10. Outline of portion of cross section of ovary showing two nucelli, Dec. 8. (× 70, material somewhat shrunken.)

FIG. 11. Outline of portion of cross section of ovary showing nucellus with slight swelling at one side, Mar. 3. (× 70.)

FIG. 12. Portion of longitudinal section of nucellus, showing enlarging hypodermal cells, Mar. 3. (× 310.) *M*, probable megaspore mother cell.

FIG. 13. Portion of longitudinal section of nucellus, showing megaspore mother cell enlarging, Mar. 14. (× 310.)

FIG. 14. Portion of longitudinal section of nucellus showing megaspore mother cell, April 13. (× 310.)

FIG. 15. Portion of longitudinal section of nucellus, showing nucleus of megaspore mother cell in synapsis and origin of inner integument, April 25. (× 310.)

INDEX TO AMERICAN BOTANICAL LITERATURE

(1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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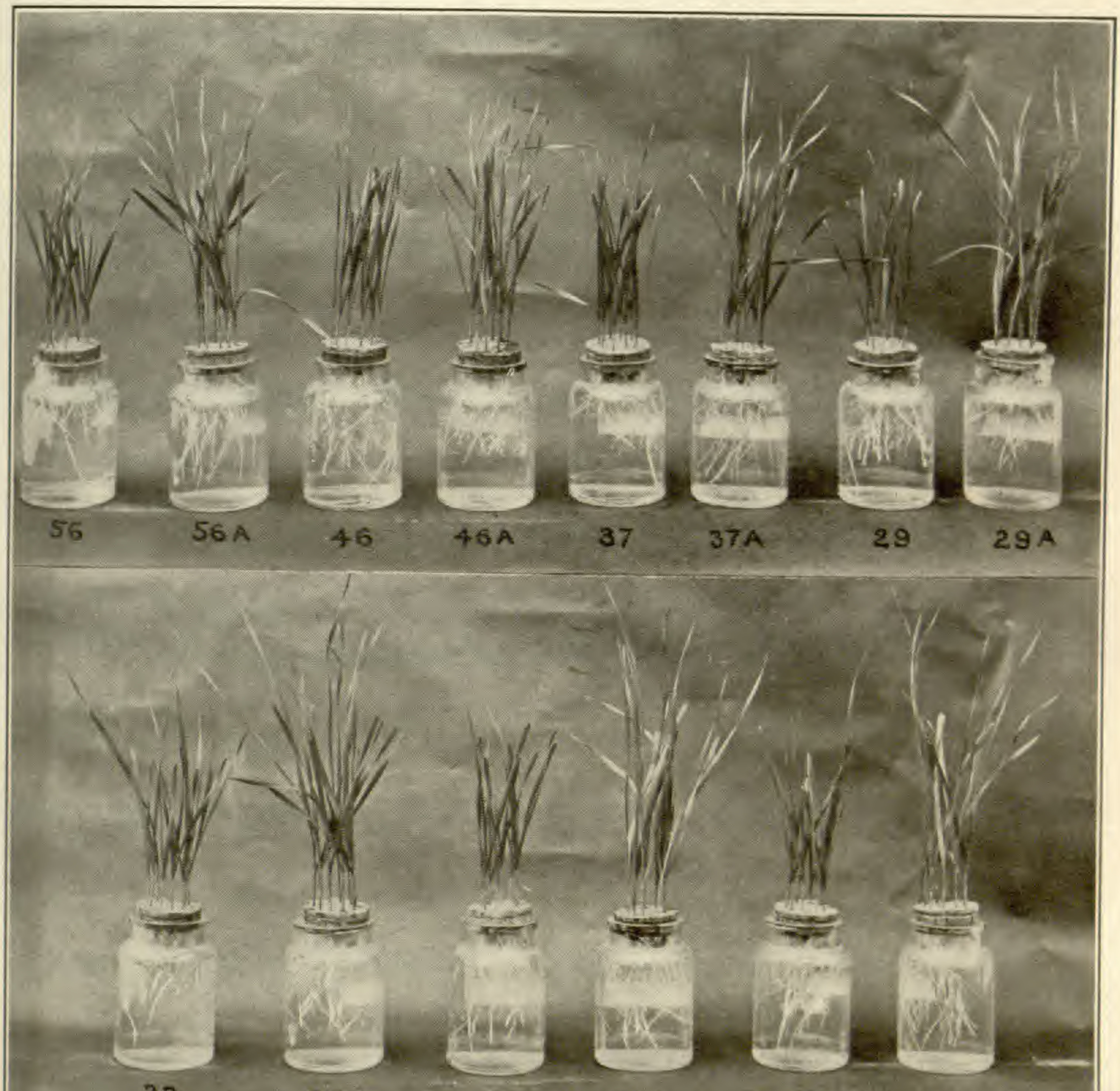

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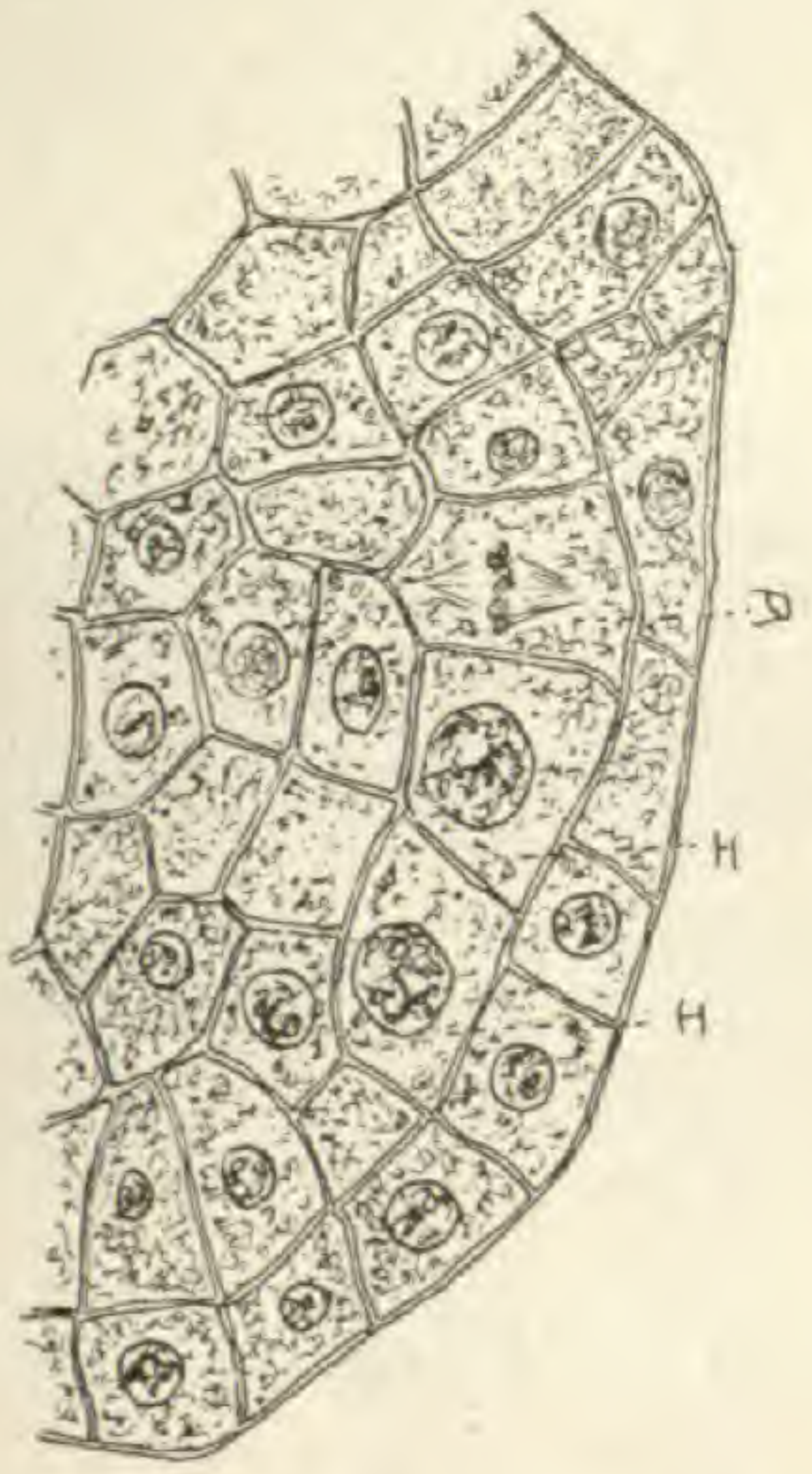

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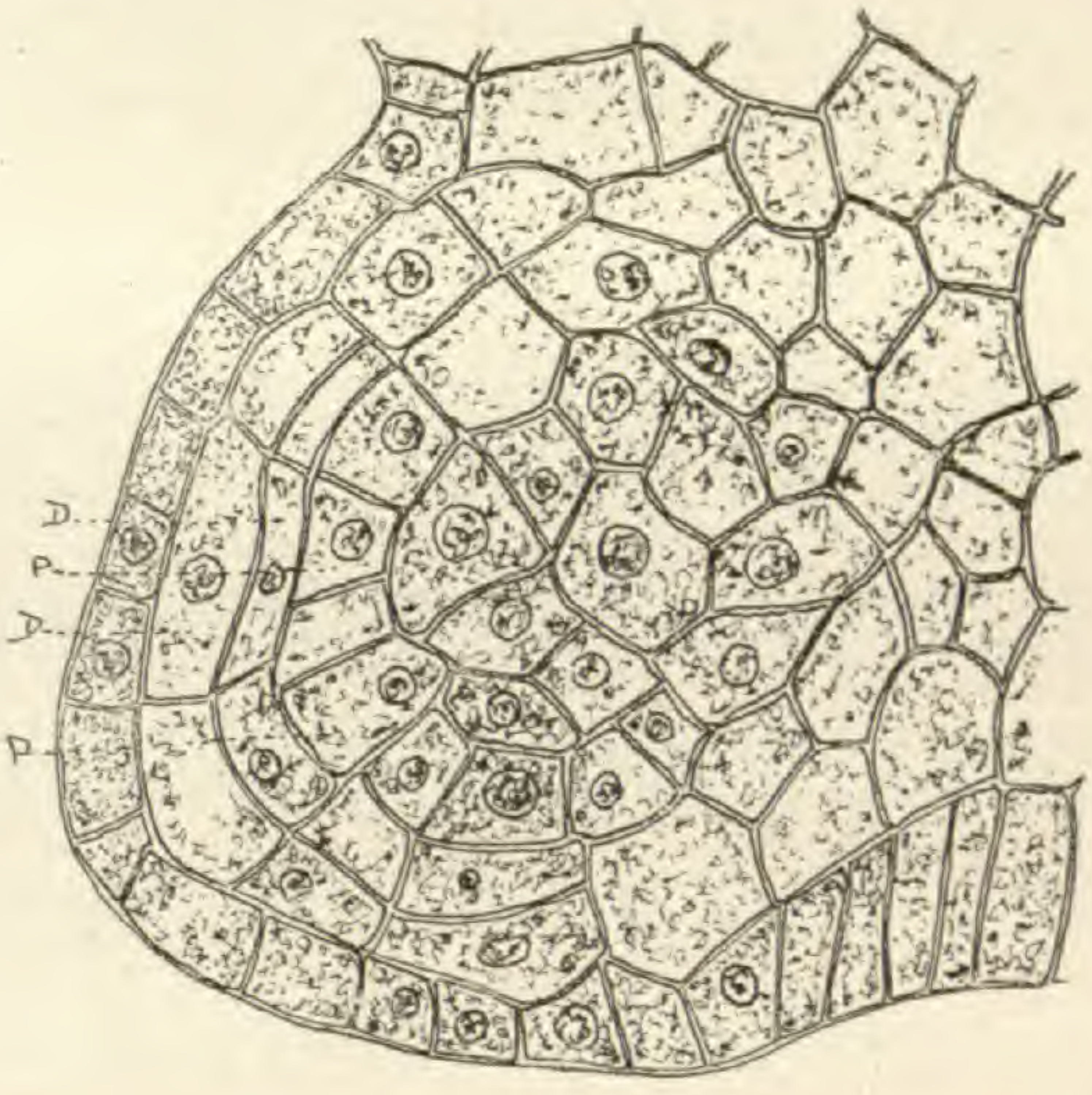

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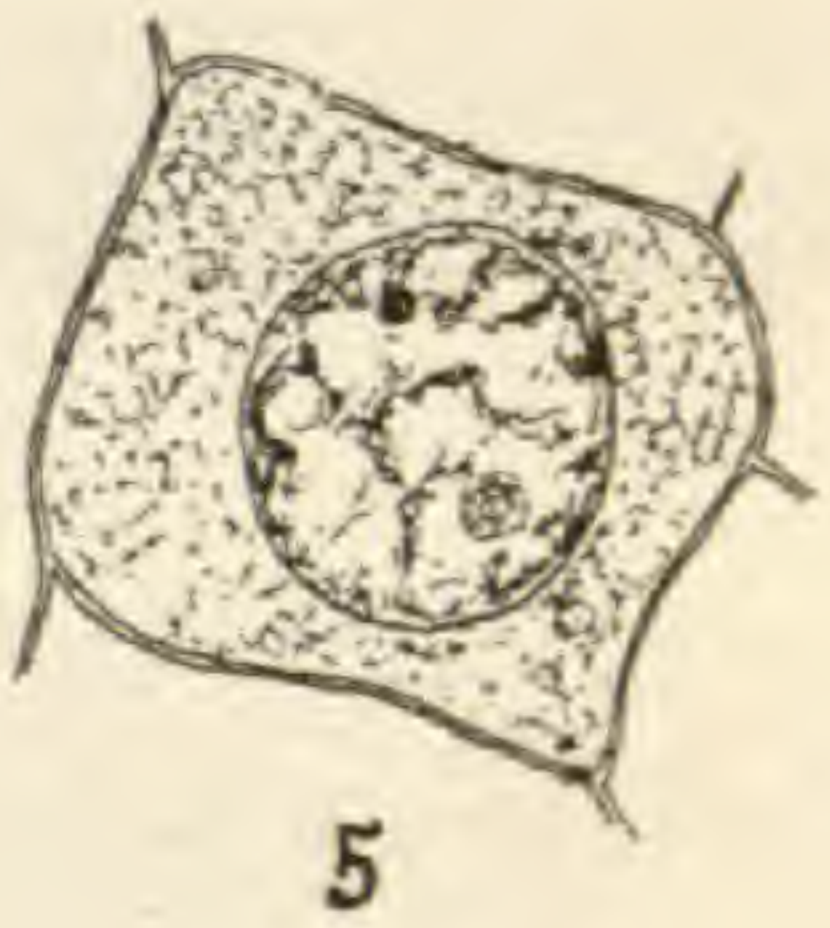

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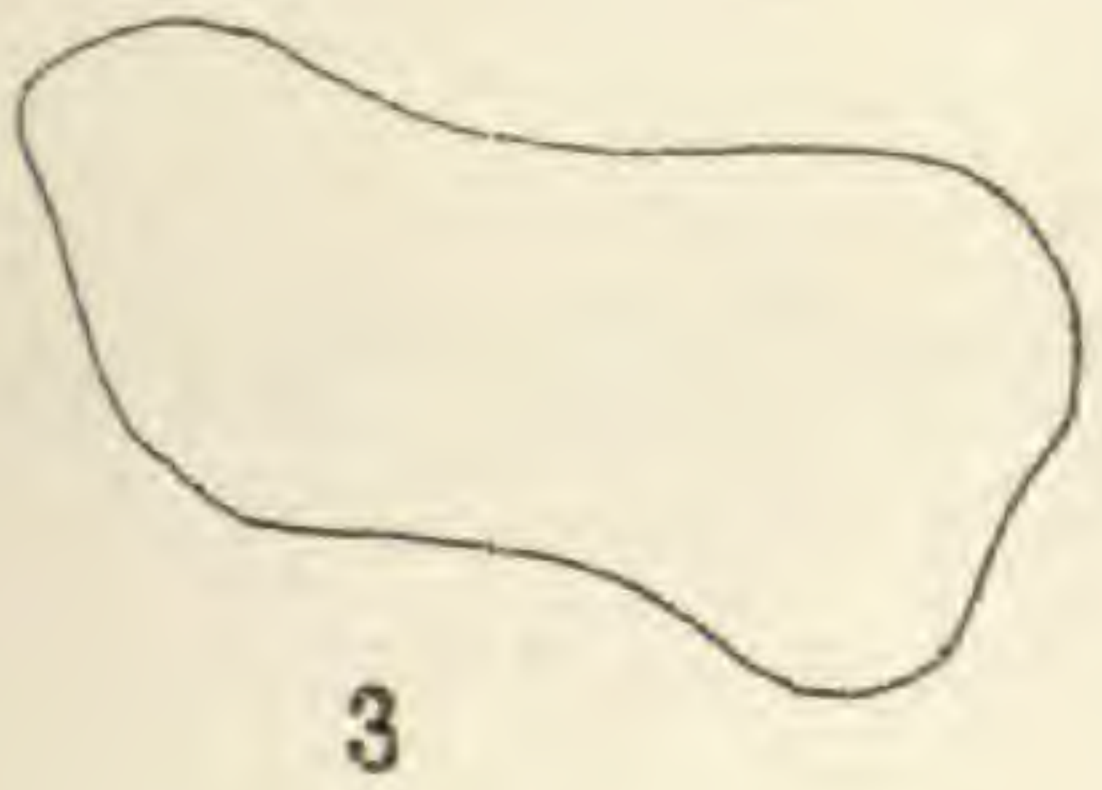

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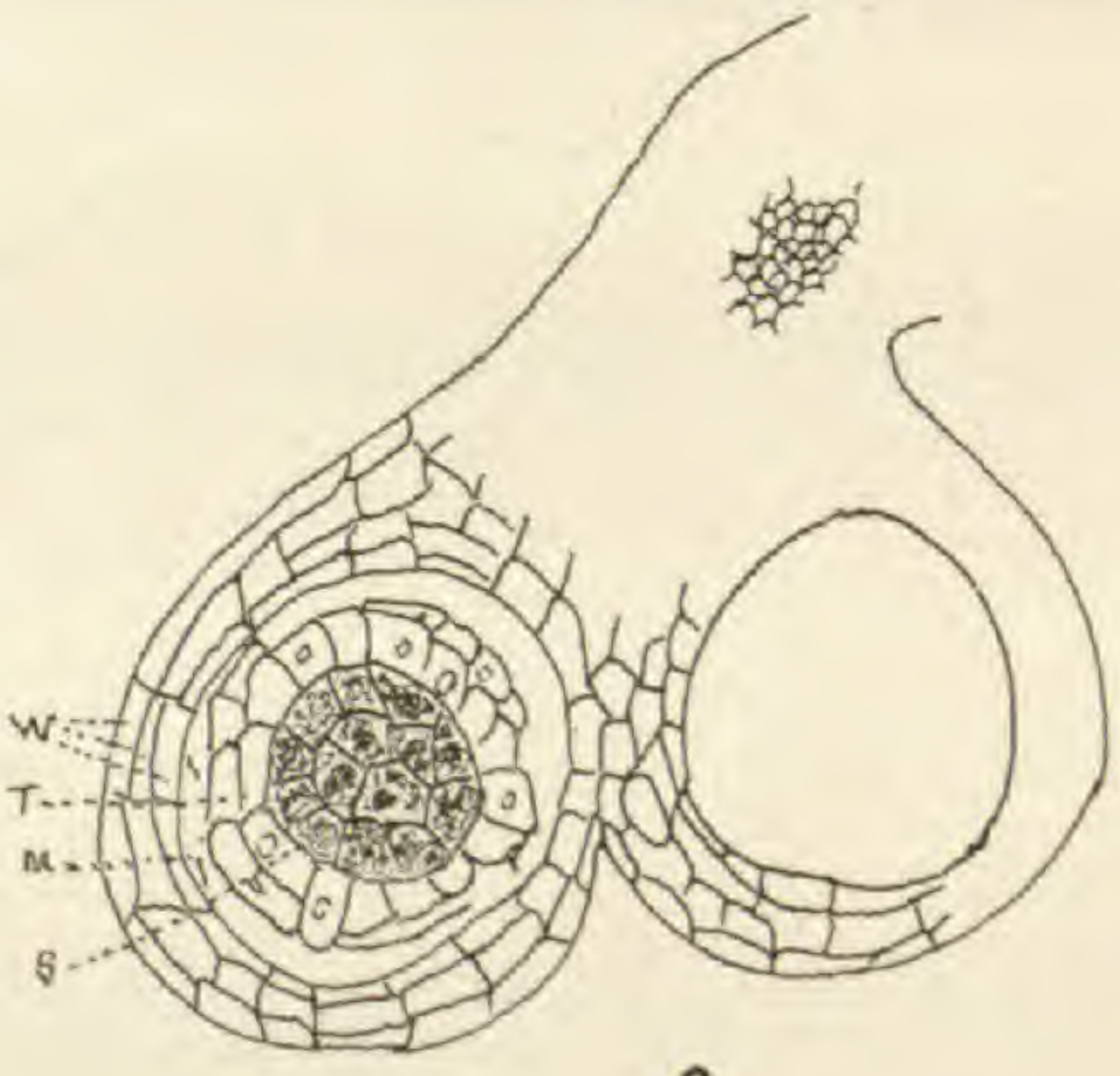

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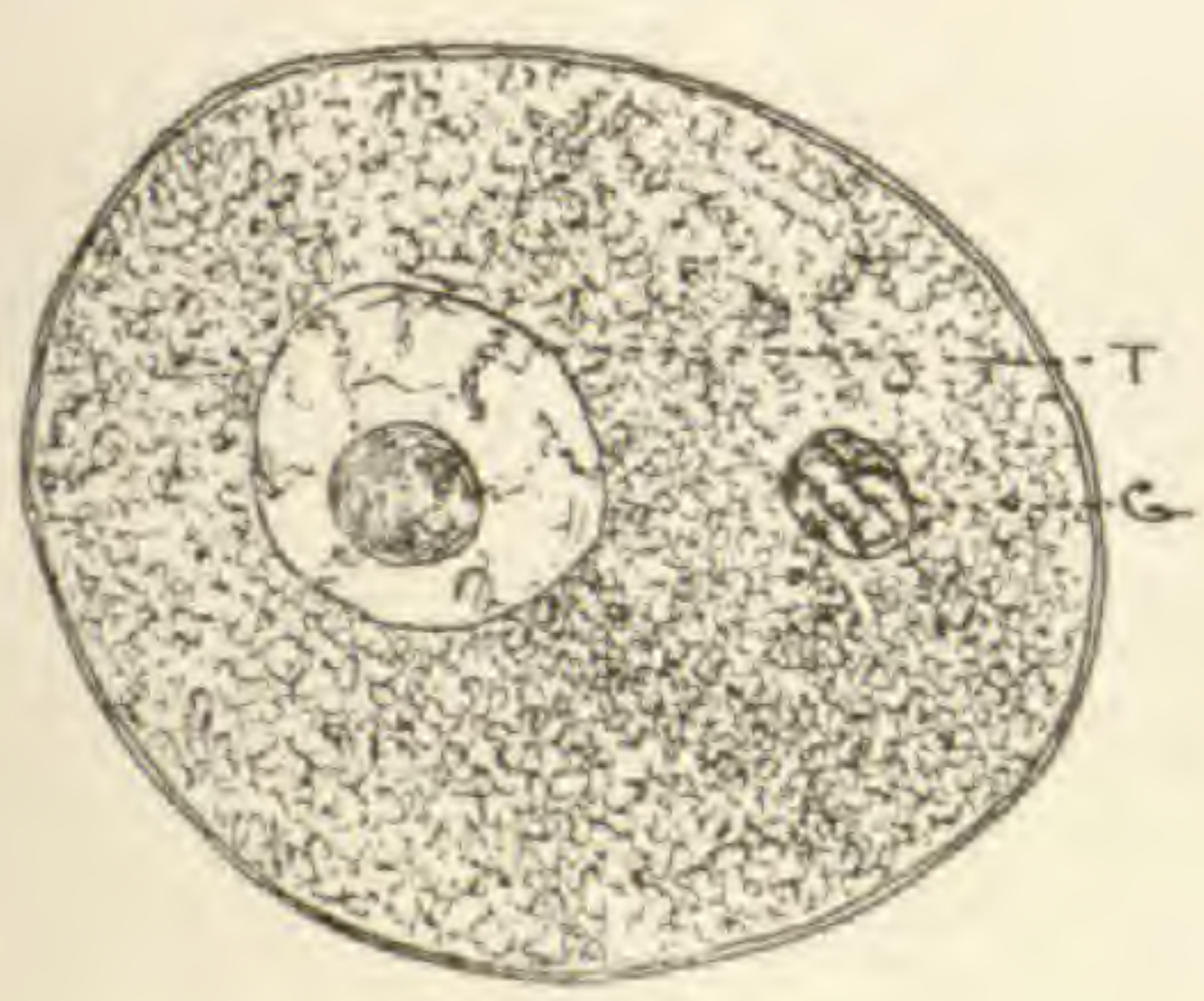

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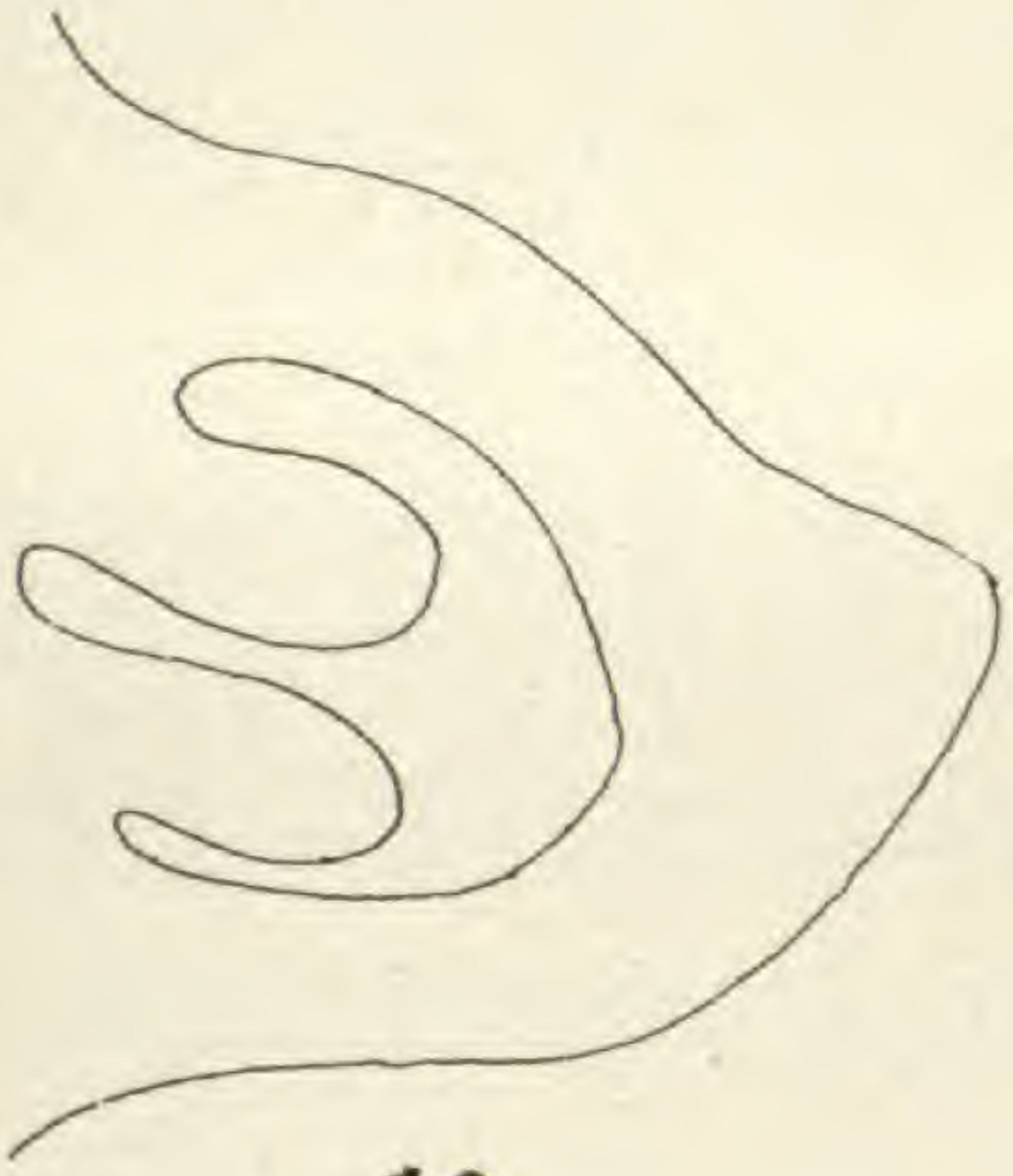

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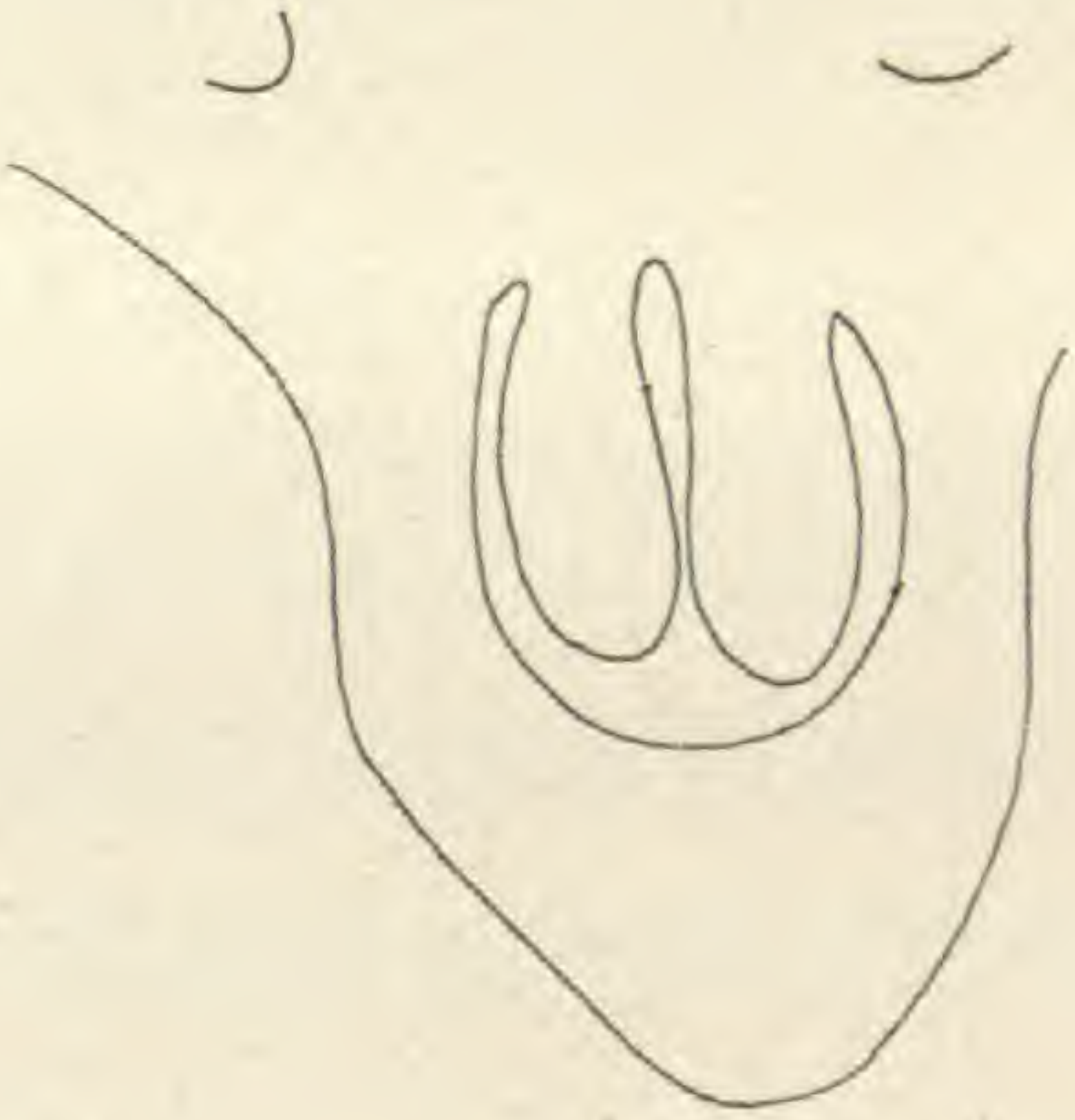

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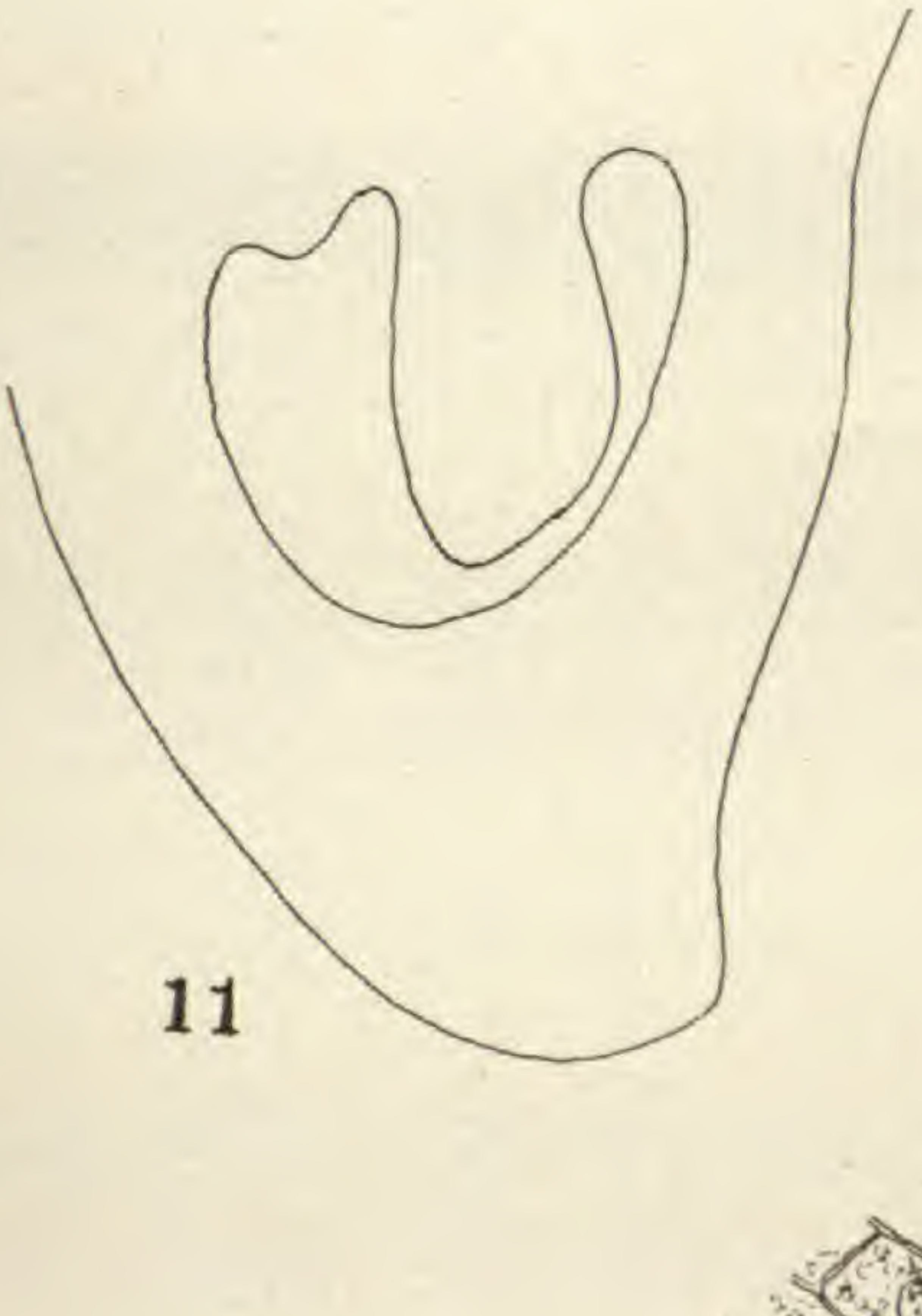

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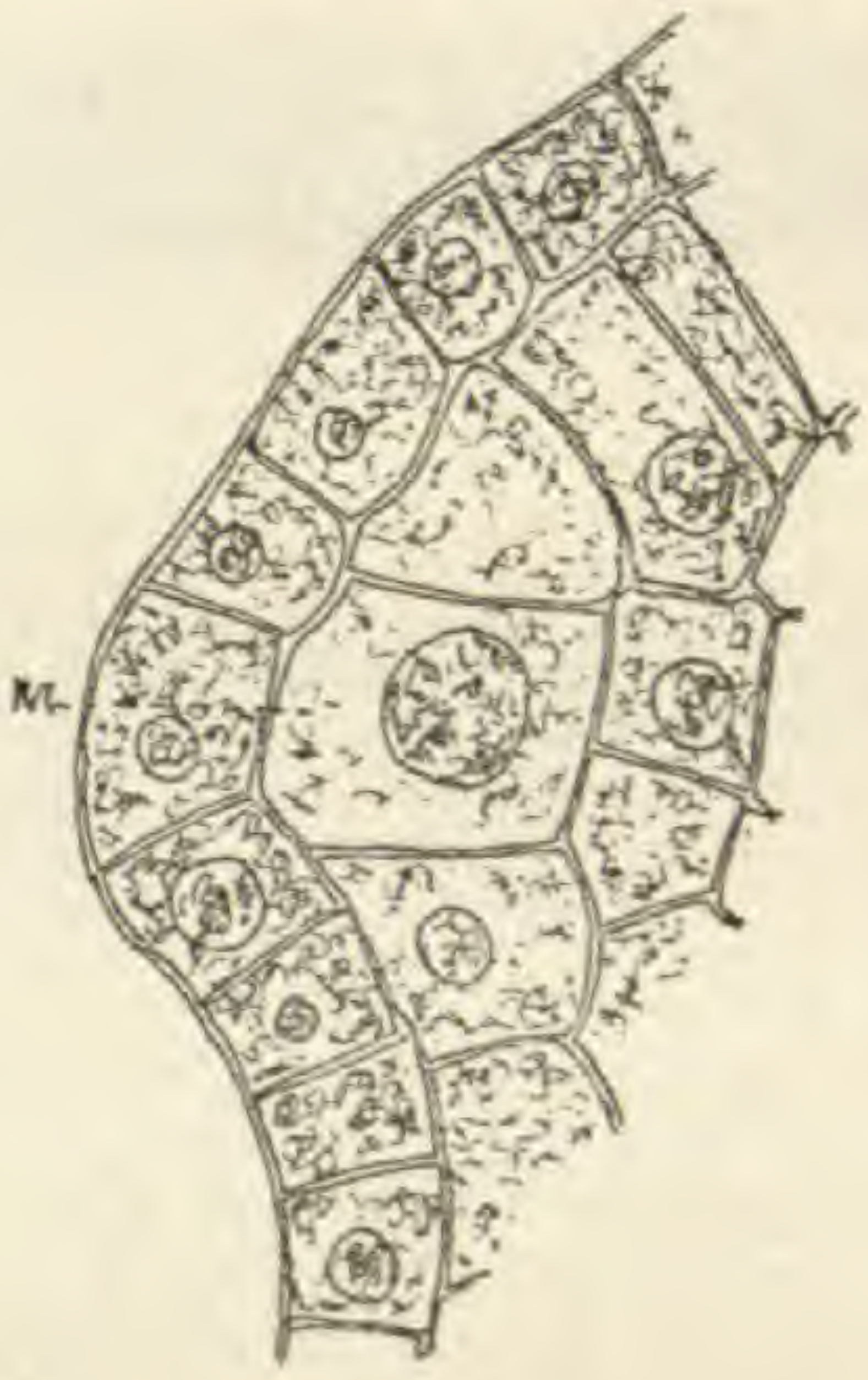

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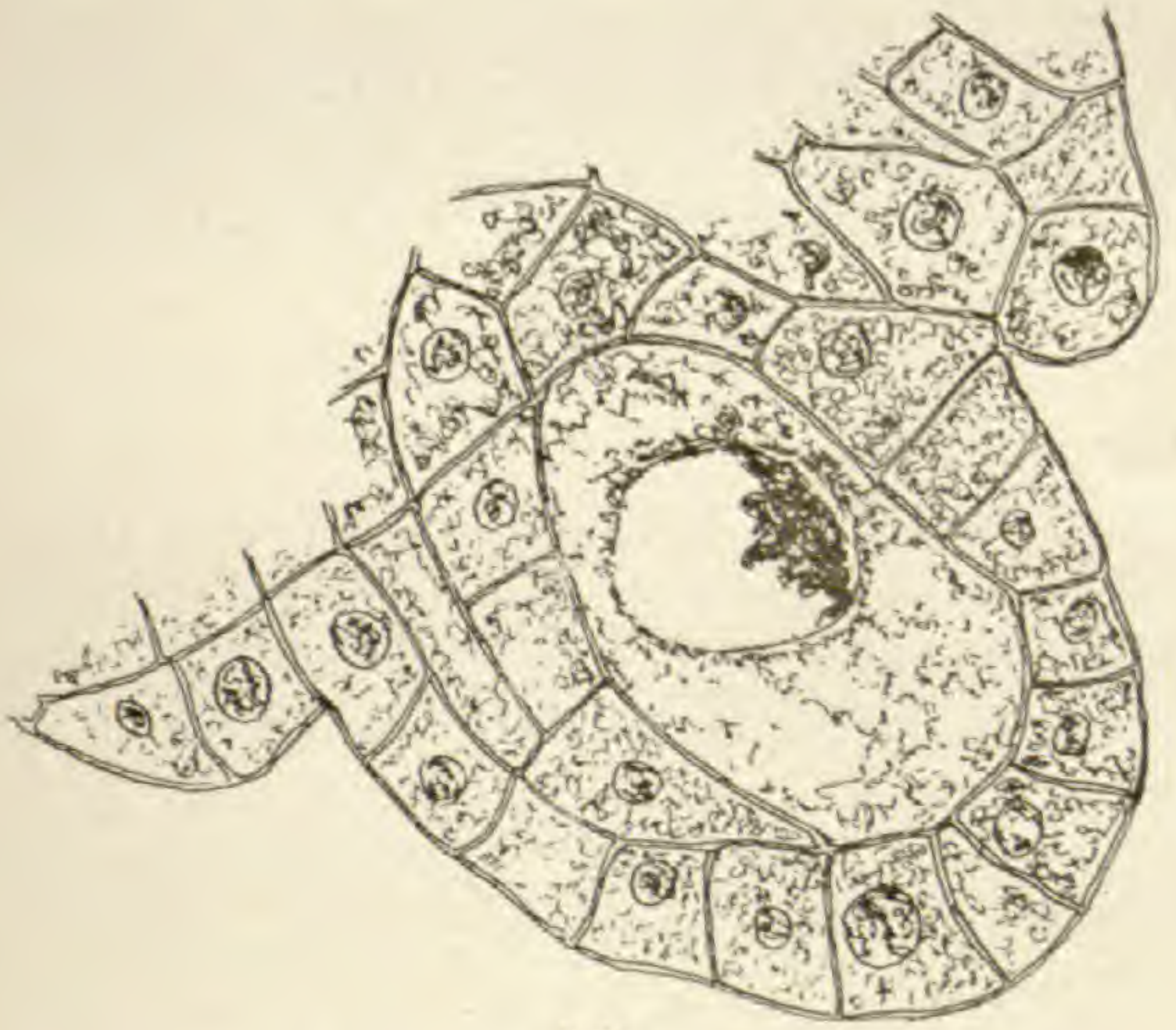

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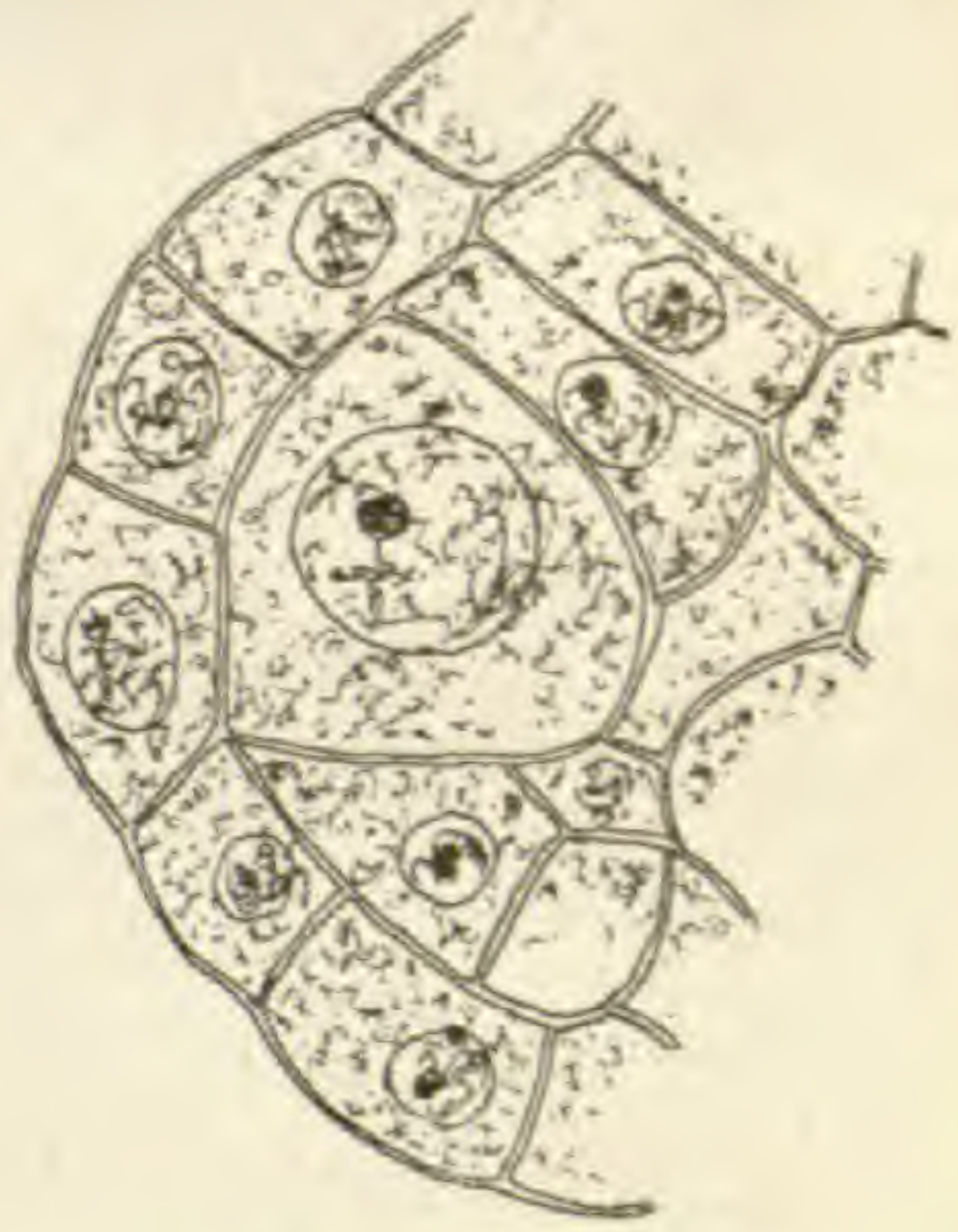

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BULLETIN

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OCTOBER 1912

Protoplasmic streaming in Mucor

F. M. ANDREWS

INTRODUCTION

During the years 1903 and 1904 Alfred Schröter* carried out a series of experiments in the botanical institute at Leipzig under Pfeffer's direction on the subject entitled Über Protoplasmaströmung bei Mucorineen. The subject of Schröter's study was to investigate the effect of different external influences on protoplasmic streaming. Among the influencing factors he studied were light; temperature; injury, as the severing of a hypha or a sporangium; pressure, as upon a cover glass; influence of nutrient media; osmotic substances, especially of different concentration; and transpiration. In making the above study Schröter also desired to test the accuracy and application of the work of Ternetz† on the fungi he investigated.

Some of Schröter's experiments and conclusions, however, do not seem to be altogether above criticism, and I have found some of his results and statements to be incorrect, as the following pages will show.

Accordingly, during my recent study in Pfeffer's laboratory I began a reinvestigation of the various experiments of Schröter in order to ascertain to what extent they were defective. I have also extended the investigations of Schröter in some places and have given special attention to those experiments he performed which do not seem to be entirely conclusive.

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* Schröter, Alfred. Flora **95**: 1–30. 1905.

† Ternetz, Charlotte. Jahrb. Wiss. Bot. **35**: 273–309. 1900.

[The BULLETIN for September 1912 (**39**: 415–454. *pl. 33–35*) was issued 9 S 1912.]

As to the historical account of the study of protoplasmic movements in the fungi it may be said that this has been given in sufficient detail by Schröter* and will only be mentioned here as reference makes necessary. Also Arthur† has made several references to brief accounts of protoplasmic movements in fungal hyphae. It will be seen by referring to the literature mentioned in this paper that the work of Woronin‡ appeared 31 years before the paper of Arthur. Since then a number of contributions on the subject of protoplasmic movements in the fungi have appeared, but the amount of study which this subject has received is very small in comparison with the attention that has been paid to such movements in the cells of other plants. And furthermore we find that protoplasmic movements in the fungi have been known for only about 45 years,‡ whereas in other plants such movement was observed 137 years ago, when Corti saw it, in 1774, as stated by Pfeffer.§

PLANT MATERIAL USED

In these investigations I have used *Mucor stolonifer*, *Mucor Mucedo*, and *Phycomyces nitens*. Of these three *Mucor stolonifer* and *M. Mucedo* were used in all my experiments. I found it inconvenient to use *Phycomyces nitens*, since as is well known the spores of this fungus seem to live for only a few months. I have been able at different times to keep some of the spores of *P. nitens* for as much as three months, but even then the majority of the spores with which I began to experiment refused to germinate. Therefore, in these experiments, while some spores germinated after a month or more, the uncertainty of their growth caused me not to use them so extensively as I did the other two forms above named. At all events it would be an interesting study and well worth investigating to ascertain, if possible, the reason for this short period of life that is shown by the spores of *P. nitens*. It is stated by Pfeffer‖ that the spores of most molds often live from one to three years. I have yet on hand the spores of *Mucor stoloni-*

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* Schröter, Alfred. Flora 95: 1. 1905.

† Arthur, J. C. Annals of Botany 2: 491. 1897.

‡ Woronin, M., cited by Ternetz in Jahrb. Wiss. Bot. 35: 274. 1900.

§ Pfeffer, W. Plant Physiology (Eng. Transl.) 3: 289. 1905.

‖ Pfeffer, W. Plant Physiology 2: 328. 1905.

fer and some of *M. Mucedo* that have kept for two years, and most of them still grow quite as well as the spores of these plants that are only a few days old. They have been preserved in a dry condition on bread, on which they grew in wide-mouthed bottles closed with cotton. This is also a very convenient way in which one may preserve the spores of those plants it is desired to grow—when first it is ascertained that the culture sealed in the bottle is a pure one. One may then by means of a sterilized needle or forceps easily remove a few spores to the desired culture media and in this way by a great saving of time and labor obtain pure cultures for study. Schröter[*] used *Phycomyces nitens* and *Mucor stolonifer* for his study; Arthur[†] used *Rhizopus nigricans;* de Vries,[‡] *Phycomyces nitens;* Ternetz,[§] *Ascophanus carneus;* and Woronin,[||] *Ascobolus pulcherrimus.* Of the three forms that I used, viz: *Mucor stolonifer*, *M. Mucedo*, and to some extent *Phycomyces nitens*, I found *M. Mucedo* also to be easily obtainable and as well adapted to the investigations of this paper as *M. stolonifer.* In addition, then, to my work on the other two forms my experiments with *Mucor Mucedo*, made to confirm or disprove Schröter's results, will also show whether or not the phenomena he and Ternetz describe are observable in still another fungus to the same extent as he mentions[¶] for *M. stolonifer.*

APPARATUS AND METHOD

A description of the methods used in working out this paper can not all be described in one place, but the methods used in the various experiments can be materially shortened by describing and figuring at the outset a few of the principal pieces of apparatus used, to which reference may be made in the study where they were employed. For this purpose FIG. 1 is an illustration of the apparatus used. In some of the earlier experiments the apparatus shown in FIG. 1 was used in a somewhat more simplified form, but

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[*] Schröter, loc. cit. 2.

[†] Arthur, loc. cit. 493.

[‡] De Vries, H. Bot. Zeit. 44: 1–6. 1885.

[§] Ternetz, loc. cit. 273–309.

[||] Ternetz, loc. cit. 273–309.

[¶] Schröter, loc. cit. 10–29.

as the work progressed, some additions to it were found necessary for the sake of certainty of results and convenience. FIG. 1 was used especially for obtaining the hydrogen in a pure form. As here arranged, the gas generator *A* is to the left. The generator contained the purest zinc made. The sulphuric acid mixture used was composed of one part concentrated sulphuric acid diluted with nine parts of water,* and on its surface was poured a thick layer of liquid paraffin. The generator connects with the four-way stopcock *B* by means of which the stream of hydrogen may be sent to either of the U-tubes *C* or *C′*. Or the stopcock may be so arranged that the generator *A* is cut off from the rest of the apparatus and air drawn through *B′*. Of the U-tubes shown *C* and *C′* contain a concentrated solution of potassium hydrate, and in addition the arms of the U-tube are in each case nearly filled with pumice stone that has been saturated with the same solution. Hydrogen passed slowly through a tube arranged in this way will be freed from any hydrochloric acid, sulphur dioxid, or hydrogen sulphid that it may contain when prepared by the action of sulphuric acid on zinc.† The U-tubes *D* and *D′* contain silver nitrate for removing any traces of arsenic which may be present according to the equation:

$$6AgNO_3 + AsH_3 + 3H_2O = 6Ag + H_3AsO_3 + 6HNO_3.$$

The U-tubes *E* and *E′* contain potassium permanganate for the removal of organic substances and are connected with *F* and *F′* containing pyrogallol and concentrated potassium hydroxid for freeing the gas from any trace of oxygen.‡ It will be seen by the

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* Andrews, F. M. Annals of Botany **19**: 523. 1905. "If, as sometimes happens, the sulphuric acid does not attack the zinc readily, so as to cause a rapid evolution of hydrogen, this may be brought about by the addition of a small quantity of platinum tetrachloride or copper sulphate to the sulphuric acid."

† Andrews, loc. cit. 523, where a similar but briefer method of washing hydrogen for another set of experiments is discussed.

‡ Hempel, W. Methods of gas analysis. Eng. Transl. 149. 1902. This gives the following formula for making an alkalin solution of pyrogallol which is a good and rapid absorbent for oxygen.

"5 grams pyrogallol dissolved in 15 ccm. of water,
120 grams potassium hydroxide dissolved in 80 ccm. of water."

"The absorptions do not take place well," says Hempel, "under 15° but since all my experiments, except those of temperature were above 15° the method could be used" and "A solution prepared as above stated gives off no carbon monoxide during the absorption."

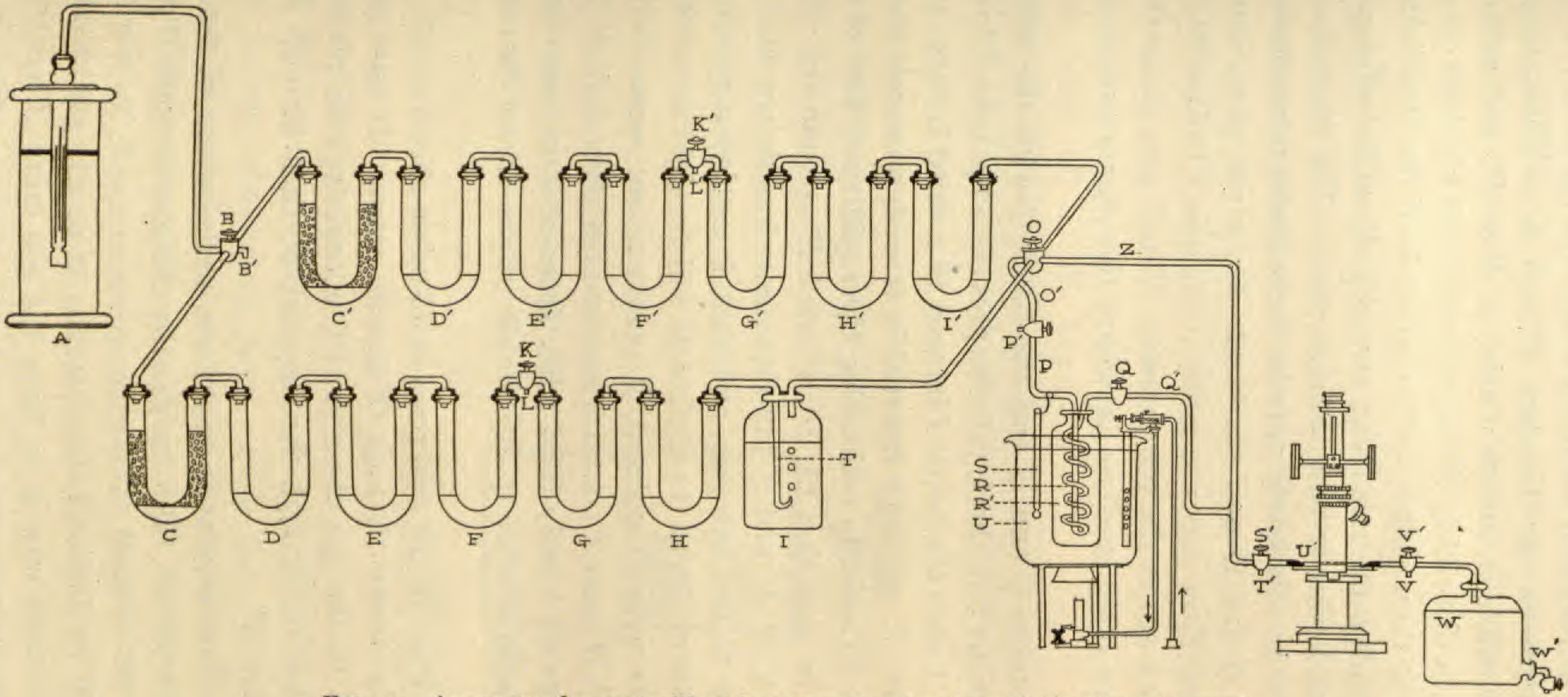

FIG. 1. Apparatus for controlling the temperature and purifying the gases used.

figure that a three-way stopcock is inserted between *F* and *G* and also one between the U-tubes *F′* and *G′*. This arrangement makes it possible to attach a tube at *L* or *L′*, and without disconnecting or disturbing the apparatus to quickly draw off samples of the gas at these points and to ascertain if the chemicals in the various U-tubes are removing any objectionable substance from the gas and letting it pass through pure. The tests showed the hydrogen to be absolutely pure in the samples taken in this way. The tubes *G* and *H* and the bottle *I* contain pure water and pieces of wet filter paper to moisten the gas. Unless this is done the air which enters the gas chamber *U′* will soon cause the drops of water, or other medium in which the plants are growing, to evaporate.

The U-tubes *G* and *H* and the bottle *I* with the water they contain also act as a check valve to prevent a backward flow of any gas used. I used the bottle *I* instead of a third U-tube, so that a curved tube, *T*, might be inserted in it with a narrow opening of known size to assist in estimating the rapidity of flow of the gas.

It will be seen that *C′*, *D′*, *E′*, and *F′* contain the same substances as *C*, *D*, *E*, and *F*, but experience has shown that it is the better plan to use two sets, and that it avoids a possible early deterioration of any of the chemicals which might occur before the experiments were completed, if only one set were used. The U-tubes *G′*, *H′*, and *I′* contain concentrated glycerin, and the arms of the tubes are loosely filled with pieces of filter paper saturated with the same solution to dry the air or gas drawn through these tubes.

From either of the two rows of U-tubes above mentioned the gas may be drawn through *O′* in two ways. It may go either through *Z* to the gas chamber *U′*, containing the plants under investigation, or through the stopcock *P*, then through *R* to the gas chamber *U′*.

By the first way only gas of the temperature of the room is passed through *U′*. But by passing the gas through *P* and then *R* it may be warmed to any temperature in *R* by warming the water in *R′* as desired before sending it to the gas chamber. A more convenient way is to have the gas lamp *X* controlled by an accurate thermoregulator, or a still better method is to place the vessel R', containing R, in a small well-regulated thermostat. Unless the generator A is very large it is rarely the case that a gas generated by it would be forced through the apparatus shown in FIG. 1. In order to make this possible an aspirator, W, is also attached and the flow controlled by a stopcock, W'. An aspirator may be graduated to estimate the outflow and gas drawn through, or the stopcock W' may be adjusted by means of a meter used on the outflow stopcock as shown by Detmer.*

If strong suction is not required a constant flow of any gas through the gas chamber U' may be obtained by the use of a floating siphon shown by FIG. 1*a* taken from the work of N. W. Lord.† The figure shown here is about $\frac{1}{6}$ the size of the apparatus I constructed for this work. It can not be used with the apparatus shown by FIG. 1 but can be employed when the gas has to pass through only a shallow liquid, or if gas only is to be drawn through. Its value lies in the constancy of the flow of gas it will cause, while other apparatus used for this purpose must be continually watched and regulated to insure accurate results. In some cases a suction pump, such as are attachable to water pipes, is an advantage to use. Wherever possible, and this was generally the case, all glass connections were made by having the tubes fused together in one continuous piece. (FIG. 1.) This made leakage impossible, which with hydrogen is very difficult to prevent under ordinary circumstances. The other connections, as for example with the generator, U-tubes, and the gas chamber, were made by means of rubber stoppers and sealing wax according to

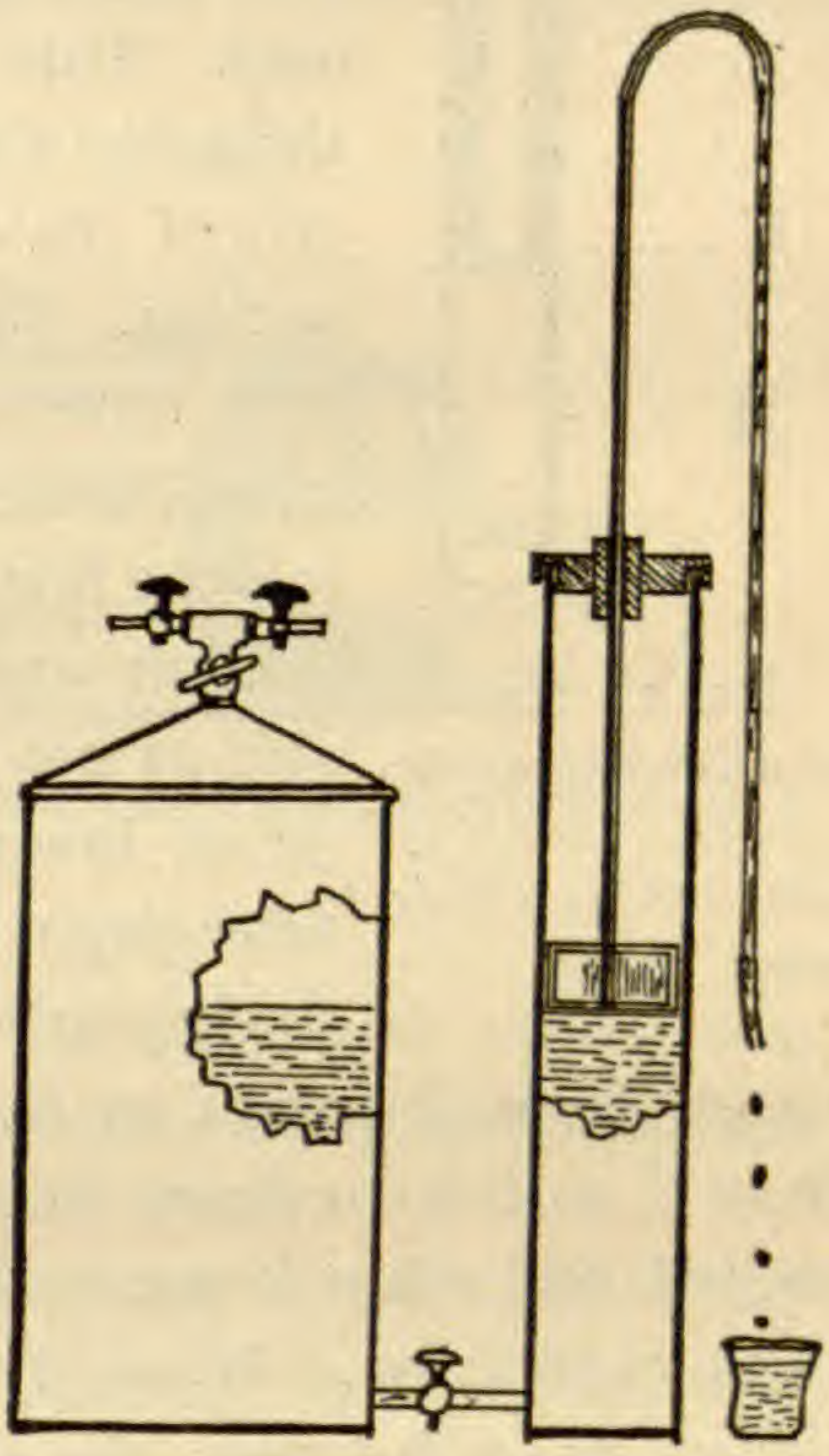

FIG. 1*a*. Floating siphon used to draw through a constant stream of gas.

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* Detmer, W. Pflanzenphysiologische Praktikum 821. 1905.

† Lord, N. W. Notes on metallurgical analysis 181. 1903.

another efficient method I have used.* In some of my experiments, not shown in FIG. 1, I made connections between glass tubes in the following way, which were absolutely proof against leakage.

The method may be illustrated by the accompanying diagram, FIG. 2. Tubes of somewhat different but convenient sizes were used. The inner surface of *A* from *C* to *D* and the outer surface of *B* over the same distance were covered with paraffin and then these parts submerged in hydrofluoric acid. This etched the unparaffined surfaces of the tubes and allowed a more perfect and firmer grip of the sealing wax used in making the connection. The hydrofluoric acid was always carefully removed by washing and then drying the tubes before using the sealing wax. Or the tubes may be fastened gas-tight together by means of litharge and removed, when desired, by nitric acid as was done by Pfeffer.† One tube, *A*, had on its inner end, at *C*, a few layers of compact filter paper so as to make it fit *B* tightly. Very finely powdered sealing wax was then sifted in between *A* and *B* from *C* to *D*. Then, on gently heating the tubes from *C* to *D* in a flame the powdered sealing wax was carefully melted, and when it was cooled there was produced an absolutely tight connection. When it was desired to disconnect the tubes joined by sealing wax, the joint was gently heated to soften the wax, when the tubes were easily drawn apart. The joints made as above described were perfectly tight even when tested in water by a pressure of about one half an atmosphere. The U-tubes can be so arranged as to be totally under water as shown by Ewart.‡

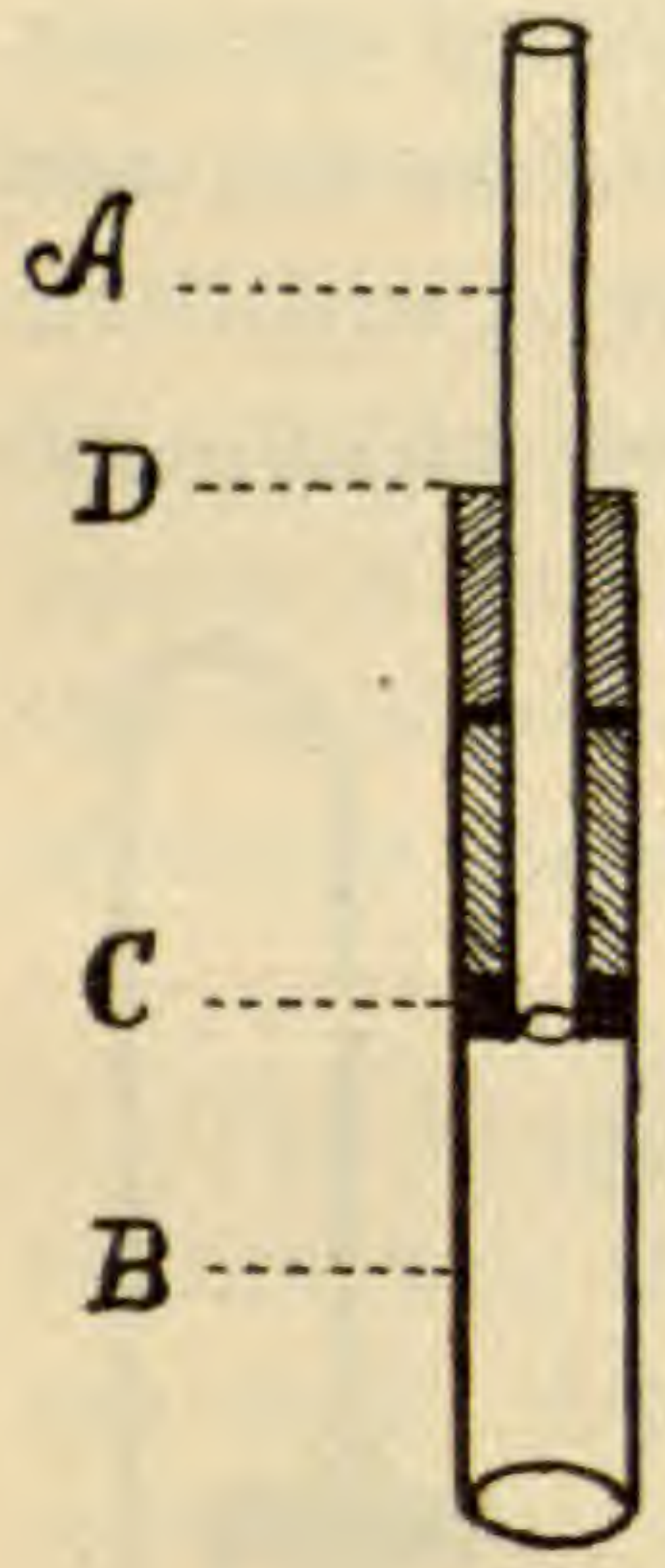

FIG. 2. Method of making glass tube connections by means of sealing wax.

A more simple and convenient way is to test the various joints by means of the large, short glass tube shown in FIG. 3. Each end of the large glass tube is closed by a split cork to hold the apparatus

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* Andrews, loc. cit. 523.

† Pfeffer, W. Osmotische Untersuchungen 7, 12. 1877.

‡ Ewart, A. J. Protoplasmic streaming in plants 41. 1902.

on the tubes and make it water-tight. In case there should be vertical joints the same scheme as shown by FIG. 3 could again be used, if the lower end is closed by a split cork as before and the opening *D* closed by a rectangular piece of rubber or cork. Any leakage in a joint so surrounded with water would, of course, be easily detected, while the apparatus has the advantage of being quickly and easily changed from one connection to another.

In some cases metal gas chambers of the Engelmann type were used for the investigations, but in some others, where hydrogen especially was not used, the ring form of gas chamber was employed. These were fastened to the slide with sealing wax or paraffin. A still better way is to use the glass ring form of gas chamber having a continuous glass base of its own.

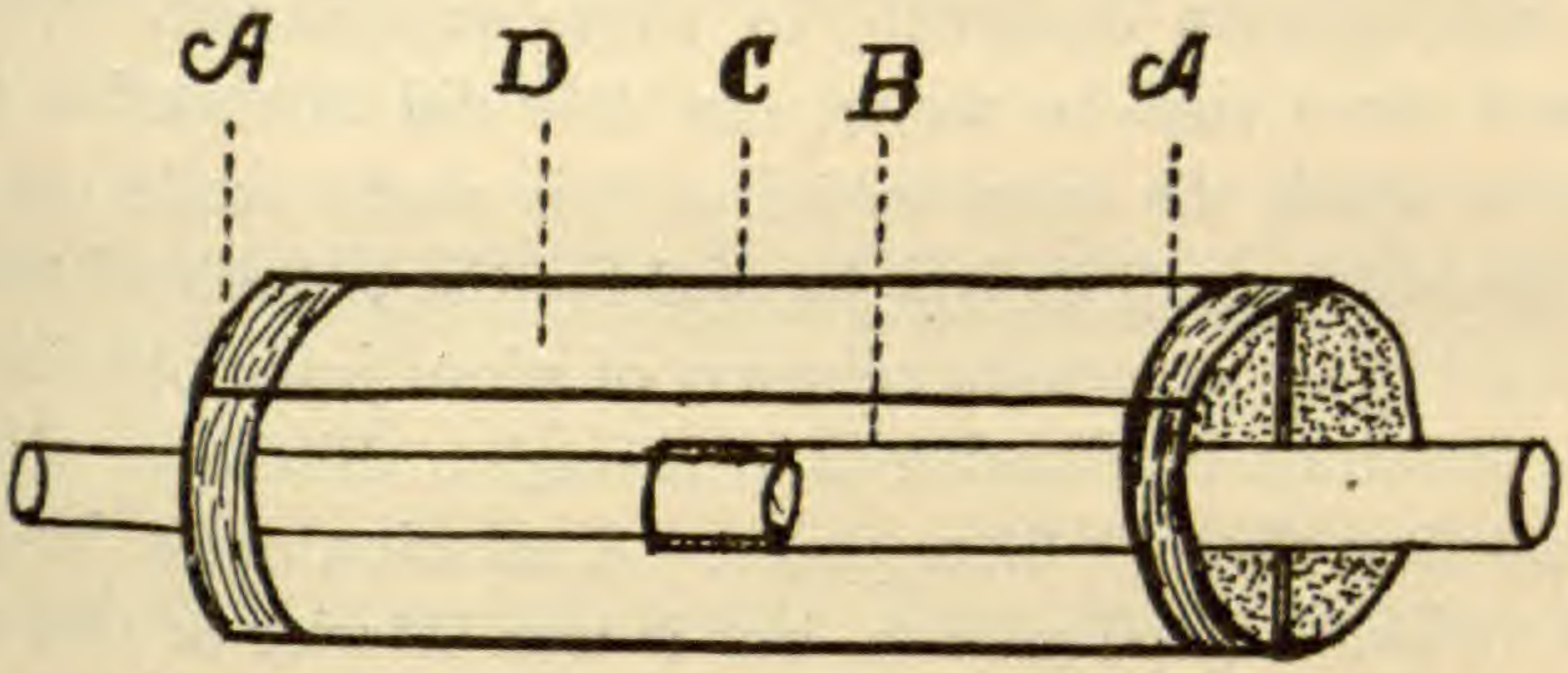

FIG. 3. Method of testing for leaks in glass tube connections under water. ×½.

In those cases where it was not necessary to pass gas of any kind over the specimens under investigation, simply glass rings were used and these were cemented to the slide by sealing wax or paraffin as above described. The cover glass to which the medium containing the specimens hung was made gas-tight by cementing it to the gas chamber, of whatever form used, by means of vaselin or a mixture composed of vaselin and wax as indicated by Pfeffer.* In some cases, as mentioned by Pfeffer, shellac of the proper thickness may be used to advantage especially in experiments requiring some considerable time. The gas chamber and apparatus were always thoroughly freed from any gas foreign to the investigation before beginning the experiments.

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* Pfeffer, W. Plant Physiology 3: 239. 1905.

EXPERIMENTAL PART

The investigations were begun by a series of experiments to ascertain what culture media were best for the growth of these fungi. The specimens of *Mucor stolonifer* and *M. Mucedo* were grown in various nutrient media, which require a word of explanation here. Some of the spores of *Mucor Mucedo, M. stolonifer*, and *Phycomyces nitens* were observed to germinate very well in a 5 per cent solution of pure cane sugar. Other concentrations of the cane sugar solutions were used, but the 5 per cent solutions gave excellent results and under favorable conditions of temperature etc. a rapid growth resulted. In some experiments they grew quite well for a time in water, but this did not suffice for the conditions which the experiments of this study made necessary. Also a favorable medium was formed for the growth of the fungi in a tolerably concentrated solution of plum juice obtained in a suitable condition by filtering first through a thin layer of cheesecloth and then through filter paper. A solution made from horse manure caused a good growth, but it was inferior in this respect to sugar or plum solution, as was also a solution made by adding a little glycerin to pure water.

Another good medium for the growth of these fungi is bouillon made as follows:

50 grams lean beef,
100 c.c. water.

Let this stand from one to two hours at 50° C., then filter through cheesecloth. If less than 100 c.c. filter through add water to make that volume. Add 1 gram dry peptone and 0.5 gram of common salt, then boil, neutralize, clear, and filter.

In some experiments gelatin was used, made as follows:

50 grams lean beef,
gelatin 10 grams,
dry peptone 1 gram,
salt 0.5 gram.

Heat, neutralize, clear, and filter.

Agar-agar was also used. It was made by adding 15 grams of finely chopped agar-agar to the bouillon solution above mentioned. A concentrated solution of very saccharin grape juice was also a good medium for fungal growth.

Schröter also used several of the media I have just mentioned, but they differ in some respects as to the various ingredients and concentrations. I did not have good success in my experiments with citric acid on the fungi studied and abandoned it entirely after a few experiments. With the exception of the water and citric acid solutions I obtained good growths of large actively streaming fungi. The protoplasm sometimes moved as rapidly as from 2 to 4 mm. per minute, and it often maintained this movement to and from the apex for hours under the artificial conditions to be mentioned later, or as long as the observation lasted, which was frequently continued from morning till evening and recommenced the following day.

Some specimens of *Mucor stolonifer* and *M. Mucedo* were kept growing in a weak solution of grape juice and still others in a dilute solution of plum juice for five days. The streaming was apparent during all this time whenever the plants were placed under artificial conditions. In this culture medium the hyphae were small and the growth weak. They were grown in a hanging drop solution of the substances above referred to on a cover glass, and this was cemented to a glass ring cell by means of the wax mixture previously mentioned. The glass ring cell was cemented to the slide with soft paraffin. A better growth than in the last case, and also a specimen that lived longer, was produced by the spores of *Mucor Mucedo* in a 1 per cent solution of cane sugar. In this mixture most of the spores germinated, forming long hyphae. Many of these spores germinated very unevenly although all were mature. Some of them began to germinate only after two or three days or even longer, after others sown at the same time had produced hyphae of considerable length. The specimens were observed from time to time, and the movement of the protoplasm could be seen although not so rapid or in such volume as in those specimens grown in some of the nutrient media mentioned earlier in this paper. This protoplasmic movement was often evident almost as soon as germination was well begun and continued generally, when artificial conditions were introduced, for the entire life of the filaments. The growth shown by this experiment was not very rapid and the fungal filaments were small. Klebs* also

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* Klebs, G. Bedingungen der Fortpflanzung bei einigen Algen und Pilze 506, 507. 1896.

has found that the nature of the nutrient medium was of great influence in causing a very large growth of fungal filaments where sugar was used. But this he found not to be the case for all sorts of sugar. He also found that the same applies to peptone solutions of certain concentrations. It has therefore been of importance in this study to select those culture media that will cause a rapid growth of fungal hyphae having large diameter so as to carry on the investigation to better advantage. The gelatin solution grew fungal hyphae of very large diameter and conspicuous streaming movements. The nutrient media, then, in some cases produced only small specimens unfavorable for study, while in other and good nutrient media large and favorable specimens for study were obtained. Such an investigation for suitable media is, as these experiments and the work of Klebs have shown, an extensive and valuable study in itself, but space does not allow a further consideration of it here.

In inoculating the various culture media above described a large steam-tight chest in Pfeffer's laboratory was used. The glass sides of this box were first carefully washed, and then live steam was rapidly passed into it from a steam boiler for one hour or so until well sterilized. All inoculations of the culture media with the desired spores could then be made within the glass box by proper care without the cultures becoming contaminated with bacteria or other forms. Unless this precaution was observed bacteria and other forms would frequently gain access to the cultures and interfere with the success of the experiment, or if it were continued for some time, frequently outgrow and destroy the forms under experimentation.

PROTOPLASMIC STREAMING IN MUCOR STOLONIFER AND M. MUCEDO

TRANSPIRATION

In these investigations a study was next made in order to ascertain how the protoplasm would behave when saturated air and the air of the room were alternated with each other. Accordingly the spores of *Mucor Mucedo* were placed in a hanging drop culture consisting of 5 per cent pure cane sugar and arranged in the glass ring cell as described above. The same was done in the case of spores of *Phycomyces nitens* and also those of *Mucor stoloni-*

fer, and in all cases large active growing hyphae were obtained. So far as could be ascertained from a great many cultures prepared in this way, all of the fungal spores just mentioned above seemed to grow about equally well. The temperatures were controlled by placing the cells containing the specimens in a constant temperature room in Pfeffer's Institute. A change of temperature, even though it be very slight, may sometimes cause an acceleration or retardation in protoplasmic movements. To prevent this the microscope and all apparatus concerned in such experiments were also put in the constant temperature room at the time the culture was started, in order to avoid a change of temperature, which would occur if the cell were placed on the colder surface of the stage of the microscope.

In such an investigation as this, where the temperature was to be considered, some experiments were carried on in the constant temperature room at 24° C. A more convenient way for the investigator is, in case the cover glass is properly attached, to make use of a warm chamber like that of Pfeffer[*] or that of Ewart.[†] Another rather convenient and exact way to control the temperature of the specimen for an indefinite period is by the use of the Molisch[‡] freezing-box, in which the ice ordinarily employed is replaced by water of the desired temperature, which is siphoned in and out. The best and most exact method of controlling the temperature is to arrange an ordinary thermostat having an adjustable glass door. The microscope may be placed in the thermostat and operated as in the Molisch freezing-apparatus. The heat may be exactly regulated by means of a thermoregulator. In the study of the effect of temperature I did not attempt to ascertain what result the optimum temperature had on the hyphae of very different ages, if it has any, as is probable. Ewart[§] has shown this to be the case in the cells of *Nitella* and *Chara*. At all events an investigation to ascertain this exactly in various fungi is much to be desired. The following two experiments will show the behavior of the protoplasm when saturated air and air

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[*] Strasburger, E. Das botanische Practicum 3: 22. 1887.

[†] Ewart, A. J. Protoplasmic streaming in plants 60. 1902.

[‡] Molisch, H. Untersuchungen über das Erfrieren des Pflanzen 2–6. 1897.

[§] Ewart, loc. cit. 63.

of the room are alternated and the specimens are grown under constant temperature. In the first experiment the spores were grown in a 5 per cent solution of cane sugar. The tables (I and II) will be self-explanatory with the exception of the first column, which indicates the number of times the saturated air and air of the room were alternated. The flow to the tip was caused when the dry air of the room was drawn through the gas chamber, and the flow from the tip when saturated air was admitted.

TABLE I

EXPERIMENT WITH *Mucor stolonifer* GROWN IN 5 PER CENT SUGAR SOLUTION AT CONSTANT TEMPERATURE AND EXPOSED TO DRY AND MOIST AIR ALTERNATELY

Trials	Order of streaming	Direction of streaming	Time of streaming to tip	Time of streaming to base	Rate of streaming	State of vacuoles	Temperature
1	First	to tip	15 min.		rapid	Compressed	24° C.
2	Next	to base		20 min.	slow	Compressed	24° C.
3	Then	to tip	8 min.		slow, then faster	Compressed	24° C.
4	Then	to base		7 min.	slow	Compressed	24° C.
5	——	——	——	——	still for 3 min.	Compressed	24° C.
6	Next	to tip	9 min.		slow, then faster	Compressed	24° C.
7	Then	to base		4 min.	slow, then faster	Compressed	24° C.
8	Then	to tip	7 min.		slow, then fast, then stopped with jerk	Compressed	24° C.
9	Then	to base		5 min.	slow	Compressed	24° C.
10	Then	to tip	8 min.		slow, then fast	Compressed	24° C.
11	Then	to base		2½ min.	slow	Compressed	24° C.
12	——	——	——	——	still for 1 minute	Compressed	24° C.
13	Next	to tip	7 min.		slow	Compressed	24° C.
14	Then	to base		1½ min.	slow	Compressed	24° C.
15	Then	to tip	1 min.		slow	Compressed	24° C.
			Total 55 min.	Total 40 min.			

In this experiment the hyphae protruded from the sugar solution into the surrounding air of the gas chamber. It will be seen also that while the protoplasm flowed 15 minutes longer toward the tip than to the base of the hyphae, the velocity of the apical stream

TABLE II

EXPERIMENT WITH *Mucor stolonifer* GROWN IN 10 PER CENT GELATIN AT CONSTANT TEMPERATURE AND EXPOSED TO DRY AND MOIST AIR ALTERNATELY

Trials	Order of streaming	Direction of streaming	Time of streaming to tip	Time of streaming to base	Rate of streaming	State of vacuoles	Temperature
1	First	to tip	10 min.		fast, then slow	compressed	24° C.
2	Next	to base		7 min.	fast, then slow	compressed	24° C.
3	Next	to tip	12 min.		slow	compressed	24° C.
4	Next	to base		3 min.	fast	compressed	24° C.
5	Next	to tip	5 min.		fast	compressed	24° C.
6	Next	to base		4 min.	fast	compressed	24° C.
7	Next	to tip	8 min.		slow	compressed	24° C.
8	Next	to base		2 min.	fast	compressed	24° C.
9	Next	to tip	11 min.		slow	compressed	24° C.
10	Next	to base		1 min.	slow, then stopped with jerk	compressed	24° C.
11	Next	to tip	4½ min.		slow	compressed	24° C.
12	Next	to base		15½ min.	slow	compressed	24° C.
13	Next	to tip	14 min.		slow	compressed	24° C.
14	Next	to base		3 min.	slow	compressed	24° C.
15	Next	to tip	19 min.		slow	compressed	24° C.
16	Next	to base		30¾ min.	slow	compressed	24° C.
17	Next	to tip	60 min.		slow	compressed	24° C.
18	Next	to base		70 min.	slow	compressed	24° C.
			Total 143½ min.	Total 136¼ min.			

was also much greater at first than the basal flow. The amount of protoplasm, therefore, carried in either direction over a given distance varied considerably during more than 1½ hours, during which time the observations of this experiment were continued.

A measurement of the distance traversed in the time given for the apical and basal stream would also substantiate this. In the second experiment the spores were grown in 10 per cent gelatin and under the same conditions as the previous experiment.

A glance at the figures in TABLE II will show that the total time of streaming to the tip in the experiment shown by TABLE II was also slightly greater than the time the protoplasm streamed to the base, by 7¼ minutes. An estimate of the time spent in streaming to the tip and base, taking into consideration the rapidity of flow of the protoplasm, shows that the difference as to time, as is above seen, is not very great in this experiment. The observations recorded in TABLE II were made from plants that were studied continuously for about five hours, and when the observations were discontinued at 8 P. M. the streaming of the protoplasm was still going on and could be seen again the next morning. The results of TABLES I and II in the two preceding experiments were also substantiated by numerous other such experiments not recorded here. Under natural conditions, however, if any difference could be detected in hyphae that were fully active in every respect, a slightly greater activity or flow toward the tip or young portions would be expected. To prove this would require uninterrupted observation from the time streaming first begins in the hyphae of these fungi. The streaming, as above mentioned, does not begin as soon as the spore has germinated, but only after the hyphae have attained some length. Good streaming hyphae were found in many cases after the spore had been sown about 18 hours, and nearly always 24 to 30 hours were sufficient at the optimum temperature to grow hyphae showing active protoplasmic streaming.

It is by no means always the case as Schröter* seems to think, that branching of the young hyphae is necessary for streaming to occur. It is true that no streaming of the protoplasm occurs when the filament is very young and entirely filled with granular protoplasm. As soon, however, as the filament has increased considerably in length and before any branches whatever have been formed, streaming is often plainly visible. Generally a much branched rapidly growing filament shows more rapid streaming than

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* Schröter, loc. cit. 7, 8.

a slow-growing one or one without branches. Especially is this true in the case of an unbranched filament where the transpiration is influenced by artificial means. The sudden action of very dry air, for example, has a much more noticeable effect in producing streaming in the branched filament with large exposure surface, by the rapid withdrawal of water, than in the single unbranched filament with a much smaller exposed surface, in which streaming has just begun or in which it can for the first time be produced. The difference in the character of the cell walls of the branched and the unbranched filaments as to transpiration is unimportant in this connection. In unbranched filaments it is possible to cause streaming by artificial means before it would normally occur.

The two previous experiments show that a streaming of the protoplasm may be easily produced by artificial means. The artificial means in the instances just cited was transpiration. They also show that as transpiration is active or inactive, streaming is active or suppressed. The filaments grow when completely submerged, but the growth is not so rapid in wholly as in partly submerged fungal filaments.

In order to ascertain if streaming could occur in a saturated atmosphere, glass ring cells were made and the spores of *Phycomyces nitens* grown in the suspended 5 per cent solution of cane sugar. The filaments grew at the optimum temperature out of the solution into the completely saturated air of the closed cell, and when observed 48 hours later no streaming was present. In another cell similarly arranged the cover glass was slightly raised after the filaments had grown 48 hours. Streaming began in a few minutes and was very evident. This last arrangement allowed a slight interchange between the air of the artificial cell and the drier air of the room; and this small difference was sufficient to cause a rapid movement in the second experiment, and at the same time showed that while the change in humidity was slight, a little change in this respect may produce a considerable increase in transpiration and consequently a decided acceleration in protoplasmic streaming. The same experiments with the same results were carried out with *Mucor stolonifer* and *M. Mucedo*. The movements of the protoplasm shown by these experiments were therefore induced wholly by the transpiration occurring in that part of the filaments protruding from the water, for in those spores that had germinated and whose filaments had not grown out of the hanging drop of sugar solution the streaming was absent. In every case of the many specimens examined streaming always began just as soon as a filament protruded from the solution into unsaturated air; and during the whole active life of the fungal filaments the velocity of protoplasmic streaming would be accelerated by artificial conditions, as the length of the filaments outside the drop became greater and the transpiring surface was increased. These specimens were kept growing in the glass cells for five days, at the end of which time the filaments had attained a great length, and in these rapid streaming was visible. Sporangia were also formed in both cultures.

In another experiment the spores of the fungi were grown under the cover glass on an ordinary slide in a 5 per cent solution of sugar or at times in water and the filaments allowed to grow from under the cover glass into the warm air of the constant temperature room or warm chamber. As before, so long as the filaments were completely submerged no streaming occurred, but as in the preceding experiment, as soon as the filaments emerged from the cover glass into the warm dry air an active streaming of the protoplasm commenced. In other experiments the fungal filaments were caused to grow from under the cover glass directly into a drop of water. When the water outside the cover glass was removed, streaming began immediately and was slow or rapid according as the amount of surface of the fungal filaments thus exposed to the dry air was small or large. The movements thus induced to the point where transpiration was occurring continued visible for a long time, or until practically all the movable part of the protoplasm was crowded as nearly as possible into the transpiring parts. When this occurred the vacuoles, which before were more or less elongated parallel to the long axis of the filaments, were now so crowded together and were so strongly compressed that their long axis was generally transverse to the filament. When water was again placed on any filament or filaments outside the cover glass from which it had been removed, a streaming movement immediately began away from the point at which such addition was made. This return movement continued, by this absorption, until equilibrium was again practically established. Or if other parts were then exposed to the air the direction of motion was to them. In all cases excessive and prolonged transpiration in the ways indicated must be avoided to prevent a fatal termination. If this be done and care used, the number of times the protoplasm may be caused to stream to a transpiring part or away from what was a transpiring part, is unlimited. These experiments show, therefore, that transpiration causes streaming under the conditions here mentioned.

The dependence of protoplasmic movement on transpiration in the cases here referred to was further proved by growing the spores of the fungi mentioned, on the under side of a cover glass of an ordinary metal or glass gas chamber. Under these conditions, when saturated air was drawn through, the protoplasm did not stream in those filaments protruding into the saturated air. When, however, air that was nearly saturated was drawn through, slow streaming began. When very dry air was drawn through the gas chamber after the filaments had been in saturated air, streaming instantly began with great rapidity; and if this dry air was drawn through very long, the filaments were soon dried out and the exposed parts killed. The streaming finally stopped in those filaments in which it had been caused by dry air. When this occurred streaming was again produced by admitting air that is somewhat drier than that used to induce streaming before, if one does not delay too long before admitting the air. If after the use of the several degrees of dryness of dry air to induce streaming one readmits moist air in different degrees of humidity, streaming from the exposed parts of the filaments takes place for a time with a velocity in accordance with the humidity of the surrounding air. This movement continues till equilibrium is established, the time for which, however, will vary. The return streaming movement is slower and continues longer if the air is only partly made moist than if the air is saturated.

THE INFLUENCE OF HYDROGEN

In the filaments of *Mucor Mucedo* and *M. stolonifer*, grown as above described, hydrogen stopped the movement of the protoplasm in 20 minutes in moist air. Schröter gives about 5 minutes as the time required, but this seems a little too short a time in view of the average of 20 minutes which I found from experimentation with a large number of fresh plants. After streaming had been stopped by hydrogen it began again in one minute after fresh air had been readmitted. This experiment was repeated many times on the same filaments, always with the same effect. The streaming had in each case again become visible, but the effects had not entirely disappeared, as it responded less quickly after many trials.

Fresh specimens of *Mucor stolonifer* and *M. Mucedo* were not affected so soon by hydrogen passed through in moderately dry air as in saturated air. For example, it required pure hydrogen, as shown by many experiments, on the average 54 minutes to stop the streaming of the protoplasm in this plant in dry air. Also a somewhat longer time as compared to those in moist hydrogen was required for recovery. After streaming had been stopped in dry hydrogen, 5 minutes instead of 1 minute were required for recommencement of streaming after fresh air had been drawn through.

The protoplasmic streaming of fresh specimens of *Mucor stolonifer* and *M. Mucedo* was again stopped by a stream of saturated hydrogen in 20 minutes. When this experiment was performed the streaming was at first toward the base. Then, when dry hydrogen was passed over the specimen, the streaming began to the tip and continued for one-half minute. Again, moist hydrogen was admitted and streaming began to the base, stopping in 15 seconds. Then dry hydrogen was passed through and streaming began to the tip, ceasing in 10 seconds. This experiment was repeated ten times with the dry and moist currents of hydrogen, alternating them each time, always with the same result that streaming was reinduced each time. The moist hydrogen was easily obtained by causing it to pass through *G*, *H*, and *I* before entering *U′*, FIG. 1.

In another series of trials like the preceding, but on another specimen, the length of time the protoplasm streamed from the moist or to the dry hydrogen, respectively, is shown by the following experiment, TABLE III:

TABLE III

Trials	Streamed to the dry hydrogen	Still	Streamed from the moist hydrogen
1	2 minutes fast		1 minute fast
2	½ minute fast		5 seconds slow
3	23 seconds slow		3 seconds slow
4	1 minute very fast		10 seconds slow
5		5 seconds still, starts with jerk	
6	5 seconds very fast		2 minutes very slow
7		3 seconds still, starts with jerk	
8	20 seconds fast		14 seconds slow
9	12 seconds fast		9 seconds slow
10	5 seconds fast		3 seconds slow
Totals	275 seconds		224 seconds

It will be seen from the above figures that the time of flow in either direction varied greatly. The greatest amount of time, as well as the greatest velocity of streaming, was to the dry hydrogen. In only the first trial with moist hydrogen did the streaming appear fast. The totals of time above given and also the velocities observed are much less, as a rule, than where dry and moist air were used. The specimens used in the above experiment were replaced in fresh air and put away for 24 hours, at the end of which time they were living and streamed as actively as before. The air used in the experiment just mentioned was made perfectly dry by passing it over pure glycerin (FIG. 1). Other experiments, however, were performed in which weaker solutions of glycerin were used. It is sufficient to mention here one instance in which 30 per cent glycerin was used. The streaming to the dry hydrogen in this case was much slower, as expected, and continued for 7 minutes, which is a much longer time than the total of the same number of trials as in the previous experiment.

As has been shown above, transpiration may be practically suppressed and streaming stopped or prevented by a saturated air in 20 minutes. When saturated hydrogen is passed through under precisely the same conditions, the streaming stops in less time than in saturated air alone. This was shown by causing saturated air to be drawn over the filaments of *Mucor stolonifer* and *M. Mucedo*, which stopped streaming in 45 minutes by preventing transpiration. When, however, saturated pure hydrogen was drawn over the specimens the streaming of the protoplasm stopped in 20 minutes. This is the average time of many experiments of this kind with both saturated air and saturated hydrogen. As there was a difference shown by these separately, it was thought that a difference could be proved when they were used successively on the same specimen. Accordingly, pure saturated hydrogen was used again on a fresh specimen and the streaming stopped in about 20 minutes as before. Just as soon as streaming ceased, saturated air was drawn through and immediately a slow streaming of the protoplasm began and continued for 8 minutes. This and other experiments indicate that when the streaming of the protoplasm is controlled or influenced by transpiration this may be partly caused, as in this experiment, by physiological action. This agrees with Schröter's opinion concerning transpiration in these fungi. When spores were sown in small drops of the solution of the different liquid nutrient media and a rapid growth occurred so that numerous long and rapidly transpiring filaments projected into only moderately dry air, the streaming of the protoplasm produced by transpiration continued often for several hours. This finally resulted, as Schröter states, in a concentration of the various liquid nutrient media to an extent that streaming to the transpiring or formerly transpiring tips finally ceased. If the small drops of liquid nutrient media be again diluted, streaming in the former direction will occur; and this experiment may be repeated a good many times with the same specimen, and always with the same result if due care is observed.

In these experiments on transpiration the air or hydrogen that was drawn over the specimens was warmed (in *R*, FIG. 1) before coming in contact with the plants under investigation. In all cases when hydrogen was employed in the experiment, suitable bacteria were used in order to ascertain that no oxygen was present to interfere with the results.

A series of experiments was next tried to show the effect on transpiration of different strengths of glycerin, also glycerin in combination with other reagents. The glycerin mixtures did not in any case come in direct contact with the nutrient media in which the fungi experimented with grew and also did not touch the exposed fungal filament when these projected from the culture media. The spores of the fungi were grown in hanging drop cultures over the glycerin solutions in the ordinary glass ring gas chambers. When good growing and streaming specimens were obtained they were placed, in the first of these experiments, over a 50 per cent solution of glycerin for 15 hours. This was much longer than it had been intended to allow the experiment to continue, and at the end of that time, as was expected, the specimens were all killed by being completely dried up and collapsed beyond easy recognition. This takes place in the filaments of the fungi here studied in a much shorter time, as mentioned, than 15 hours; for when the experiment was repeated, with 50 per cent glycerin, it was found that the fungi were desiccated to a point beyond vital recovery in 47 minutes.

In a third experiment of this strength of glycerin it was found that when a specimen of each of *Mucor stolonifer* and *M. Mucedo*, which were growing in a saturated air, were changed to a cell over a 50 per cent solution of glycerin, all streaming of the protoplasm stopped in 15 minutes. When the specimen was first placed over the glycerin solution the streaming, which to begin with was absent, began almost instantly and continued for a few minutes with great speed to the exposed portions of the filaments from which the water was being rapidly removed by vigorous transpiration. As the air became drier the streaming which at first was so rapid became in a short time slower and slower, as the water was removed from the filaments, and in a little longer time, as stated, stopped in 15 minutes. When the specimen was then changed back over a cell containing pure water or one through which saturated air was passed, the streaming recommenced in 5 minutes on the average. This recovery of the streaming under these restored conditions was at first slow but in a few minutes increased in velocity from the tips or exposed portions which had formerly transpired rapidly. The increase in velocity of streaming continued till the filaments were again about turgid or equilibrium was established, when it finally ceased, as it did when they were in the saturated air before being placed over the glycerin. This experiment can be repeated many times with the same active specimen if care is taken not to allow desiccation to progress too far. When the transpiration has been excessive for some time, the filaments are often more or less collapsed or their diameter somewhat reduced after the loss of a considerable quantity of water. Even when all streaming has ceased and collapse of the filaments has then occurred to a quite noticeable degree, they may recover their normal dimensions and streaming recommence if they are surrounded with moist air from which the water is reabsorbed by the filament. In one experiment, when this collapse occurred in 22 minutes in air dried by 50 per cent glycerin, recovery in saturated air took place in 52 minutes and streaming reoccurred. Collapse and cessation of streaming can easily be produced over 50 per cent glycerin solution in considerably less time than it is possible to restore the filaments fully to the normal condition.

As was to be expected, when the solutions of glycerin employed were made weaker, the effect on streaming as the result of weaker transpiration was less pronounced. For example, when *Mucor stolonifer* and *M. Mucedo* were placed over a 20 per cent solution of glycerin the streaming stopped in one hour. During all this time the streaming was, as in the 50 per cent glycerin, to the tips exposed to the air that was being dried by the glycerin. The streaming was not so rapid as over the 50 per cent glycerin. After replacing the specimen in saturated air streaming recommenced and regained its normal velocity much sooner than when left an equal time over 50 per cent glycerin. Frequently all that is necessary to produce streaming in such fungal filaments which apparently are inactive, is to cause transpiration by drying the air around them with glycerin and as a rule only slightly. The effects of still weaker solutions of glycerin will be seen by the following experiments. When the fungi were placed over a 10 per cent solution of glycerin the transpiration was so diminished that streaming continued for 3 hours to the portions exposed. When they were placed over a 7½ per cent solution slow streaming was to be seen to the transpiring parts for 5 hours. When they were placed over a 5 per cent solution of glycerin the streaming was still visible 8 hours after the experiment was started, and the filaments were not perceptibly dried up. The transpiration was very slow and streaming was always to the exposed parts.

In several of the experiments, where the spores were grown under the cover glass, bubbles of air of different sizes were also present. In those cases where a good many spores were grown under the same cover glass some of the filaments or their branches just entered or passed entirely through some of the air bubbles. In these, however, the air was saturated and no streaming occurred. Even when they had just grown into the bubble no streaming was seen. When the position of a saturated bubble under the cover glass was shifted so that it was placed over a filament or a part of a filament that had previously been entirely submerged, no streaming of the protoplasm began. This shifting can be easily done by very slight pressure on the cover glass when it is nearly swimming in the solution which submerges the filaments. If this pressure is properly applied, a bubble which is a little distance from a filament can be caused to flow over it. At the same time, since the cover glass does not rest directly on the filaments, the pressure is not sufficient in this case to cause any injury, as the experiments showed. If, however, a dry air bubble is gently brought under the cover glass directly in contact with the filaments by means of a glass capillary tube, streaming will be induced immediately and will continue for a time. A convenient way of growing the filaments so as to prevent them from from being affected by pressure in moving a bubble around under the cover glass is to make a cell of a layer of filter paper and fill it with the solution and a few air bubbles. For the use of the capillary tube here mentioned the filter paper cell should be cut away on two sides to freely admit the tube. At first I forced air bubbles under the cover glass through a very fine capillary tube by means of an automobile pump. By the use of the automobile pump directly connected it was difficult to regulate the flow and constancy of the air bubbles. To overcome this difficulty the air was forced directly into an ordinary autoclave, *A*, as an air receiver, by the pump *B* and from this was conducted through the capillary glass tube to the specimen. A mercury manometer, *C*, was connected with the apparatus to show the pressure more accurately than the autoclave gauge would do. From $\frac{1}{7}$ to $\frac{1}{2}$ of an atmosphere was necessary to force the air quickly through the capillary glass tube *D*, according to the size used (FIG. 2*a*). By care, with this method a number of bubbles or a stream of them may be forced in, and their number and size controlled by the dimensions of the glass capillary tube, which is often of importance. Small bubbles may in this way be brought to only a part of a long filament and the effect studied. A stream of small bubbles generally quickly ran together when they touched a filament near one another. It was possible by this means to expose for a time to dry air, only one side of a filament that had previously been completely submerged. The streaming, which occurred due to the bubble of dry air forced in through the glass capillary, was slight if only a small part of the filament was touched or covered. If a number of bubbles were let in, so that a larger part of the filament's surface was exposed to dry air, the streaming was somewhat faster, and it continued to increase according to the amount of surface thus suddenly exposed to the dry air.

In these experiments the streaming was never so fast and did not continue so long as in the experiments where the fungal hyphae were exposed to moist and then dry air in a gas chamber. The streaming was always to the part exposed to the dry air where transpiration was taking place. When the filament was resubmerged, streaming occurred for a time away from the part that had been exposed to dry air, but it was never so rapid as it was to the tip when this part was in dry air. These experiments are also a confirmation of all those investigations in which it was proved that in a saturated air in a gas chamber streaming which had begun ceased, and when dry air was let in began again. What is practically the same is that streaming may be induced by forcing warm dry air by means of a glass capillary tube gently among the fungal filaments in a hanging drop, if it be continued long enough and if the stream of bubbles be rapid. The streaming was in the latter experiment slower than in the preceding experiment. Some of the bubbles were caught in the mesh of fungal filaments and held; and in these cases where they touched and remained in contact with the filaments streaming was induced to that point, but after a few seconds or minutes it ceased.

The method of using a capillary glass tube was not at first so easily manipulated, and many trials and the loss of a good many specimens resulted before it was successful to my entire satisfaction.

Some other specimens for these experiments on transpiration

FIG. 2*a*. Apparatus for applying bubbles to the specimens under the cover glass.

were grown in a 10 per cent solution of gelatin. Under favorable conditions this medium produced large actively streaming specimens. The various fungi behaved in this 10 per cent solution of gelatin in the same way when subjected to artificial conditions to produce or suppress transpiration, as they did in the solution of cane sugar. For example, when the streaming of *Mucor Mucedo* and *M. stolonifer* had been stopped in a saturated air and the plant was then placed over a 20 per cent solution of glycerin, the streaming began and moved rapidly to the exposed tips at first but gradually became slower and then stopped in 50 minutes. This was the average time required under such conditions, which will be seen to be a somewhat shorter time than when the filaments grown in a cane sugar solution were placed over a 20 per cent solution of glycerin. It was probably partly due to the lack of easily available water in the glycerin medium so that transpiration could not continue so long. When the spores were grown in a gas chamber and saturated air drawn through, the streaming ceased, but began again when dry air was passed through the cell. The velocity of streaming was dependent on the dryness of the air as prepared in the apparatus shown in FIG. 1.

FIG. 4. Part of a filament of *Mucor stolonifer* partially collapsed by excessive transpiration. × 400.

In all the experiments, when transpiration had proceeded too far the protoplasm was drawn wholly or partly away from the cell wall and gave the appearance shown by FIG. 4. In such cases as in FIG. 4, if moist air was readmitted, the protoplasm in a short time resumed its natural position and streaming recommenced.

EXPERIMENTS WITH ETHYL ETHER

When the same specimen as used above, whose protoplasm stopped in 50 minutes over 20 per cent glycerin, was laid over a cell containing 20 per cent glycerin to which a ¼ per cent solution of ether had been added, streaming began again, more slowly at first; then placed over the 20 per cent glycerin alone its streaming continued slowly for 15 minutes to the tip. When this specimen was again placed over pure water streaming began very rapidly from the tip and continued so for 10 minutes, but again it moved to the tip when the air was slightly dried. The ¼ per cent solution of ethyl ether used in this experiment was still further weakened to ⅛ per cent when it was added to the 20 per cent glycerin. The same experiment was carried out over a full ¼ per cent ether. As above mentioned a temporary awakening of the protoplasmic activity occurred. Schröter* states that a ¼ per cent solution of ether in a glycerin solution will stop streaming, but he does not state the concentration of the glycerin or the time required. This I also found to be true as above stated, but he has evidently overlooked the fact that a very weak solution of ethyl ether in dilute glycerin may cause a temporary recommencement of streaming if the ether is immediately applied. In either case it shows that transpiration is not purely mechanical but that certain physiological factors enter into the process. The above experiment is not easy to perform, owing to the liability of the protoplasm to lose too much water before the ether may be properly caused to act upon it. A reawakening of protoplasmic activity resulting in earlier or increased growth has been shown for other plants by Johannsen.† While this is true of small amounts of ether, by increasing the dose to a certain concentration not only a mere awakening of activity was caused but a more rapid growth.‡ In these experiments with a weak solution of ether on the fungal filaments a great many groups of the fungi were grown on a glass plate which fitted a large glass cell tightly. An apparatus like FIG. 5 is convenient to use to quickly draw into a cell a solution of glycerin and ether. By opening the stopcock *A* and applying suction at *C* the 20 per cent glycerin is drawn out, and then by turning the three-way stopcock *A* again and opening *B* the desired glycerin and ether mixture in *D* is drawn into *E* under the specimens at *F*.

Strong solutions of ether in glycerin caused an unfavorable

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* Schröter, loc. cit. 29.

† Johannsen, W. Das Aether—Verfahren beim Frühtreiben 61. 1906.

‡ Johannsen, loc. cit. 61.

effect. For example, when the specimens were placed over a 20 per cent solution of glycerin plus a 1 per cent of ethyl ether, streaming did not recommence as in the preceding experiments. When a new and actively streaming specimen was placed over the mixture, streaming ceased in 24 minutes. The protoplasm streamed fast at first over this solution but became gradually slower till it stopped. The specimens were not killed, for when they were placed over water or saturated air drawn through the cell, streaming began again. The movement was at first to the base then to the tip of the filaments again when the air was only slightly dried. The time required for a recommencement of streaming under these conditions varied according to the state of desiccation; but on the average, where streaming had just ceased, it began again in moist air in about 3 minutes. The movement was at first from the tip, where absorption was occurring, and then to the tip again when the air of the room, which was slightly drier than that of the cell, was admitted.

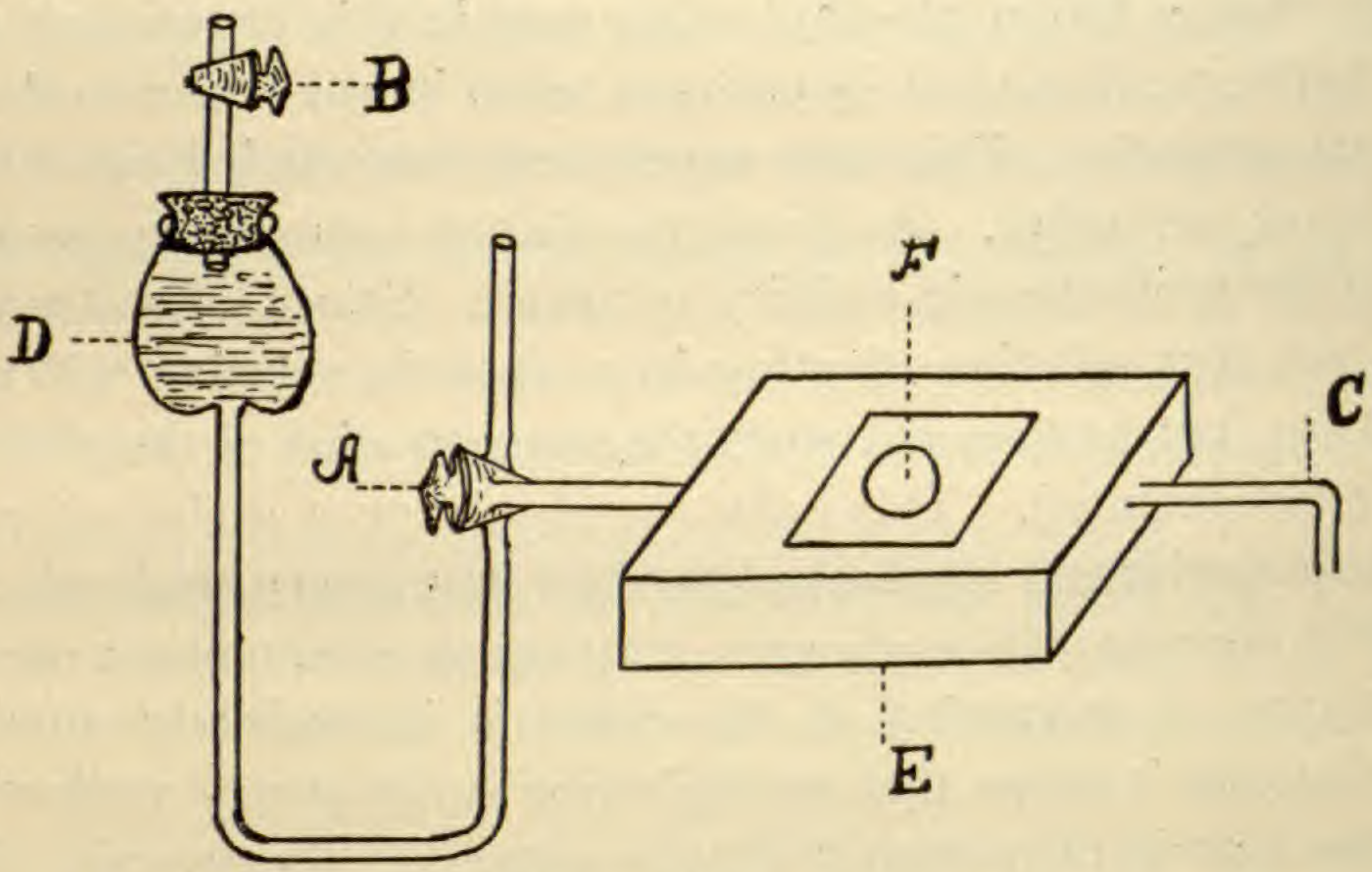

FIG. 5. Apparatus for drawing a solution into the gas chamber.

EFFECT OF OSMOSIS

For the study of the effect of osmosis on protoplasmic streaming in fungal filaments the spores of *Mucor Mucedo* and *M. stolonifer* were grown in water at a constant temperature on a glass slide. The cover glass was supported by bits of a cover glass so as not to rest on the spores or filaments and to admit a capillary tube.

A small capillary tube which had been filled with a 5 per cent solution of cane sugar was then carefully inserted under the cover glass and so placed that its open end was near one of the fungal filaments. In 10 minutes the sugar solution had diffused out in the water and come in contact with the filaments, and the protoplasm began to stream very fast to the point by the open end of the capillary tube. Sometimes the induced streaming was slow and then suddenly became more rapid. The capillary tube offered a convenient method of enabling one to bring the sugar solution to any desired part of a filament and thus study the behavior at certain places. No perceptible difference could be detected in this way between the base and apex of filaments capable of active streaming. At whatever part of an active filament the capillary tube containing the 5 per cent solution of cane sugar was applied streaming to that point was always induced and in a very short time. As was to be expected, weaker solutions of the cane sugar required more time and produced slower streaming while more concentrated ones caused more rapid streaming in less time. This method of using the glass capillary tube is not quite so simple as it may seem, as certain mechanical difficulties are experienced, especially when it was used with objectives of sufficient power to see the streaming distinctly.

A somewhat similar experiment in principle is one in which streaming almost immediately began in the filaments when a drop of sugar solution was brought to the edge of the cover glass. Here, however, the movement stopped sooner than when the solution was applied at one place by means of a capillary tube, since it diffused all around the filaments and the water was more quickly and uniformly withdrawn.

I can confirm the experiment of Schröter* in which he found that a sugar solution added to one side of the cover glass caused streaming in that direction, and I found that it continued from 2 to 17½ minutes according to concentration and the condition of the filaments. This is the time for both *Mucor Mucedo* and *M. stolonifer*. Also, I have found that the excessive loss of water by a sugar solution results in a great decrease in the size of the

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* Schröter, loc. cit. 21, 22.

filaments and in some instances a breaking of them, allowing the contents more or less completely to escape. By adding the sugar solution first to one end and then to the other, of a filament or a mass of them, and washing away the sugar after each application before reapplying it to the opposite end, the protoplasm may be made to stream to the sugar at each new application. If the sugar solution is applied to one side, movement occurs in that direction and then stops as above mentioned. If then the sugar solution is washed away with pure water, the part of the filament toward which streaming occurs will take up water, and streaming will take place away from this part for a time, or until equilibrium has been established. After stoppage in this way, the addition of even a weak solution of sugar at the part toward which streaming was moving causes it to recommence in this direction.

The following experiment will show the effect of sugar and give an idea of the number of times streaming may be induced and the duration of each period of streaming. To do this a glass slide was supported at each end on a glass block in a petri dish, the latter to hold the liquids that ran from the slide. The spores of *Mucor Mucedo* and *M. stolonifer* were grown in a very small drop of gelatin. Two wet strips of filter paper were so arranged that the edge of each just touched the edge of the cover glass and their ends hung down some distance into the petri dish. On one of the strips of filter paper was placed a lump of cane sugar, which was renewed as fast as necessary. As soon as the sugar was moistened and the solution passed under the cover glass, streaming to the sugar began at once. When streaming ceased, drops of water were added to the other strip of filter paper, which washed away the sugar solution, causing streaming in the reverse direction. The velocity of streaming in this experiment, especially toward the sugar solution formed in this case by the dissolving lump, varied. This was due to the unequal solubility of the sugar under the conditions here presented, which caused the solution to vary in concentration. At other times the sugar solution did not diffuse or pass under the cover glass with equal rapidity, owing to the fact that it was impossible more than approximately to control the amount of water supplied to or removed from the specimen. The number of times this experiment was performed and the duration of streaming in each case is shown by the following TABLE IV:

TABLE IV

Trials	Streamed to sugar	Stream reversed to water when added	Still	State of vacuoles	Temperature
1	7 min.	——		compressed	24° C.
2	——	11½ min.		compressed	24° C.
3	6 min.	——		compressed	24° C.
4	——	10 min.		compressed	24° C.
5	10½ min.	——		compressed	24° C.
6	——	3 min.		compressed	24° C.
7	17½ min.	——		compressed	24° C.
8	——	4 min.		compressed	24° C.
9	12½ min.	——		compressed	24° C.
10	——	2 min.		compressed	24° C.
11	6 min.	——		compressed	24° C.
12	——	——	still 4 sec.; starts with jerk to sugar solution	compressed	24° C.
13	8 min.	——		compressed	24° C.
14	——	14 min. very slowly		compressed	24° C.
15	9½ min.	——		compressed	24° C.
16	——	12 min.		compressed	24° C.
17	7 min.	——		compressed	24° C.
18	——	16 min. slow		compressed	24° C.
19	5 min.	——		compressed	24° C.
20	——	——	still 8 min.; starts with jerk to water	compressed	24° C.
21	2½ min.	——		compressed	24° C.
22	——	6½ min.		compressed	24° C.
23	1 min.	——		compressed	24° C.
24	——	20 min.		compressed	24° C.
	92½ min.	99 min.			

The experiment, as will be noted, was continued about three hours. The streaming was always faster to the sugar than to the water. Even an incomplete return of the protoplasm to the water before cessation of movement required a longer time than a complete transfer of all movable contents to the sugar, as is shown by the total time required for streaming in either direction. As will be seen, the total time the protoplasm was observed to move to the sugar during about 3 hours of constant observation was 92½ minutes, while the movement to the water for all the different times amounted to 99 minutes, or a difference of 6½ minutes. To this, as stated above, must be taken into consideration that the streaming to the sugar solution was much faster than to the water.

On two occasions, as will be observed by referring to TABLE IV, the streaming stopped once for 4 and at another time for 8 seconds to the sugar and to the water, respectively, and in starting did so with a jerk. After the 3 hours of experimentation with the fungal filaments in the above mentioned manner the specimen was put away for 24 hours at the optimum temperature to see if this treatment had had any detrimental effect. It was again observed at the end of this time and found to be in a perfect condition, and it again responded to the reagents which produced streaming as readily as when the experiment was at first begun. This experiment is similar to the one performed by Schröter* with a sugar solution and water, which I have also repeated and can confirm.

The streaming may also be caused to recommence when it has been stopped by cold. Specimens of *Mucor Mucedo, M. stolonifer*, and *Phycomyces nitens* grown in 10 per cent gelatin ceased to show streaming when suddenly transferred from a temperature of 24° to 9° C. When a 5 per cent solution of cane sugar was added, streaming began again in 15 seconds, but as is to be expected, not so rapidly as in specimens that were kept at optimum temperatures. The same specimens were then subjected to a temperature of 5° C. after washing out the sugar with water; and in this case too streaming was induced by a 5 per cent solution of cane sugar, but a longer time was required. The streaming was feeble and was not seen until one minute after the sugar was applied. The direction of motion was to the sugar solution, which was applied first to one end and then the other with previous washing with water before each new application. It is not necessary to use as high a concentration of sugar (10 per cent) as mentioned by Schröter.† A higher concentration of sugar than 5 per cent will start streaming in less time and more rapidly than mentioned above. No matter what concentration of sugar solution was used, the protoplasm did not flow as freely or as rapidly as when the plants were growing under the most favorable circumstances. The most favorable results are obtained if the sugar solution is applied immediately after streaming has been stopped by cold.

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* Schröter, loc. cit. 21, 22.

† Schröter, loc. cit. 21.

It has been shown that chloroform may stop streaming if used in a strong solution, but if used in a very dilute solution it may accelerate streaming or even cause it to begin.* The same is true of ether as regards the fungi used for this investigation. The solution of ether used to cause streaming to begin must be very dilute and the protoplasm be in a condition to stream. I have not experimented with chloroform on the fungi mentioned in this paper.

Specimens of *Mucor Mucedo* and *M. stolonifer* were grown in 10 per cent gelatin, and then a solution of ⅛ per cent ethyl ether was added. The streaming ceased in a few seconds after the ether was applied but began again slowly in 15 minutes. This same experiment was tried on other specimens of these same fungi with the same results. A quantity of the ⅛ per cent ethyl ether solution was also placed in the bottom of the glass cell below the specimens. As soon as it was found that streaming ceased for some time after the direct application of ⅛ per cent ether, a 4 per cent solution of cane sugar was added immediately to the specimens whose streaming had just ceased due to the ether. Streaming began again in three seconds, and all movement was to the parts of the filaments with which the sugar solution came in contact. When the sugar solution was washed away and water added, the streaming began but in the reverse direction.

Another series of the same fungi were grown as in the preceding experiment, but this time a ¼ per cent solution of ethyl ether was added directly to the specimens growing in 10 per cent gelatin. The protoplasm stopped streaming almost as soon as the ether was applied. The specimens were not killed by the addition of ether of the above strength, for when the ether was replaced with water the streaming recommenced and after a time regained its normal velocity. If a 4 per cent solution of cane sugar was applied immediately to the specimens that had just ceased to stream due to the ¼ per cent ether, streaming began in from 10 to 15

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* Hauptfleisch, P. Untersuchungen über die Strömung des Protoplasmas in behäuteten Zellen. Jahrb. Wiss. Bot. **24**: 220. 1892; Ewart, A. J. Protoplasmic streaming in plants 87. 1902; Pfeffer, W. Plant Physiology **3**: 319. 1905; Josing, E. Jahrb. Wiss. Bot. **36**: 210. 1901.

† Ewart, loc. cit. 86; Josing, loc. cit. 210.

seconds. The specimens for these experiments were grown at the optimum temperature and treated in exactly the same way except that in the last case the strength of the ether was greater. The amount of time, however, required for the resumption of streaming in the last case was much increased. If the cane sugar was weakened, as was done in this case by using only a 3 per cent solution, the streaming began again in about 25 seconds. When the ether was washed away from the still protoplasm with water, streaming began as before.

When specimens prepared as the above were covered with a 2 per cent solution of cane sugar, streaming recommenced in about one minute on the average but was less active than in the stronger solution of sugar. A 5 per cent solution of sugar caused streaming to commence in 30 seconds, and a 10 per cent solution of cane sugar caused a recommencement of streaming under the above conditions, almost instantly and very actively in all cases, to the sugar.

When the specimens are placed in a ½ per cent solution of ether, streaming stops immediately, but it can be caused to recommence by adding a sugar solution if this be applied at once. A 5 per cent solution of sugar caused streaming to commence in 30 seconds. The time, however, will vary according to the strength of the solution, as shown above, and the length of time the ether has acted. In respect to the water solutions (½ per cent ether) above mentioned I can confirm the experiments of Schröter.*

A saturated solution of ethyl ether was added directly to the filaments, and streaming ceased instantly. No acceleration of the streaming occurred before it stopped. When the ether was washed away at once with water streaming did not recommence.

A 1/20 per cent solution of ethyl ether directly applied to the fungal filaments causes streaming to begin in them when they are in a condition for such activity. This movement continued for about the usual time, and when finally the dilute ether was washed away with water the streaming continued. This was true of any filaments whether they were branched or not.

A convenient way to apply the cane sugar in any case where

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* Schröter, loc. cit. 21.

an exact per cent is not required is to place on the under side of the cover glass a small grain of sugar, close to the water in which the spores of the fungi have produced filaments. The sugar will adhere to the moist surface of the glass. A thick ring of vaselin may be put on the edge of the glass ring cell, which prevents the cover glass from coming directly in contact with the glass cell and admits of a fine platinum wire being introduced between them without admitting air. When the streaming has ceased for any reason or become retarded, the particles of sugar may be shoved into the liquid containing the fungal filaments by means of the platinum wire and its effect observed immediately through the microscope. We have in this arrangement not such a change as might bring about streaming by the drier air of the room entering the glass cell when the filaments are growing. Streaming would, as shown before, occur by transpiration, if in the experiment here mentioned the filaments protruded beyond the edge of the drop. In such a case it would be difficult to determine how much of the accelerated or induced streaming is due to transpiration and how much to osmosis. In the method here outlined, however, the factor of transpiration is excluded and osmosis alone is responsible for the result. All the experiments tried in this way resulted, as expected, in streaming being induced or accelerated, and they thus confirmed the previous and similar ones of this paper. In like manner the result was confirmatory of and useful in the experiments just performed with ether. Where the streaming had been stopped by the addition of ether in any of the stronger solutions mentioned, it could always be awakened and caused to continue from 1 to 15 minutes, according to the strength of the ether, its time of action, and the quantity of sugar. The sugar was placed on the cover glass at the same time the ether was added to the specimen.

INJURY

Frequently injuries of various kinds, if not too severe, cause protoplasmic streaming in many plants.* Generally a rather serious injury is necessary to stop the protoplasmic movements permanently. Ternetz† found in *Ascophanus carneus* that by

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* Pfeffer, W. Plant Physiology 2: 816–820 and literature there quoted. 1905.

† Ternetz, loc. cit. 282.

cutting an actively streaming part in two streaming ceased and did not recommence.

My experiments as regards injury have been performed on both *Mucor stolonifer* and *M. Mucedo*, and in both plants I obtained the same results. Schröter used *Mucor stolonifer* and *Phycomyces nitens*. I can confirm his results on *M. stolonifer*, but I was not successful in preserving *P. nitens* for this study.

When the filaments of actively growing specimens had their tips removed, a temporary increase in streaming was observed, due to the outflow of some of the contents and a relief of the pressure. This streaming could be traced back for a considerable distance among the filaments of the injured specimen. The streaming caused by such injury soon ceased. The specimens were then put away for 24 hours under favorable conditions and afterwards observed. They were found not to have been killed and were still in a living and streaming condition.

By separating the filaments of the fungi into two parts the specimens were not killed. They were observed after 18 hours and were found, Schröter states,* to have healed the wound. All of them were living, and streaming was either directly observable or was produced by the addition of a sugar solution.

A light pressure on the cover glass is sufficient to stop streaming temporarily and this, as Schröter states, will recommence when the pressure is relieved. The time of recovery of the streaming will depend on the amount of injury imparted and varies from an immediate recommencement to one delayed a few seconds. Pressure is, however carefully applied, too severe to excite streaming in these fungi or to accelerate that which may be present. A momentary acceleration may seem in some cases to be produced, but this is simply due to a partial compression of the filaments. When thisis relieved the streaming will continue as before.

INFLUENCE OF LIGHT

It has been known for a long time, as mentioned by Pfeffer,† that light may cause streaming. Also Ewart‡ makes reference

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* Schröter, loc. cit. 17.

† Pfeffer, W. Plant physiology 3: 318. 1905.

‡ Ewart, loc. cit. 71.

to this same point. Schröter has shown that light may cause or accelerate streaming, and I can confirm his observations on *Mucor stolonifer*, which he used, and also on *M. Mucedo.* These remarks refer to light of moderate intensity, for the light may be too strong for streaming to occur.

My experiments were carried out partly in daylight and darkness alternated and partly in gas light. In the first case the investigations were made by means of the freezing-apparatus of Molisch. With this arrangement the specimens could easily be kept at the desired temperature by means of warm or cold water siphoned in and out and the observation be carried on directly in the laboratory under the influence of light or dark. On heating the apparatus to the optimum temperature the specimens were kept first in the dark for two hours, when the protoplasm ceased to move. On admitting light a slow streaming began in five minutes and after a time became as rapid as the streaming of the control specimen. This experiment was repeated several times with the same specimen and always with the same result. When the temperature of the specimens was lowered from the optimum to 17° C. and then to 14° C., and the experiment repeated otherwise the same, the streaming became slower and slower on each new admission of light. Also, when the temperature was raised above the optimum but slightly (28° C.), the streaming on admitting light showed a rapid decrease in velocity. Too great heat or too intense light can readily, especially the former, make the protoplasm non-responsive. If, however, these are not continued too long the protoplasm of these fungi will recover in from one-fourth to one hour and stream as actively as before.

In the experiments made with the gas light an ordinary Welsbach burner was used and the investigations carried out in daylight and darkness repeated. The same results were obtained. In both of these series of experiments the specimens were preserved for 24 hours to see if in all cases they would become normal as compared to the controls for activity of streaming. At the end of this time both the specimens experimented on and the controls were normal and equally active.

TEMPERATURE

It has been shown by Hofmeister* and others long ago that a sudden change in temperature may excite streaming. More recently these observations have been confirmed by Hauptfleisch,† Ewart,‡ and others, for various plants. The same is referred to by Pfeffer,§ and Hörmann|| observed the same result. The literature on this subject as regards the higher plants is too voluminous to enter into fully here, so that the above brief references must suffice.

As regards the fungi I can confirm the statements of Schröter¶ that temperature also has much to do with the ability of *Mucor stolonifer* to show streaming. *Phycomyces nitens* I have not studied in this respect. I have also found, as in the higher plants and as Schröter did for *Mucor stolonifer*, that a sudden change of temperature may produce streaming in those specimens of this fungus that were in a condition for such movement. The same I have found is true of *M. Mucedo*. This is the case whether the temperature is raised or lowered suddenly, but with the precaution that the change be not too great or continued too long.

I can not, however, agree altogether with Schröter** that the optimum temperature for streaming in *Mucor stolonifer* is 26° C. and for *Phycomyces nitens* 28° C. My studies have shown that the optimum temperature for streaming in *M. stolonifer* and *M. Mucedo* each ranges from 23° to 26° C. and for *P. nitens* from 26° to 29° C. These temperatures, as given by Schröter, seem to be too sharply drawn, for as stated I have found a difference of a few degrees Centigrade. I did not attempt to ascertain what effect the age of the hyphae had on the optimum temperature for streaming, if any exists, as is probable. Ewart†† has pointed out for some of the higher plants that it is almost impossible to ascertain the required temperature exactly or within a degree, owing to various factors which enter into the problem and which are not

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* Hofmeister, W. Lehre von der Pflanzenzelle 53, 54. 1867.

† Hauptfleisch, P. Jahrb. Wiss. Bot. 24: 210. 1892.

‡ Ewart, loc. cit. 66 and literature there quoted.

§ Pfeffer, W. Plant Physiology 3: 316 and literature there quoted. 1905.

|| Hörmann, G. Studien über die Protoplasmaströmung bei den Characeen 44. 1898.

¶ Schröter, loc. cit. 56.

** Schröter, loc. cit. 15.

†† Ewart, loc. cit. 60.

controllable by the experimenter. Nor can I agree to Schröter's* idea that streaming can be induced only in branched hyphae. I have caused streaming to occur in the filaments of *Mucor stolonifer* and *M. Mucedo* when unbranched as in FIG. 6, 7, and 8, when they were put under the optimum conditions of temperature, etc. Also, as stated heretofore, I have induced streaming in such unbranched filaments by osmosis and transpiration.

The filaments of *M. stolonifer* are not always filled with granular protoplasm before branching, as Schröter seems to think. In those cases where this is not the case streaming may easily occur. I performed some of my experiments of this kind in room temperature varying from 16° to 19° C., where fairly rapid streaming occurred, but it was noticeably slower than at the optimum temperature.

As also mentioned above, a sudden change almost immediately caused streaming. When a specimen whose protoplasm was still, but in a condition to stream, was suddenly cooled from 23° to 16° C. streaming was induced, or if heated from 16° to 19° C. or from 23° to 26° C. streaming was generally produced.

The movements of the protoplasm in the hyphae of several filamentous fungi have been described by Arthur,† Ternetz,‡ and Schröter.§ In *Mucor stolonifer* and *M. Mucedo*, both of which I have studied, the streaming shows no difference, so that my remarks on this point apply equally well to both. FIG. 9 shows a portion of one filament of *M. stolonifer* grown in a sugar solution. It was found that the rate of growth of these fungi, their size, and branching frequently varied greatly although grown under the same conditions. The streaming also showed a great difference as to velocity. Sometimes it was so slow as to be scarcely discernible, as for example when osmosis or transpiration was very feeble. On the other hand, streaming was fast or very rapid according as some factor such as those just mentioned was active. In those filaments that had attained some length numerous vacuoles were generally present, and these varied greatly in size

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* Schröter, loc. cit. 15.

† Arthur, loc. cit. 493.

‡ Ternetz, loc. cit. 280.

§ Schröter, loc. cit. 4.

Fig. 6, x 400

Fig. 7, x 400

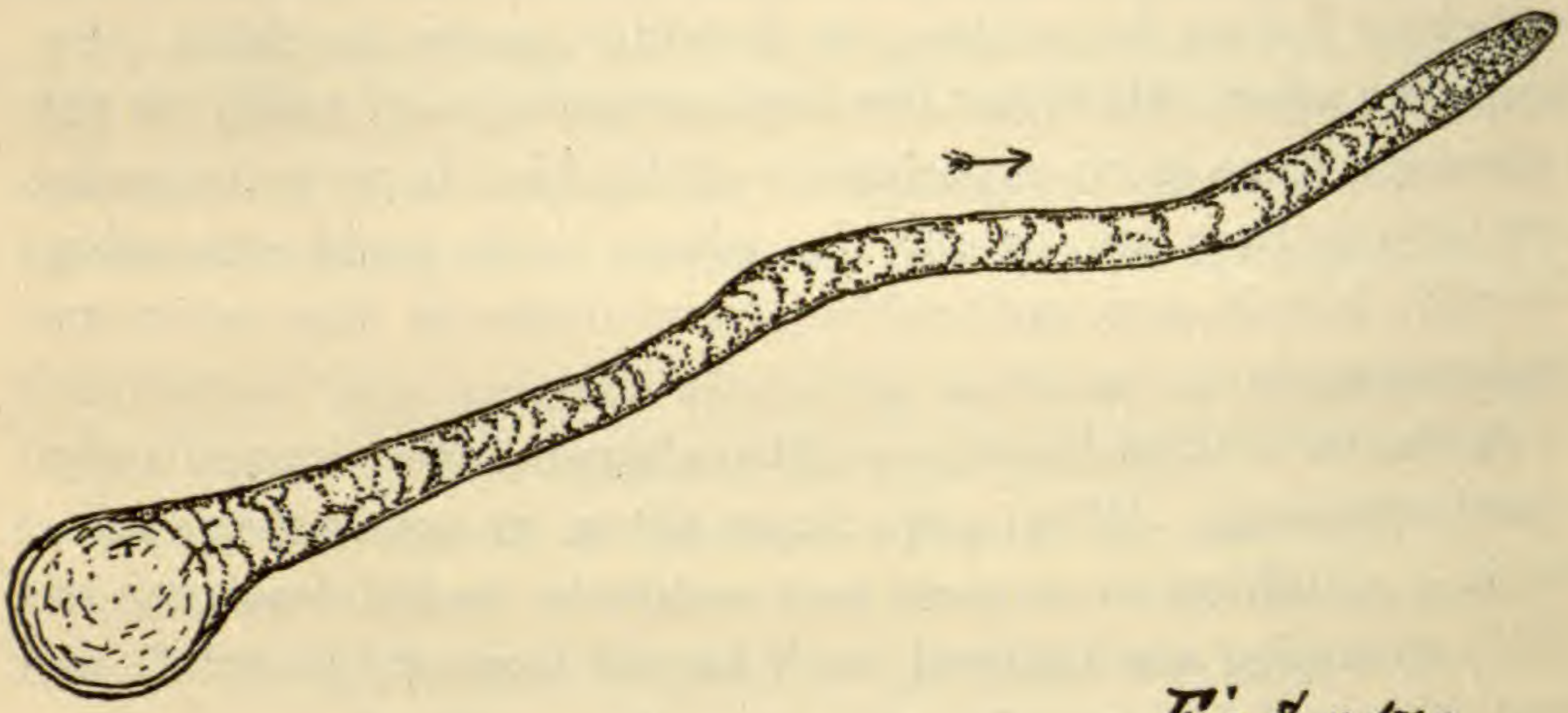

Fig. 8, x 520

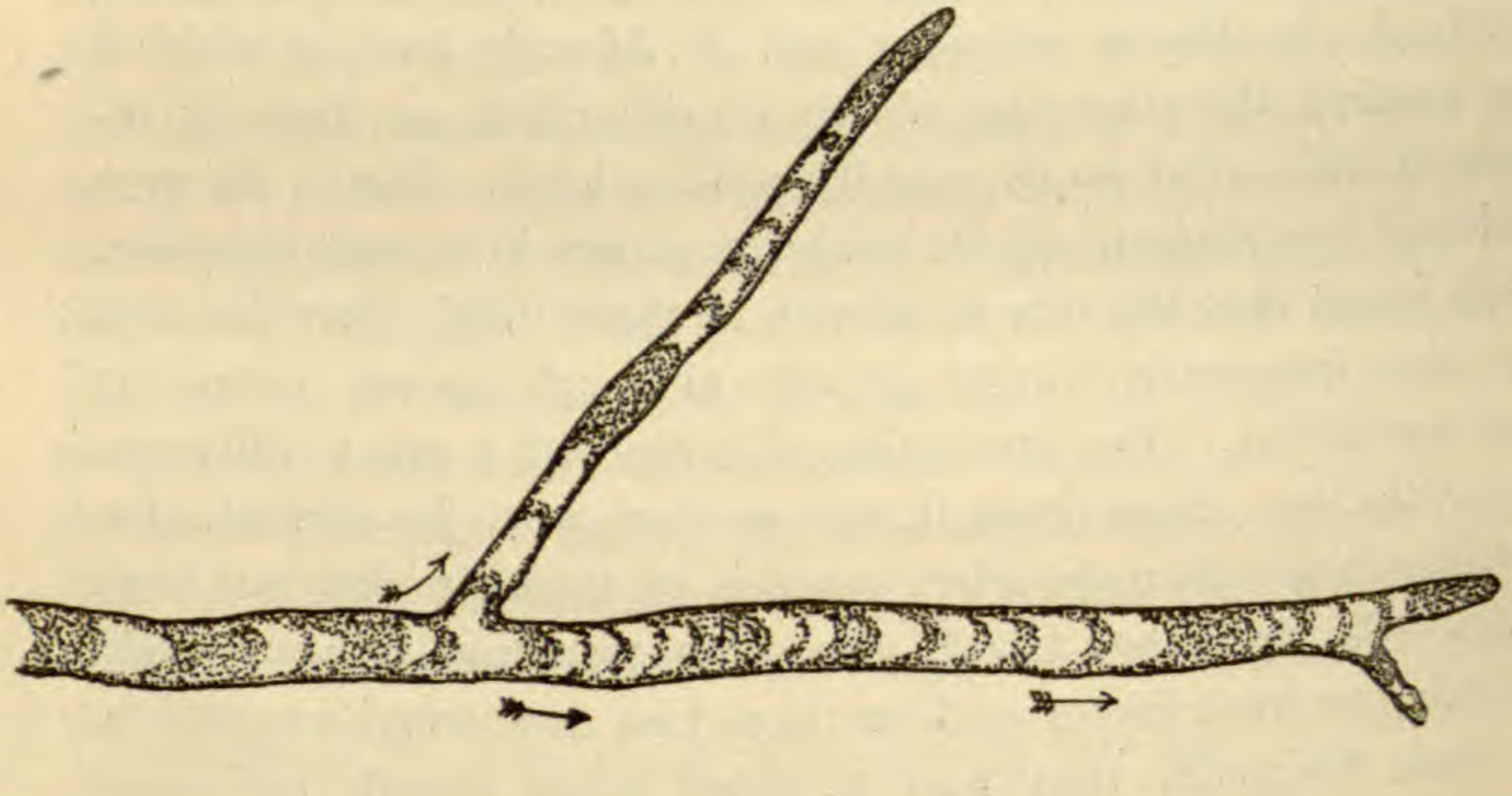

Fig. 9, x 400

FIG. 6, 7, 8. Unbranched young filaments of *Mucor stolonifer*.

FIG. 9. Branched filament of *Mucor stolonifer* showing streaming and division of vacuoles at the point of branching.

The direction of streaming is in all cases shown by the arrows.

and shape, due mostly to the streaming back and forth. This caused some of the vacuoles to be separated into several or sometimes many smaller ones and in other cases caused small ones to fuse into one or more vacuoles.

The division of vacuoles, especially the larger ones, was well shown in those instances where a stream of protoplasm (FIG. 9) divided on coming to a branch. Then, frequently about one half or often only a small part would go into the branch. Whether the streaming is slow or fast the vacuoles are always carried along with the whole mass. They are convex on the end toward which the flow is directed and concave on the opposite end. This shows that a relief of pressure exists in the direction of streaming. Sometimes the streaming stops very suddenly with a jerk and when starting frequently does so in the same way, although the factors producing streaming are active. This kind of sudden cessation of motion generally lasts for from one to a few seconds, when streaming is resumed at the normal rate. It is caused, as careful observation will show, by a mass of temporarily impermeable protoplasm suddenly entirely plugging up the cavity of the filament at some point. As soon, however, as more water is removed, as for example by osmosis, transpiration, or some other factor, the pressure is gradually relieved and the obstruction suddenly gives way, allowing a recommencement of streaming so suddenly as to cause the protoplasm to appear as if jerked forward. Unless the obstruction is removed the filament beyond that point frequently collapses, due to excessive transpiration or other factor. Sometimes the velocity would vary for no apparent reason, as is known to be the case in other plants.

At times when no streaming was visible an extremely thin layer of protoplasm between the large vacuoles and the ectoplasm could be seen to be in motion. Part of the time it moved in the same direction as the streaming had moved and sometimes in the reverse direction. I was unable to see it moving in the opposite direction to the streaming protoplasm. I can therefore not agree with Schröter* on this point but find, as stated by Ternetz for *Ascophanus carneus*, that during streaming all of the moving protoplasm of *Mucor stolonifer* and *M. Mucedo* goes only in one direction.

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* Schröter, loc. cit. 30.

It is hardly possible, even if a reverse movement did take place along the wall during the streaming, that it would be sufficiently active to account for the return of the protoplasm. The streaming occurs first in one direction, and when the factor that has caused this subsides or is overcome, it streams back in the opposite direction.

Streaming may be easily induced in *Mucor* and be caused to continue in first one direction and then the other without apparent harm to the plant for an indefinite time. This and other facts tend to show that it is not a "pathogenic" state of affairs as Keller* seems to think. The streaming may be of use in the long cells of these fungal filaments, as de Vries† suggests, to transfer substances. This, however,. would not hold true for small cells as Ewart‡ has shown, for in such cases diffusion would distribute substances more rapidly than streaming.

SUMMARY

The foregoing experiments have proved the following points, most of which confirm Schröter's work, but some show his work in a few places to be incorrect:

1. The kind of nutrient media is of great importance for the proper growth of these fungi.

2. Streaming is caused in many cases by transpiration, and streaming is strong or weak according to the intensity of the transpiration.

3. Streaming is also caused in many cases by osmosis, as by the use of sugar. The streaming is always to the sugar. The rapidity of streaming depends on the concentration of the sugar solution.

4. During streaming caused by osmosis there is no peripheral streaming or movement in the opposite direction, as stated and figured by Schröter. This also confirms the statement of Ternetz.

5. Injury, as stated by Schröter, does not produce or accelerate

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* Keller, J., cited from Pfeffer, loc. cit. 2: 818. 1905.

† De Vries, Bot. Zeit. **45**: 1. 1885.

‡ Ewart, A. J. On the ascent of sap in trees. Phil. Trans. Royal Soc. 40. 1905, quoted from Pfeffer, Phys. Pl. (Eng. Transl.) **3**: 359. 1905.

streaming, but has a tendency to decrease any streaming that may be present. When the filament is cut into two pieces, only an outflow occurs. This may, in time, heal and streaming be resumed.

6. Light may cause and accelerate streaming when alternated with darkness in those fungal filaments that are in a condition for streaming.

7. A sudden change of temperature of several degrees will cause streaming in these fungi.

8. Contrary to Schröter's opinion, streaming may occur or be caused in unbranched as well as branched filaments.

My thanks are due Professor W. Pfeffer for placing at my disposal the facilities of his laboratory for this investigation and also for his constant interest and kind assistance.

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Desmos the proper generic name for the so-called Unonas of the Old World

William Edwin Safford

In connection with his work on the American Annonaceae[*] the author has had occasion to look into the question of the types of the genera of this family. To his surprise he found that the genus *Unona*, based upon an American type by the younger Linnaeus (who is quoted by all botanists as author of the genus), is declared to be exclusively Asiatic. The various American plants assigned to this genus by Dunal in his admirable monograph of the Annonaceae have all been relegated to other genera; and the recently described *Unona panamensis* and *U. bibracteata* of Dr. B. L. Robinson are undoubtedly species of *Unonopsis*.[†] Concerning *Unona discreta* modern botanists are silent.

The original description[‡] of this species, the type of the genus, is as follows:

"*discreta.* UNONA.

Peyricoboom. *Surinam.*

Habitat in Surinamo. C. G. Dalberg.

Arbor ramis virgatis, angustis, flexilibus.

Folia bifaria, alterna, petiolata, ligustrina, glabra, integerrima, digitalia.

Petioli brevissimi.

Pedicelli baccarum intra corollam, umbellati.

Flos Annonae, sed Fructus diversus, purpureus, sapidus, aromaticus, qui distinguit genus uti in Theobroma & Ambroma.

"*Annotatio*"

"Unona, Annona, Xylopia floris charactere simillimae, potius Gynandris associandae, cum stamina germini insideant."

In the above description the form of the carpels is not indi-

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[*] See Jour. Washington Acad. Sci. 1: 118–120. S 1911.

[†] Fries, Robt. E. Beiträge zur Kenntnis der süd-amerikanischen Anonaceen. Kgl. Sv. Vet.-Akad. Handl. 34^{5}: 26. 1900.

[‡] Linn. f. Suppl. 270. 1781.

cated, though they are described as stipitate and aromatic and borne in umbellike clusters on the receptacle (intra corollam).

The name *Unona* was taken up by Vahl,* who imagined that a certain East Indian plant was congeneric with Linnaeus's type. He redescribes *Unona discreta* without mentioning its type locality, but in his description he deviates somewhat from the original in characterizing the leaves as sericeous beneath, 1½ inches long, much attenuated, narrow, willowlike (salicina), and scarcely petioled. He does not describe the fruit nor indicate the number of seeds. He does, however, describe a second species, and he figures its fruit, which is elongate and moniliform or constricted between the seeds. The figure of the fruit of this species, *Unona discolor* Vahl, led to Dunal's subsequent error of describing the carpels of *U. discreta* Linn. f. as moniliform, for which he had no warrant. Dunal (Monographie de la famille des Anonacées 110. 1817) cites first Vahl and then Linnaeus f. He follows Vahl in describing the leaves of *U. discreta* as sericeous beneath; and for his description of the fruit he refers to Gaertner's figure of an Asiatic plant, *Uvaria monilifera*, which was considered as a possible synonym of the Surinam *Unona discreta*, but which in all probability is to be referred to *Unona discolor* Vahl. The latter plant, as we shall see, is regarded as a synonym of *Desmos chinensis* Loureiro (1790).

The limits of the genus *Unona* as treated by Dunal are very ill-defined. This was inevitable in many instances on account of the scant material at his disposal, in which fruits were often lacking. In the genus *Unona* he included plants of several distinct genera. His *Unona uncinata* is the fragrant *Artabotrys odoratissima* of India and Ceylon, the ripe carpels of which are not at all moniliform; his *Unona nitidissima* is an Australian plant belonging to the genus *Polyalthia;* his *Unona crassipetala*, a Guiana plant of which he did not see the fruit, is undoubtedly a species of *Guatteria;* his *Unona violacea* is a species of *Sapranthus* closely allied to *S. nicaraguensis* Seem.; his *Unona penduliflora* is the spicy xochinacaztli of the Mexicans (*Cymbopetalum penduliflorum* Baill.); and his *Unona acutiflora* and *U. xylopioides*, from South America, are both synonyms of St. Hilaire's *Xylopia grandiflora.*

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* Symb. Bot. 2: 63. 1791.

Hooker and Thomson, in their Flora Indica (1853), described a genus of Annonaceae which they called *Unona*, taking Linnaeus's name and ascribing the genus to him. Their genus, however, did not include his type, nor indeed any American species. In their revision of the Annonaceae they did most admirable work, arranging the genera according to the natural affinities of the plants and grouping them into tribes in the most logical manner. In their choice of generic names, however, they were most arbitrary. The genus which they called *Melodorum*, for instance, excludes the previously established type of Loureiro's genus *Melodorum* (1790). Their genus was based upon a section of plants which Dunal had called *Melodorum* and in which he erroneously had included Loureiro's *Melodorum*, together with Blume's division Melodorae of the genus *Uvaria* (Fl. Jav. 1828). They had seen *Melodorum fruticosum*, the type of Loureiro's genus, in the British Museum, and purposely excluded it from their genus of the same name. They had not ascertained its generic affinities, since they did not examine its flower; but they gave the comforting assurance that Loureiro's two species of *Melodorum* "will probably both be found to belong to well-known genera"; and they explain their use of the name *Melodorum* for a distinct genus by saying: "At all events his [Loureiro's] descriptions are not sufficient to identify the species nor to distinguish the genus; * it would therefore, we think, be manifestly unjust to Dunal and Blume not to retain their name."

In the same way the genus which they called *Unona* excludes all American species, even the type of the younger Linnaeus's genus *Unona*, though they cite Linnaeus as the author of the genus which they call *Unona*. This they state is "entirely an Asiatic genus" (Hook. f. & Thoms. Fl. Ind. 131. 1855), and it has continued to be regarded as such by subsequent writers, all of whom cite Linnaeus f. as authority, and the type of the genus as *Unona discreta*, an American tree. This tree we know to be endemic in the Dutch colony of Surinam, and we further know that it has slender, virgate branches, privetlike, or willowlike, two-ranked, short-petioled leaves, Annonaceous flowers, and aromatic purplish stipitate carpels radiating from the receptacles. It is not difficult

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* This statement applies also to some of Linnaeus's types.

with these indications to determine the identity of the type. It is either *Xylopia frutescens* Aubl. or *X. salicifolia* Dunal, more likely the former, both of which are commonly called peyrico, pegriko, or pegreko-boom in Surinam and are undoubtedly congeneric with *Xylopia muricata*, the type of the genus *Xylopia* as established by Linnaeus.*

This being the case, the genus *Unona* falls, becoming a synonym of the genus *Xylopia*, and it is necessary to designate by a valid name the Asiatic genus which Hooker and Thomson called *Unona*. The earliest name for this genus is that of Loureiro:† *Desmos*, signifying a chain, and given to it on account of the fruits chained together in nodes. Two species were described by Loureiro, *Desmos cochinchinensis*, the type of the genus, which Dunal afterwards renamed *Unona Desmos*, and *Desmos chinensis*, which Vahl described the following year under the name *Unona discolor*.

If we recognize the validity of Loureiro's genus but widen his definition so as to comprehend in it the species of Hooker and Thomson's genus *Unona*,‡ certain changes in nomenclature become necessary. The following is a description of the genus.

DESMOS Loureiro

Sepals 3. Petals 6, in 2 series, valvate, nearly equal, flat, in some cases 3, from the suppression of the inner series. Stamens numerous, tetragonal-oblong or cuneate, the connective expanded above the dorsal oblong or linear-oblong pollen sacs into a subglobose or truncate hoodlike process. Torus slightly raised, truncate, flat, or somewhat concave at the apex, glabrous between the stamens, pilose between the carpels. Carpels indefinite;

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* Syst. Nat. **2**: 1250. 10 ed. 1759.

† Flora Cochinchinensis **1**: 352. 1790.

‡ From this genus I have found it necessary to remove *Unona latifolia* Hook. f. & Thoms. (= *U. Brandesana* Pierre), owing to the peculiar form of the connective of its stamens, which like that of the genus *Canangium* is produced into a long tapering point and not swollen and obtuse or flattened as in *Desmos*. This plant is undoubtedly congeneric with *Canangium odoratum* (Lamb.) King. Its synonymy is as follows:

Canangium Brandesanum (Pierre) Safford comb. nov.

Unona Brandesana Pierre, Fl. Forest. Cochinch. *pl. 19*. 1880; *Unona latifolia* Hook. f. & Thoms. Fl. Brit. Ind. **1**: 60. 1872, not *Unona latifolia* Dunal, Monogr. Anon. 115. 1817, which is *Uvaria latifolia* Blume (*Melodorum latifolium* Hook. f. & Thoms. Fl. Ind. 116. 1855).

ovaries usually strigose-pilose. Ovules usually 1-seriate, forming a single column, sometimes subbiseriate. Style ovoid or oblong, recurved, with a longitudinal groove along its inner surface. Ripe carpels indefinite, either elongate and constricted between the seeds, or baccate and spheroid.

In restoring the generic name *Desmos* to its proper place the author retains the sectional division of the genus as proposed by Hooker and Thomson, changing the name of Section I, from Desmos to Eudesmos, and adopting the name Dasymaschalon in its original form for Section II. Both of these sections were used in Hooker's Flora of British India (1872), but a third section, Pseudo-Unona, was discarded in that work. In Sir George King's monumental work on The Anonaceae of British India (1893) he retains the first two sections under their original names but substitutes the name Stenopetalon for Section III., in which he places *Unona stenopetala*, *U. crinita*, and *U. desmantha* of Hooker together with *U. Wrayi*, described and figured by Hemsley in Hooker's Icones *pl. 1553*.

This section is undoubtedly composed of a heterogeneous group of plants and will have to be revised. Some of the species included in it differ so radically from the generic type, especially in the form of their ovaries and styles, that they must eventually be removed from the genus. Thus *U. desmantha* and *U. Wrayi* have nodding hairy swollen styles like those of the genus *Polyalthia*. The ovoid ovary of *U. stenopetala* terminates in an erect acute style, while the truncate ovary of *U. crinita*, as originally described and as figured by King, has a punctate stigma.

In the following review of the genus I have been much aided by the figures in Sir George King's Anonaceae of British India, above referred to, and especially by the citations of the author, which have facilitated reference to all the original authorities cited below.

DESMOS Lour. Fl. Cochinch. 1: 352. 1790. — *Unona* Hook. f. & Thoms. Fl. Ind. 130. 1855; not *Unona* Linn. f. Suppl. 270. 1781. "Nomen (Δεσμὸς, catena) ob fructus in nodos concatenatos."

Type: *Desmos cochinchinensis* Lour.

SECTION I. EUDESMOS.—Petals 6. Ripe carpels constricted between the seeds. Type: *Desmos cochinchinensis* Lour.

1. D. COCHINCHINENSIS Loureiro, Fl. Cochinch. 1: 352. 1790.
   Unona cochinchinensis DC. Prodr. 1: 91. 1824.
   Unona Desmos Dunal, Monogr. Anon. 112. 1817; Hook. f. & Thoms. Fl. Ind. 134. 1855; Hook. f. Fl. Brit. Ind. 1: 59. 1872; King, Anon. Brit. Ind. 55. *pl. 73.* 1893.
2. D. CHINENSIS Loureiro, Fl. Cochinch. 1: 352. 1790.
   Unona discolor Vahl, Symb. 2: 63. *pl. 36.* 1791; Dunal, Monogr. Anon. 111. 1817; DC. Prodr. 1: 91. 1824; Roxb. Fl. Ind. 2: 669. 1824; Hook. f. & Thoms. Fl. Ind. 132. 1855; Hook. f. Fl. Brit. Ind. 1: 59. 1872; King, Anon. Brit. Ind. 56. *pl. 74.* 1893.
3. **D. elegans** (Thwaites) comb. nov.
   Unona elegans Thw. Enum. 398. 1864; Hook. f. Fl. Brit. Ind. 1: 58. 1872; King, Anon. Brit. Ind. 53. *pl. 69.* 1893.
4. **D. zeylanicus** (Hook. f. & Thoms.) comb. nov.
   Unona zeylanica Hook. f. & Thoms. Fl. Ind. 132. 1855; Hook. f. Fl. Brit. Ind. 1: 58. 1872; King, Anon. Brit. Ind. 54. *pl. 70.* 1893.
5. **D. Dunalii** (Wall.) comb. nov.
   Unona Dunalii Wall. Cat. 6425. 1852; Hook. f. Fl. Brit. Ind. 1: 58. 1872; King, Anon. Brit. Ind. 54. *pl. 70.* 1893.
6. **D. pannosus** (Dalz.) comb. nov.
   Unona pannosa Dalz. in Hook. Kew Journ. Bot. 3: 207. 1851; Hook. f. & Thoms. Fl. Ind. 135. 1855; Hook. f. Fl. Brit. Ind. 1: 58. 1872; King. Anon. Brit. Ind. 55. *pl. 72.* 1893.
7. **D. viridiflorus** (Beddome) comb. nov.
   Unona viridiflora Bedd. Icon. Pl. Ind. Or. 34. *pl. 158.* 1874; Hook. f. Fl. Brit. Ind. 1: 60. 1872; King, Anon. Brit. Ind. 56. *pl. 75.* 1893.
8. **D. dumosus** (Roxb.) comb. nov.
   Unona dumosa Roxb. Fl. Ind. 2: 670. 1824.; Wall. Cat. 6429. 1832; Hook. f. & Thoms. Fl. Ind. 131. 1855; Hook. f. Fl. Brit. Ind. 1: 59. 1872; King, Anon. Brit. Ind. 57. *pl. 76.* 1893.
9. **D. Lawii** (Hook. & Thoms.) comb. nov.
   Unona Lawii Hook. f. & Thoms. Fl. Ind. 132. 1855; Hook. f. Fl. Brit. Ind. 1: 59. 1872; King, Anon. Brit. Ind. 57. *pl. 77A.* 1893.

10. **D. praecox** (Hook. f. & Thoms.) comb. nov.
Unona praecox Hook. f. & Thoms. Fl. Ind. 136. 1855; Hook. f. Fl. Brit. Ind. **1**: 60. 1872; King, Anon. Brit. Ind. 58. *pl. 79.* 1893.

SECTION II. DASYMASCHALON Hook. f. & Thoms.—Petals 3, in one series, the inner series lacking; ripe carpels constricted between the seeds. Type: *Desmos longiflorus.*

11. **D. longiflorus** (Roxb.) comb. nov.
Unona longiflora Roxb. Fl. Ind. **2**: 668. 1824; Wall. Cat. 6419. 1852; Hook. f. & Thoms. Fl. Ind. 134. 1855; Hook. f. Fl. Brit. Ind. **1**: 61. 1872; Kurz, For. Fl. Burm. **1**: 35. 1877; King, Journ. As. Soc. Beng. **61**^{2}: 46. 1892; Anon. Br. Ind. 58. *pl. 80.* 1893.

12. **D. dasymaschalus** (Blume) comb. nov.
Unona dasymaschala Blume, Fl. Jav. Anon. 55. *pl. 27.* 1828; A. DC. Mém. Anon. 28. 1832; Wall. Cat. 6421. 1832; Hook. f. & Thoms. Fl. Ind. 135. 1855; Kurz, For. Fl. Burm. **1**: 36. 1877; Hook. f. Fl. Brit. Ind. **1**: 61. 1872; Scheffer, Obs. Phyt. Anon. 6, Nat. Tijdschr. Ned. Ind. **31**: 6. 1870; King, Journ. As. Soc. Beng. **61**^{2}: 47. 1892; Anon. Brit. Ind. 59. *pl. 81.* 1893.

SECTION III. STENOPETALON.—Petals 6; ripe carpels baccate, not constricted between the seeds. Type: *Desmos stenopetalus* (Hook. f. & Thoms.).

13. **D. stenopetalus** (Hook. f. & Thoms.) comb. nov.
Unona stenopetala Hook. f. & Thoms. Fl. Ind. 136. 1855; Hook. f. & Thoms. Fl. Brit. Ind. **1**: 60. 1872; Miq. Fl. Ind. Batav. **1**^{2}: 43. 1832; Kurz, For. Fl. Burm. **1**: 35. 1877; King, Journ. As. Soc. Beng. **61**^{2}: 40. 1892; Anon. Brit. Ind. 61. *pl. 85.* 1893.

14. **D. crinitus** (Hook. f. & Thoms.) comb. nov.
Unona crinita Hook. f. & Thoms. Fl. Brit. Ind. **1**: 61. 1872; King, Journ. As. Soc. Beng. **61**^{2}: 48. 1892; Anon. Brit. Ind. 61. *pl. 84.* 1893.

15. **D. Wrayi** (Hemsl.) comb. nov.
Unona Wrayi Hemsl. in Hook. Ic. Pl. III. **6**: *pl. 1553.* 1887;

King, Journn. As. Soc. Beng. **61^2**: 47. 1892; Anon. Brit. Ind. 60. *pl. 82.* 1893.

16. **D. desmanthus** (Hook. f. and Thoms.) comb. nov.
Unona desmantha Hook. f. & Thoms. in Hook. f. Fl. Brit. Ind. **1**: 61. 1782; King, Journ. As. Soc. Beng. **61^2**: 48. 1892; Anon. Brit. Ind. 60. *pl. 83.* 1893.

WASHINGTON, D. C.

A case of changed polarity in Spirogyra elongata

F. L. PICKETT

(WITH PLATE 36)

On June 19, last, the writer was examining some filaments of *Spirogyra elongata* (Berk.) Kg., taken from a ditch running through Indiana University campus, and found the holdfast structure shown in PLATE 36, FIG. 1. This structure seemed to be growing rapidly, as a camera-lucida drawing was quickly made. Three hours later a second sketch was made (FIG. 2), showing considerable development.

The slide was carefully kept in a light moist chamber for ten days. The water on the slide harbored a number of animalcules,—rotifers, phacus, ameba, etc.—which with the algae seemed to keep up a life balance. Rapid growth and division of cells in the filaments, as well as the many bubbles of oxygen produced when the light was strong, showed that conditions were quite favorable for algal growth. Most of the filaments were held in more or less sharp curves by the cover glass, but some were quite straight and free from stress (FIG. 7 and 8). The cells of *Cladophora* were old and well covered with diatoms and particles of flint.

The slide was frequently examined and several branchlike structures were found. The first one found remained as shown in FIG. 2, but another was seen in process of development (FIG. 3 and 4). In every case where attachment had occurred, the *Spirogyra* was fastened to a thread of *Cladophora*.

The structures shown in FIG. 1–6 are outgrowths near the end of a filament, near a dead cell or at a point of physical stress, and are probably holdfasts. In such cases the change in polarity shown is probably due to the abnormal stress, as suggested by Pfeffer (Pfeffer-Ewart **2**: 159. 1900). A structure similar to these was found in a chance examination of *S. communis* by Prof. F. M. Andrews in November 1904. His hitherto unpublished sketch is shown in TEXT FIG. 1. This too was evidently a holdfast, although it is not now known to what the filament was attached.

FIG. 1. *Spirogyra communis*, × 425, as observed and drawn by Professor F M. Andrews, Nov. 1, 1904.

Entirely different from the cases given above are those shown in FIG. 7 and 8 (PLATE 36). When it is taken into consideration that these two filaments were normal, rapidly growing vegetative filaments, and that no indication of fruiting activity could be found in the whole collection under consideration, the change of polarity here shown seems very unusual. There is no suggestion, either in form or in the proximity of other filaments, of these branches being holdfasts. So far as the writer can find, such forms have not been found in nature or under conditions of controlled experiment.

The drawings were made with an Abbe camera lucida and Leitz obj. 6 and oc. 4.

INDIANA UNIVERSITY,
BLOOMINGTON, IND.

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(1896–1911)

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Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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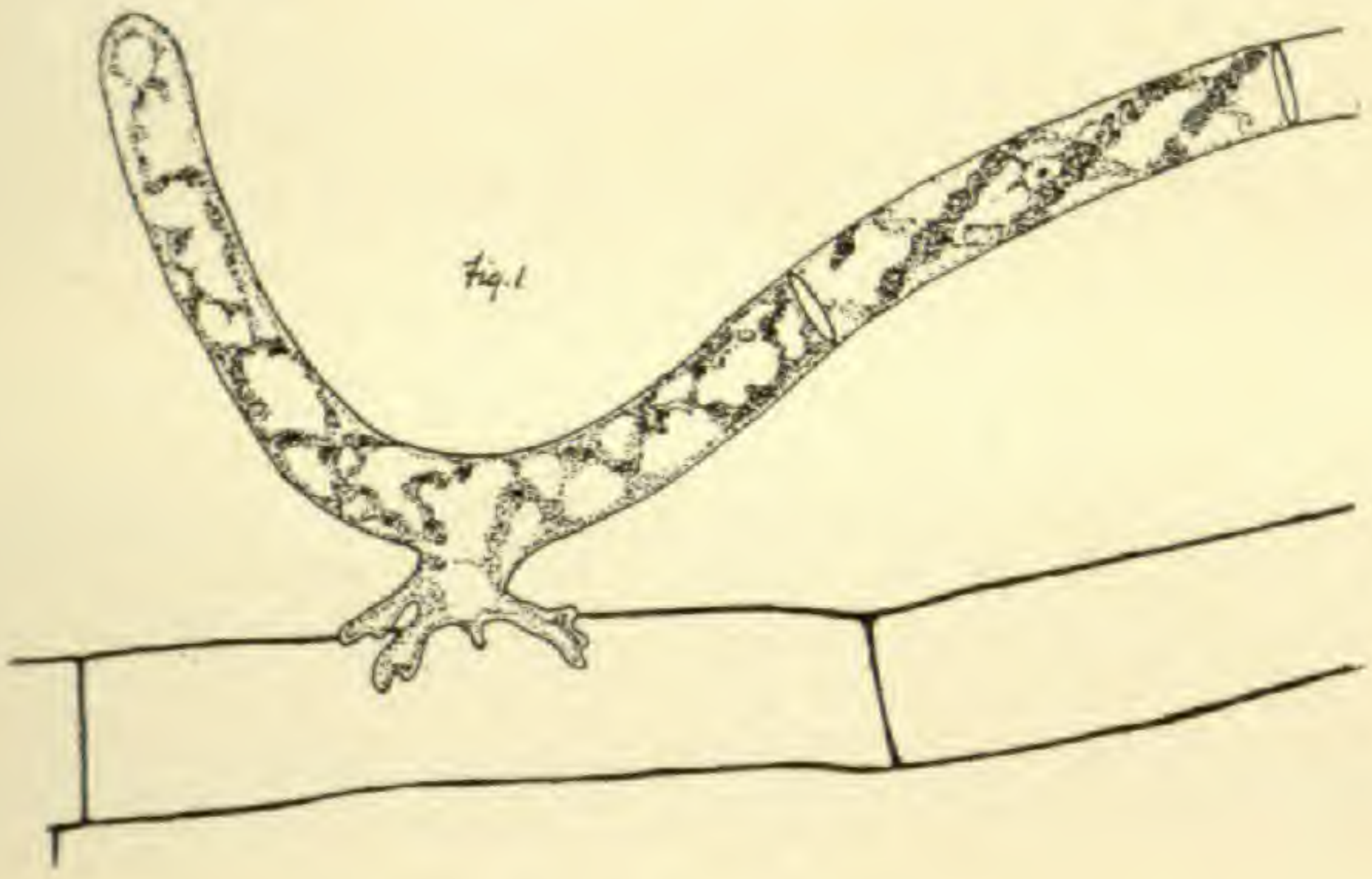
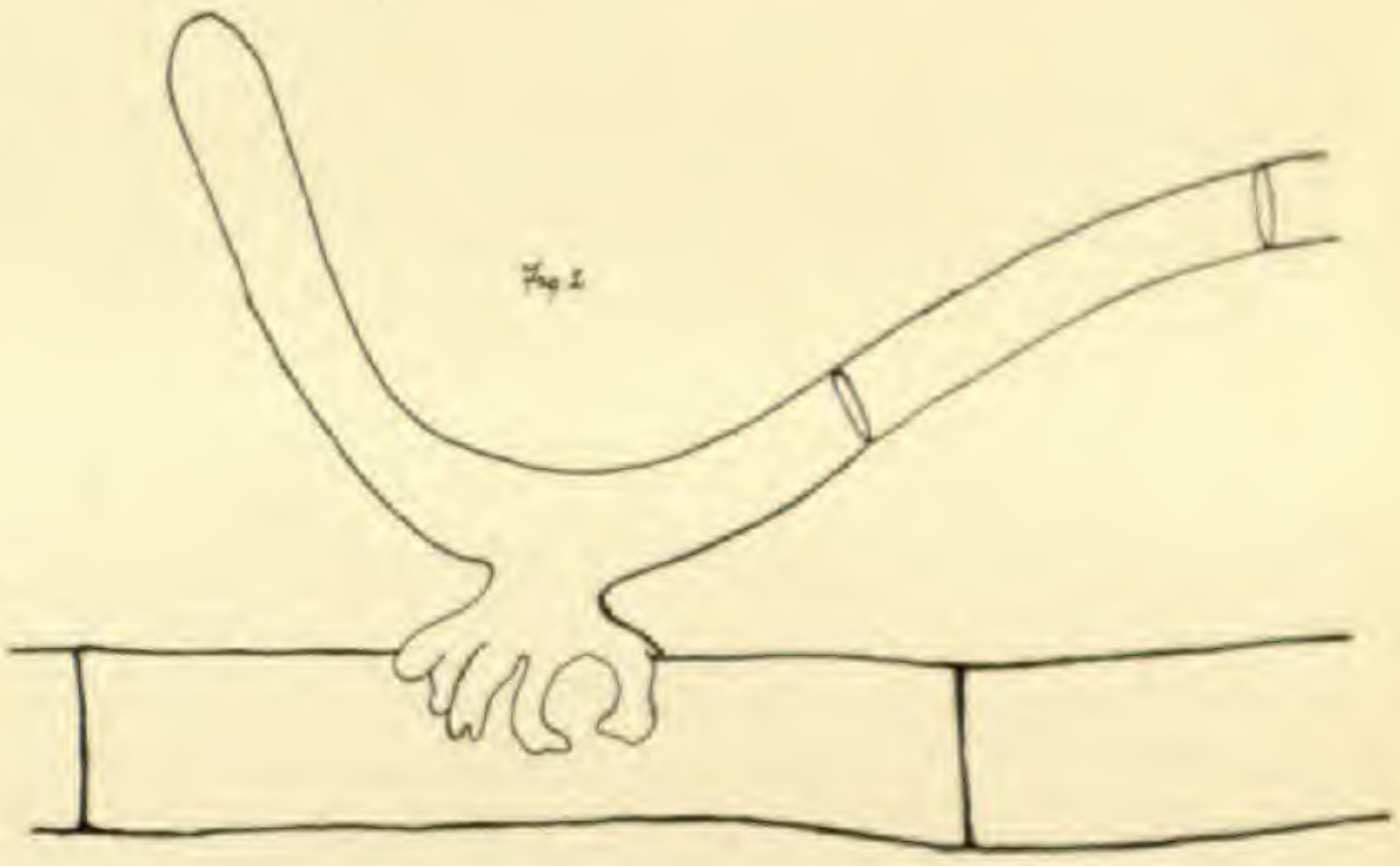


Fig. 1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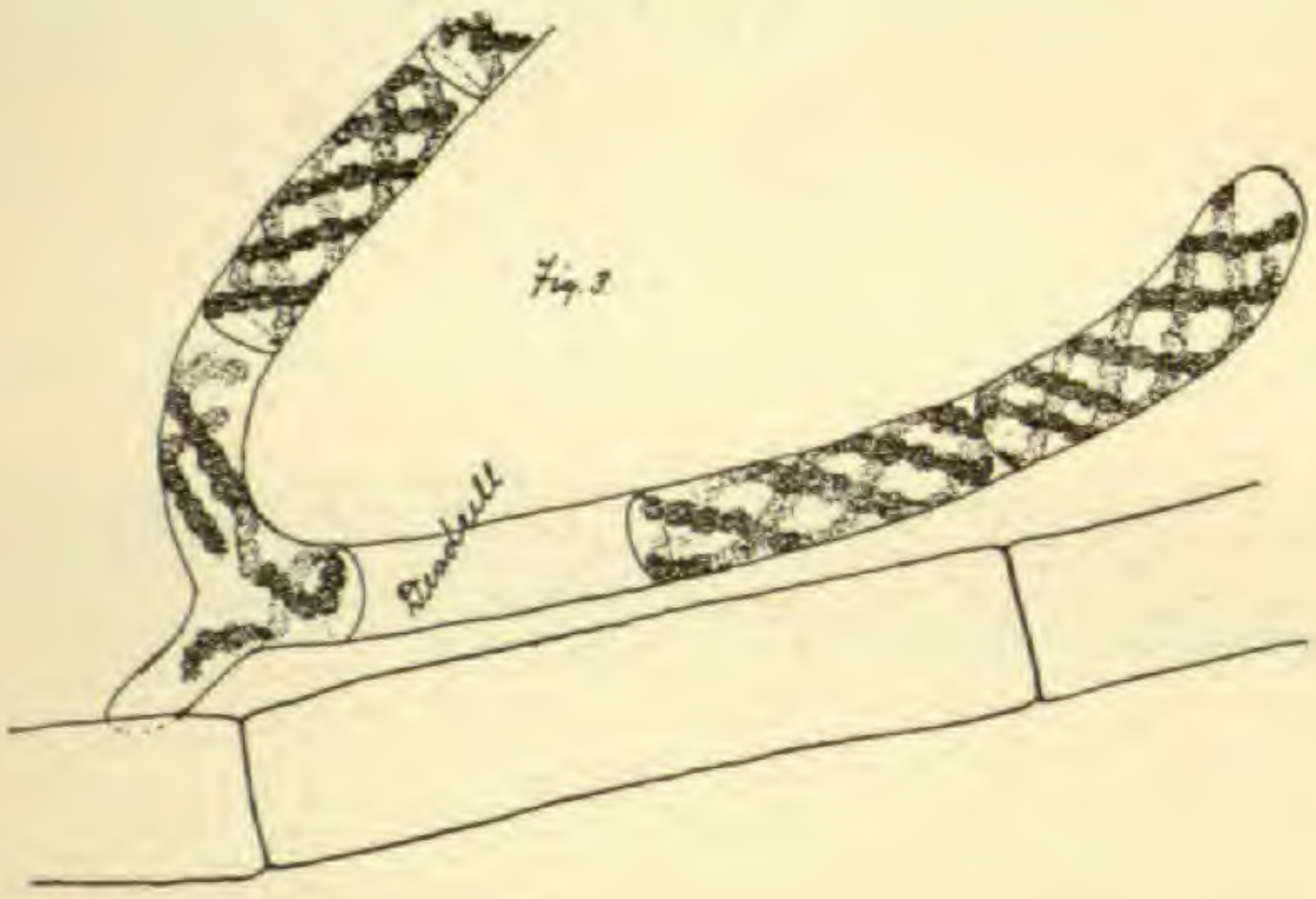
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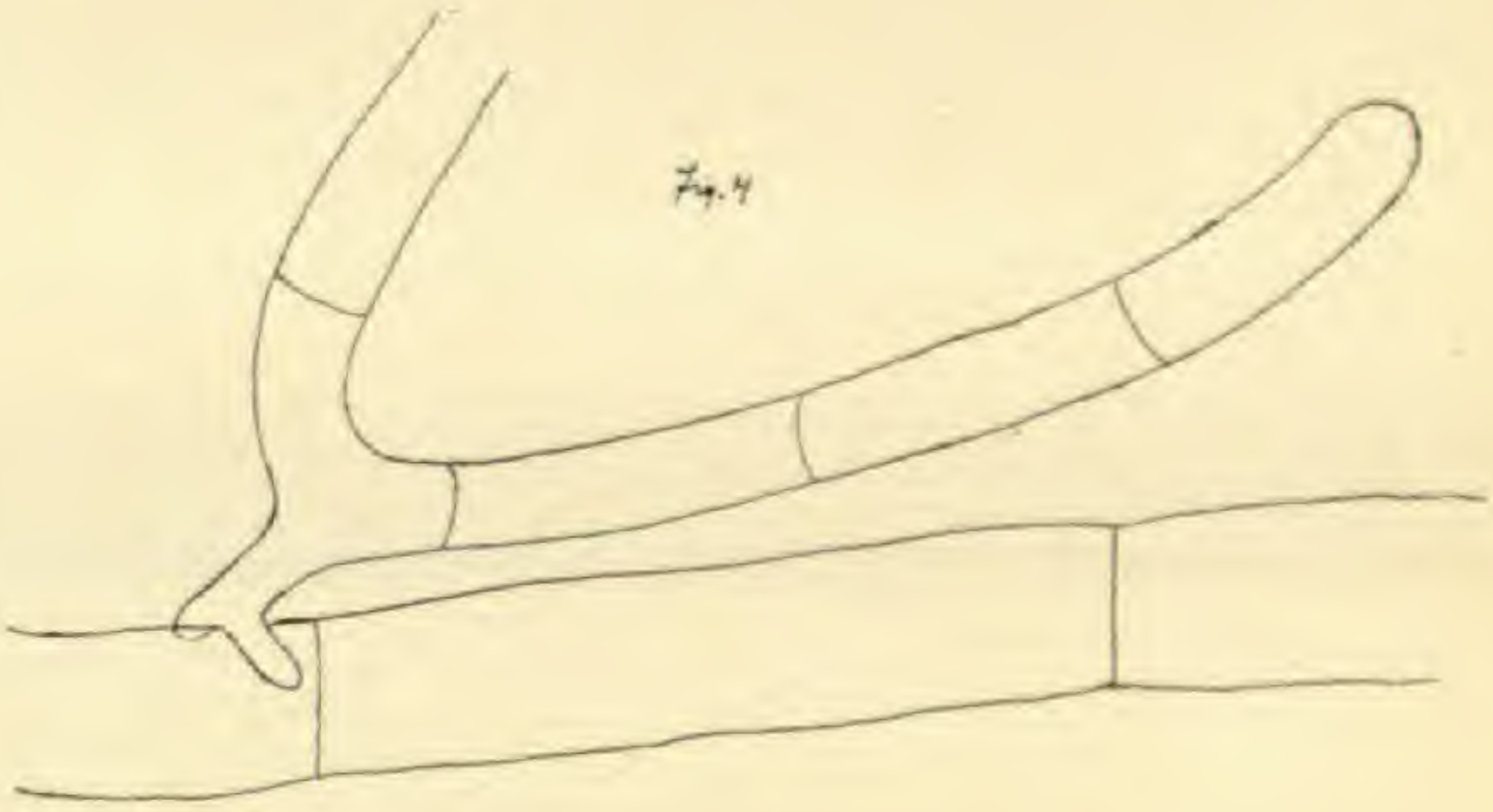
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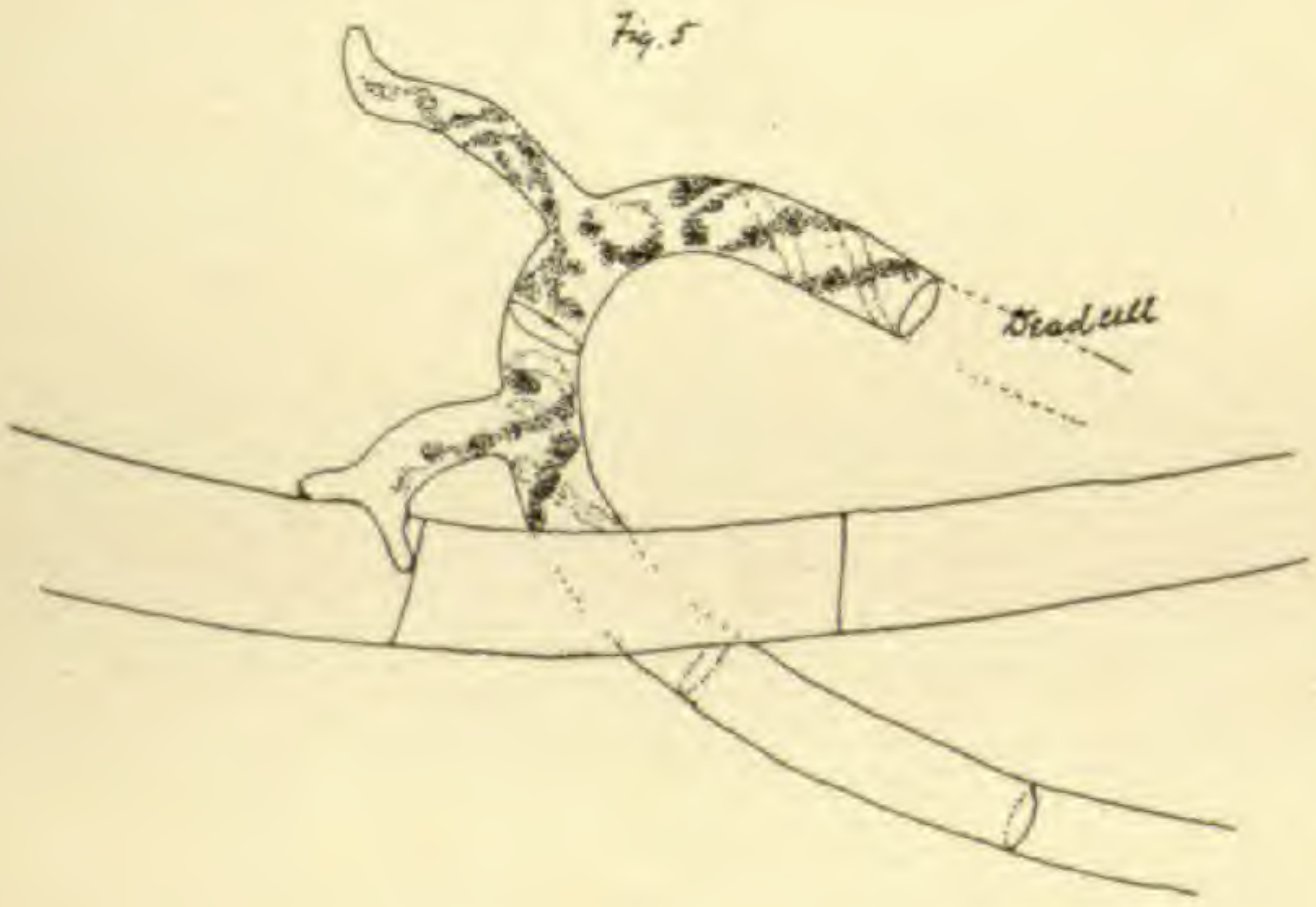
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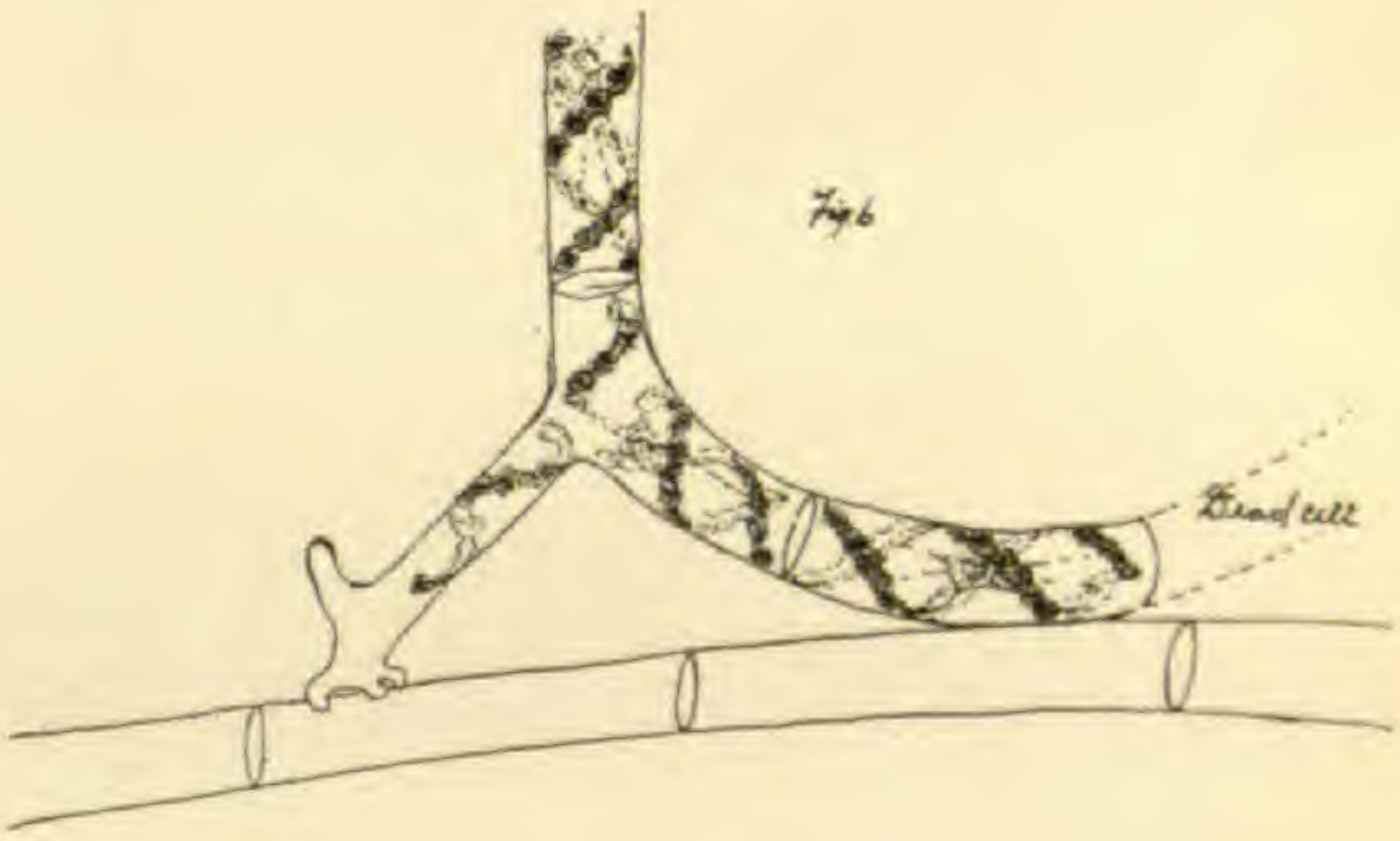
Fig. 6


Fig. 7

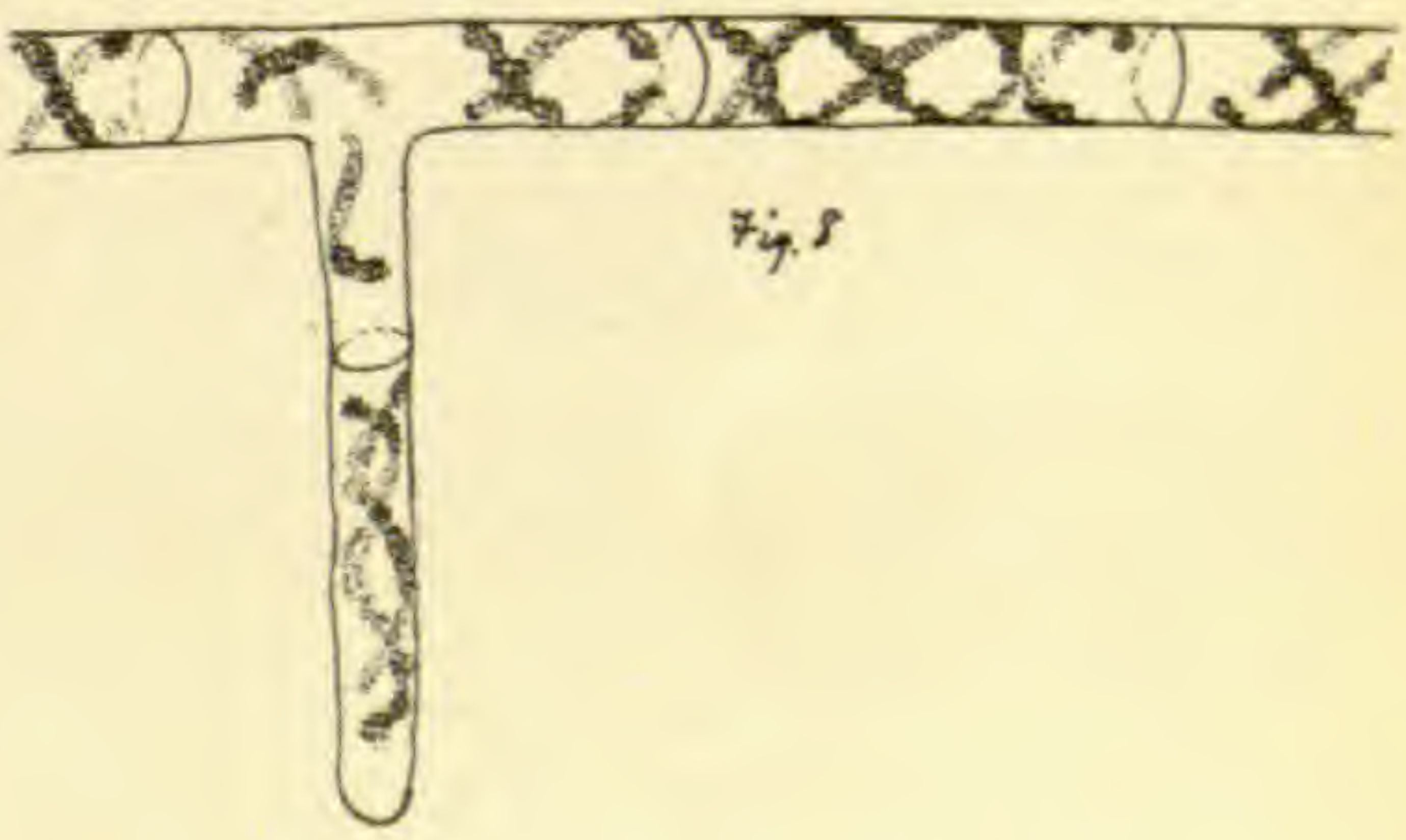
Fig. 8

SPIROGYRA ELONGATA (× 350)

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Was Lamarck's evening primrose (*Oenothera Lamarckiana* Seringe) a form of Oenothera grandiflora Solander?

Bradley Moore Davis

(with plates 37–39)

This paper will present evidence which in the writer's opinion clearly indicates that the *Oenothera* grown in the gardens of the Muséum d'Histoire Naturelle at Paris about 1796, described by Lamarck (?1798) under the name *Aenothera grandiflora* and renamed by Seringe (1828) *Oenothera Lamarckiana*, was a form of *Oenothera grandiflora* Solander (1789), introduced into England in 1778 from Alabama. If this identification is correct it follows that the name *Oenothera Lamarckiana* Seringe becomes a synonym of *Oenothera grandiflora* Solander (*O. grandiflora* "Aiton").

The evidence in the light of recent studies shows that Professor De Vries made an incorrect determination of the material of his cultures when he identified it with Lamarck's plant of 1796 or earlier. The material of De Vries's cultures is very different from this plant and can only be allowed to keep the name *Lamarckiana* when written "*Oenothera Lamarckiana* De Vries"; it is not *Oenothera Lamarckiana* Seringe.

My attention was first directed to this matter on seeing in the herbarium of the New York Botanical Garden tracings of Lamarck's plant, the type of *Oenothera Lamarckiana* Seringe, which is preserved in Lamarck's herbarium at the Muséum d'Histoire Naturelle. The resemblance of these tracings to the material of *Oenothera grandiflora* Solander from Alabama, now assembled in

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[The Bulletin for October 1912 (39: 455–518. *pl. 36*) was issued 2 N 1912.]

my own collections and at the New York Botanical Garden, was unmistakable. Miss Alice Eastwood, who kindly looked up various matters for me during her recent trip abroad, examined last winter in Paris this sheet which stands for the type of *Oenothera Lamarckiana* Seringe and reported to me her belief that it is identical with *O. grandiflora* Solander. As a result of this report I obtained through the courtesy of M. François Gagnepain negatives of this and other herbarium sheets at the Muséum d'Histoire Naturelle bearing upon the problem. M. Gagnepain further has most kindly answered a number of specific enquiries concerning the history of the specimens and certain characters of the plants not shown in the photographs. The following descriptions of these herbarium sheets are then in part from the photographs here published and in part from the notes of Miss Eastwood and M. Gagnepain, to whom I am greatly indebted.

The three sheets, to be described, were examined by Professor De Vries, who has given his interpretation (1901) in footnotes to Die Mutationstheorie, Vol. I, pp. 316, 317. De Vries believed that the first two sheets agreed with his cultures of *Lamarckiana*. The specimens on the third sheet he referred to *Oenothera grandiflora* Aiton (*O. suaveolens* Desfontaines) = *O. grandiflora* Solander. The conclusions of the present paper are (1) that the first sheet (PLATE 37), the type of *Oenothera Lamarckiana* Seringe, shows a remarkably well preserved and characteristic specimen of *Oenothera grandiflora* Solander, (2) that the specimen on the second sheet (PLATE 38) is neither *O. grandiflora* Solander nor "*O. Lamarckiana* De Vries" but a plant that is close to certain forms of *O. biennis*, and (3) that the two plants on the third sheet (PLATE 39), obviously stunted in growth, are so imperfect that an opinion of their identity can hardly be more than a guess. Our interest in this herbarium material centers upon the first two sheets.

SHEET I. LAMARCK'S PLANT, WHICH STANDS AS THE TYPE OF *Oenothera Lamarckiana* Seringe

This specimen (PLATE 37) is in the herbarium of Lamarck, acquired by the Muséum d'Histoire Naturelle in 1886. The sheet bears in the handwriting of Lamarck: "Oenothera . . . [grandiflora] . . . nova spec. flores magni lutei, odore grato, caulis

3 pedalis." The spelling of the word Oenothera is not clear; it might be interpreted "Onothera" or possibly "Aenothera." This note designating a new species, *grandiflora*, in the handwriting of Lamarck establishes the specimen as what we would now designate as the type of his species *Aenothera grandiflora* described in the Encyclopédie Méthodique Botanique **4**: 554. ? 1798. This description agrees with the specimen. It seems unlikely that we shall ever know the exact date at which the description was published. Authors usually give it as 1797, but Sherborn and Woodward (1906), from evidence presented by extraneous matter bound in with certain copies of the volume concerned, place the year as ?1798. I can find no evidence that Poiret wrote the description, as was believed by De Vries, but he is known to have written later volumes of the encyclopedia.

Seringe in his diagnosis of *Oenothera Lamarckiana* (De Candolle, Prodromus **3**: 47. 1828) gives *O. grandiflora* Lamarck as a synonym together with the comment that the species is not the *grandiflora* of Aiton. This was of course his reason for renaming the plant. The diagnosis of Seringe, as will appear later, is virtually a copy of a portion of Lamarck's description.

The following is the description of the species written by Lamarck in the Encyclopédie Méthodique Botanique; it should be noted that the abbreviation (V.S.) at the end of the diagnosis shows that the description was based on dried material.

"12. Onograire à grandes fleurs. *Ænothera grandiflora* (n). *Ænothera foliis integerrimis, ovato-lanceolatis; petalis integris, capsulis glabris.*

"Cette espèce paroît se rapprocher, par son port, de l'*ænothera longiflora;* mais elle en diffère par plusieurs caractères frappans, sur-tout par ses tiges rameuses, ses pétales entiers, ses fruits lisses & courts.

"Ses tiges s'élèvent à trois ou quatre pieds de hauteur. Elles sont cylindriques, munies de quelques poils rares, d'un rouge brun, divisées en rameaux nombreux, étalées. Les feuilles sont vertes, alternes, ovales, lancéolées, lisses & glabres des deux côtés, très-entières; les feuilles du bas sont pétiolées & munies de quelques dents à peine sensibles. Celles qui accompagnent les fleurs sont plus étroites, plus aiguës & sessiles.

"Les fleurs sont terminales, & forment, par leur disposition, une panicule étalée; elles sont axillaires, solitaires, mais trèsrapprochées. Le calice est jaune, muni d'un tube un peu plus long que la corolle, qui se divise en quatre folioles lancéolées, élargies à leur bâse, aiguës à leur sommet, terminées par un filet court, sétacé. La corolle est jaune, composée de quatre pétales ovales, très-grands, entiers, arrondis, presque aussi longs que le tube calicinal, retrécis à leur bâse en forme de coin. Les anthères sont longues, linéaires. Le fruit est une capsule courte, cylindrique, glabre, tronquée, légèrement quadrangulaire, n'ayant qu'environ le tiers de longueur du tube calicinal. Cette espèce est originaire de l'Amérique septentrionale. On la cultive au jardin du Muséum d'Histoire naturelle. (V.S.)"

An interesting point has been brought to my notice by Mr. H. H. Bartlett. Poiret has this note in the Encyclopédie Méthodique Botanique, Suppl. 4: 141. 1816: "L'Oenothera grandiflora, no. 11, est la même plante que celle d'Aiton, Hort. Kew., 2, pag. 2." The designation "no. 11" instead of "no. 12" must have been a slip of the pen on Poiret's part. Although Poiret was correct in considering *O. grandiflora* Lamarck as a synonym of *O. grandiflora* Solander, he could not have had a clear conception of this plant since he kept *O. suaveolens* Desfontaines, which is also a synonym, as a distinct species.

We will give also the short diagnosis by Seringe (1828) of *Oenothera Lamarckiana* for comparison with the longer description of Lamarck.

> "OE. Lamarckiana (Ser. mss.) caule ramoso, *foliis integerrimis ovato-lanceolatis*, *petalis integris* magnis, *capsulis glabris* cylindrico-tetragonis brevibus. ② in Americâ sept. OE. grandiflora Lam. dict. 4. p. 554. *non Ait. Fl. flavi."

I have italicized phrases that are the same as those in the brief introduction in the description of Lamarck, showing that Seringe had little or nothing to add to the original description.

Certain points should be noted in these descriptions of Lamarck and Seringe before we compare Lamarck's plant (PLATE 37) on the one hand with *O. grandiflora* Solander and on the other with the material of De Vries's cultures ("*O. Lamarckiana* De Vries"). The description of the petals as entire must not be emphasized, for while there may not be in these species a conspicuous notch at the tip of the petals there is usually at least a shallow indentation; the character is not one easily determined in dried specimens and presents so much variation as to have no taxonomic value. The leaves of these species are not strictly entire but serrulate, the teeth being small and in dried material inconspicuous; the teeth are, however, shown on some of the leaves on Lamarck's plant (PLATE 37). The glabrous fruits agree best with the seed capsules of *grandiflora*, which are almost smooth, while those of De Vries's *Lamarckiana* are decidedly puberulent and pilose. Mature capsules are not shown on the specimen of Lamarck's plant, and no importance can be attached to their description as short. The reddish brown stem with occasional hairs agrees with *grandiflora*; there is no mention of numerous hairs arising from red papillae, a striking characteristic of the plants in the cultures of De Vries. The description of the leaves as glabrous is not strictly true either of *grandiflora* or of De Vries's *Lamarckiana*, both having a minute pubescence, which is more evident in the latter form. Mr. Bartlett has called my attention to the word "sétacé" in Lamarck's description of the sepal tips; this has been translated by De Vries (1901, p. 317) as "dicke." The French is, however, from the late Latin word "setaceus," derived from "seta," a stiff hair or bristle. The meaning is, then, exactly the opposite of that given by De Vries and refers to the much attenuated sepal tips, as shown in PLATE 37, a striking characteristic of *grandiflora;* the sepal tips of De Vries's *Lamarckiana* are in contrast much shorter and thicker.

It is surprising how little information is contained in the descriptions of Lamarck and Seringe that is of value in a comparison of Lamarck's original plant with *O. grandiflora* Solander and "*O. Lamarckiana* De Vries." The most important points in the writer's opinion are the description of the attenuated sepal tips and the absence of all reference to the remarkable stem coloration which is characteristic of the material of De Vries's cultures. De Vries's *Lamarckiana* invariably, so far as I am aware, presents a green stem punctate with red papillae from which long hairs arise among a short glandular pubescence. This is not noted by Lamarck, who describes the stem in agreement with *grandiflora* as reddish brown with occasional hairs.

We may now take up the consideration of the herbarium sheet of Lamarck's plant (PLATE 37) preserved in the herbarium of the

Muséum d'Histoire Naturelle. First, however, it should be noted that Buchet (1912) in a recent paper gives his opinion that this sheet agrees with *Oenothera suaveolens* Desfontaines, which he recognizes as synonymous with *Oenothera grandiflora* Solander, an older name. Buchet also regards the sheet shown on PLATE 38 from the collection of Abbé Pourret as the same form as Lamarck's plant and identifies it also with *O. suaveolens*. On this point I cannot agree, since, as will be shown later, the specimen of Abbé Pourret has important characters that distinguish it both from Lamarck's plant (*O. suaveolens* Desfontaines = *O. grandiflora* Solander) and from the material in the cultures of De Vries.

In the following account of the sheet which stands for the type of *Oenothera Lamarckiana* Seringe, are included not only the characters shown by the photograph (PLATE 37) but also others of equal or perhaps greater importance from the notes of Miss Eastwood and M. Gagnepain. In order to obtain direct comparisons with respect to the pubescence I furnished M. Gagnepain with specimens of stems and buds from both *grandiflora* and the *Lamarckiana* of De Vries's cultures, asking him to compare the specimens with Lamarck's plant but not informing him of their source.

1. STEM AND FOLIAGE. The specimen of Lamarck's plant (PLATE 37) exhibits the rather dense branching characteristic of certain forms of *grandiflora* in sharp contrast to the long sparsely branched stems of De Vries's *Lamarckiana*. The stem, according to M. Gagnepain, does not have long hairs from red papillae, as is so characteristic of De Vries's *Lamarckiana;* the pubescence is short and the stem subglabrous. The leaves are broadly elliptical or lanceolate with serrulate margins and with short but distinct petioles as in *grandiflora;* they are not sessile or almost sessile nor so broad as are the leaves of the *Lamarckiana* of De Vries. This herbarium sheet may be readily matched in the form of the branching and in the foliage by numerous specimens of *grandiflora* collected in Alabama; it represents neither the broader- nor the narrower-leaved forms in the range of variation in this species but is nearest to the intermediate condition.

2. INFLORESCENCE. The inflorescence does not present the close spike with broad-based, sessile bracts, which are so character-

istic of the younger flowering shoots of De Vries's *Lamarckiana*. On the contrary the bracts are narrow and short-petioled and the inflorescence is more open, in agreement with *grandiflora*.

3. BUDS. The buds are not stout as in the *Lamarckiana* of De Vries and the sepal tips are much more attenuate, a distinctive character of *grandiflora*. The form of the buds is exactly as in *grandiflora*, and this character is one of the most important points of agreement with this species. The pubescence on the sepals, as described by M. Gagnepain, is short; there are not present the numerous long hairs from papillae, which are characteristic of De Vries's *Lamarckiana*.

4. FLOWERS. The flowers have the very long and delicate hypanthium characteristic of *grandiflora*. Miss Eastwood reports that the petals in a bud dissected by her are entire. This is a character typical of neither *grandiflora* nor the *Lamarckiana* of De Vries, but as stated before, the petals of these forms vary so greatly in the degree of their indentation that the character has little if any taxonomic value. The length of the petals, between 3 and 4 cm., is that of *grandiflora* and also of certain forms of De Vries's *Lamarckiana*. The style extends beyond the tips of the anthers so that the lobes of the stigma (*s*, in PLATE 37) are above the latter and could not be pollinated in the bud. In these respects the flower agrees with both *grandiflora* and the large-flowered types of *Lamarckiana* in De Vries's cultures.

5. CAPSULES. There are apparently no mature capsules on the specimen, so direct comparisons are impossible. Since the size and form of a capsule depends upon the development of the ovules, i. e. upon whether or not the stigma has been fully pollinated, it is unsafe to accept statements of size unless there is evidence that sufficient material has been examined. Lamarck's statement that the capsules are short was probably based on immature or partially pollinated capsules. His description of the capsules as glabrous points to *grandiflora;* as stated before, the capsules of De Vries's *Lamarckiana* are decidedly puberulent and pilose.

The characters of *Oenothera grandiflora*, which appear on the herbarium sheet of Lamarck's plant, and those of the *Lamarckiana* of De Vries's cultures may be more readily contrasted in the following statement.

O. grandiflora Solander AND LAMARCK'S PLANT	*O. Lamarckiana* FROM THE CULTURES OF DE VRIES
Flowering stems generally with numerous approximate branches.	Flowering stems sparsely branched or not at all.
Stems green above, reddish brown below, the papillae at the base of long hairs colored like the stem.	The papillae at the base of the long hairs colored red so that the green stem appears punctate with red dots.
Leaves of upper foliage lanceolate, rarely broad, with distinct petioles.	Leaves of upper foliage ovate-lanceolate, sessile or almost sessile.
Inflorescence more open, with narrow, petioled bracts.	Inflorescence more close, with sessile bracts broad at the base.
Buds not stout, with much attenuated sepal tips. Sepals puberulent, sometimes sparsely pilose.	Buds stout, with shorter sepal tips. Pubescence of sepals a heavy puberulent and pilose covering.
Flowers with a long delicate hypanthium. Petals 3–3.5 cm. long. Stigma lobes above the tips of the anthers.	Flowers with a stouter hypanthium. Petals in some races 4–4.5 cm. long, in others 2.5–3 cm. long. Stigma lobes in the large-flowered types above the tips of the anthers, in the smaller-flowered forms at about the level of of the anther tips.

There is another sheet in the herbarium of the Muséum d'Histoire Naturelle which is without a name but bears in the handwriting of Lamarck: "d'Amérique sept. Tige rameuse, haute de 3 à 4 pieds." Both M. Gagnepain and Miss Eastwood report that this sheet is similar to that of Lamarck's plant which we have described above and shown on PLATE 37. The history of the sheet is apparently not known and I have no evidence that it can safely be associated with the specimen upon which Lamarck undoubtedly based his description. Nevertheless, this sheet may be closely related to or even a duplicate of the specimen that served as the type for the descriptions of Lamarck and Seringe.

In summary it may be said that the specimen, which we must consider the type of *Oenothera Lamarckiana* Seringe, presents no characters in clear form that are not those of *O. grandiflora* Solander. In not one of the contrasted characters discussed above does the specimen agree with the *Lamarckiana* of De Vries's cultures. The only points in which De Vries's *Lamarckiana* may be said to resemble this specimen are the size of the petals and the position of the stigma, which in the large-flowered forms of *Lamarckiana* is above the tips of the anthers; these are characters which *grandiflora* and De Vries's *Lamarckiana* have in common.

It is exceedingly fortunate that the plant which serves as the type of *Oenothera Lamarckiana* Seringe should have come down to us so well preserved that there is scarcely a doubt of its identity with *Oenothera grandiflora* Solander, introduced into England in 1778.

SHEET 2. A SPECIMEN OF *Oenothera* FROM THE COLLECTION OF ABBÉ POURRET

This specimen (PLATE 38) is of interest for the reason that De Vries (1901, footnote to p. 317) believed that it as well as Lamarck's plant agreed with the material of his cultures ("*Oenothera Lamarckiana* De Vries"). Buchet (1912) has recently referred the specimen to *Oenothera suaveolens* Desfontaines = *O. grandiflora* Solander. I am unable to agree with either of these opinions and shall present evidence that the plant was close to certain forms of *Oenothera biennis*.

The sheet bears the label HERB. MUS. PARIS. with the statement at the bottom "Collection de l'Abbé Pourret, extraite de l'Herbier légué par M. le Dr. Barbier. 1847." On this label, in the handwriting of Spach are the names "*Onagra vulgaris* Spach" and "*Oenothera biennis* Linné." At the left is a list of old names representing synonymy, copied by Abbé Pourret, and below this list his clerk wrote the name *Oenothera biennis* L.

De Vries states that the plant was probably collected by Abbé Pourret in the garden of the museum at the time of his visit to Paris in 1788. M. Gagnepain, however, is not satisfied with the evidence for this view and writes that the history of the sheet is unknown to him.

An examination of the specimen itself (PLATE 38) shows the following characters.

1. STEM AND FOLIAGE. The long unbranched stem bears elliptical, petioled leaves very different from the sessile or almost sessile, broad-based leaves of De Vries's *Lamarckiana*. The absence of approximate flowering branches is against any relationship to *grandiflora*. The appearance of the small buds in the axils of the lower leaves is characteristic of some forms of *Oenothera biennis*. The pubescence of the stem is described by M. Gagnepain as very like the specimen of *grandiflora* and not at all like the specimen of De Vries's *Lamarckiana* sent for comparison.

2. INFLORESCENCE. The bracts of the inflorescence are not broad at the base and sessile as in the *Lamarckiana* of De Vries. They are narrow-elliptical and short-petioled.

3. BUDS. The size and form of the buds present perhaps the most important characters on the sheet. They are short and stout, and these characters alone make it impossible that the plant could have been *O. grandiflora* Solander. (Compare PLATE 38 with PLATE 37.) Forms of *O. biennis* frequently show these peculiarities. The sepals have a greater pubescence than those of *grandiflora*.

4. FLOWERS. The flowers are medium-sized, petals probably between 2 and 2.5 cm. long. They are not large enough for *grandiflora* or for the large-flowered forms of De Vries's *Lamarckiana*. The stigma (*s*, PLATE 38) appears to be at about the level of the anthers, the style not extending well beyond as in the types mentioned above. The flowers, in size and in the relation of the stigma to the anthers, agree with forms of *biennis*.

5. CAPSULES. The capsules appear to be of the *biennis* type, which is similar to that of De Vries's *Lamarckiana*.

In conclusion, the forms of the leaves and bracts distinguish this plant of Abbé Pourret from the *Lamarckiana* of De Vries's cultures. The size and form of the buds, the size of the flowers, and the position of the stigma distinguish it from *O. grandiflora* Solander as well as from the larger-flowered forms of De Vries's *Lamarckiana*. All of the characters described above are represented in the assemblage of forms included under the name *Oenothera biennis*. Since we know nothing of the rosette, general habit, and lower foliage of this plant, it is quite impossible to follow its determination further.

SHEET 3. SPECIMENS REFERRED BY DE VRIES TO *Oenothera grandiflora*

The specimens on this sheet (PLATE 39) are so imperfect and their form so abnormal that a satisfactory determination of their identity is probably impossible. De Vries (1901, footnote to p. 316) considered them to be *Oenothera grandiflora* Aiton = *O. grandiflora* Solander (*O. suaveolens* Desfontaines).

The sheet bears a label of Michaux with "Ameriq. sept." On this label in the handwriting of Desfontaines is "*Oenothera suaveolens* Hort. Paris." Above this name has been written "*Oenothera grandiflora* Poiret Encycl.," and below, Spach wrote "*Onagra vulgaris grandiflora* Spach." A second label bears the name "*Oenothera grandiflora*," probably in the handwriting of André Michaux. M. Gagnepain states that the specimens were imported as dried plants from North America. The chief interest in this sheet lies in the fact that Desfontaines evidently considered the specimens to be his own species *Oenothera suaveolens*.

Both specimens are entire plants, the smaller about 3.5 dm., the larger about 5 dm. in height. They are unbranched and obviously dwarfed. The leaves are petioled as in *grandiflora*, but those of the smaller plant are much below the average size for this species. The stigma (*s*, PLATE 39) shown in the flower of the smaller plant seems to be above the tips of the anthers as in *grandiflora*. The pubescence of the stems and sepals, from notes of M. Gagnepain, appears to be somewhat similar to *grandiflora*; it is not that of De Vries's *Lamarckiana*.

There appear to be no characters on these plants that might not have been those of *O. grandiflora* Solander under very unusual or abnormal conditions. There is, however, little or nothing in these specimens that is typical of *grandiflora*, and apparently nothing that determines a relationship to any other *Oenothera*. It is hardly possible that plants so different from one another grew together in the same environment and it seems more probable that they were quite unrelated. They remain to us as the flotsam of the herbarium, plants of whose precise origin and parentage we know nothing.

DISCUSSION

The reader will have noted that throughout this paper the name *Lamarckiana* has been kept strictly for the plant that has come down to us from the cultures of De Vries, a plant well known to scores of botanists and grown in numerous botanical gardens. If this paper has shown that Lamarck's plant in the gardens of Paris at about 1796 or earlier, the type of *Oenothera Lamarckiana* Seringe (1828), was a form of *Oenothera grandiflora* Solander (1789) the former name becomes a synonym of the latter. The *Oenothera* of De Vries's cultures is left without a name or at least without the authority of Seringe. I propose, however, that the name "*Oenothera Lamarckiana* De Vries" be kept for this plant, which has been the subject of such extensive experimental study by De Vries and whose origin and behavior is a matter of such great interest to the geneticist.

The name when written "*Oenothera Lamarckiana* De Vries" is clear to all who have knowledge of the relation that this plant bears to the mutation theory. If there were evidence that "*O. Lamarckiana* De Vries" is or ever was a component of the American flora as a native species, there might be some reason to change its name. However, the evidence indicates that *Lamarckiana* has come to us greatly modified, that its parentage is far from pure, that it is in fact of hybrid origin. We are dealing with the product of the garden, and as such the plant may reasonably be exempt from a change of name that would carry endless confusion through the literature of experimental morphology. Should any taxonomist contemplate the introduction of a new name let him first ponder the inscription over the grave of William Shakespeare.

The introduction of *Oenothera grandiflora* Solander into England in 1778 marked a very important date in the development of the *Oenothera* flora over parts of Europe. This species undoubtedly holds the key to many puzzling herbarium sheets and records. Botanists do not yet realize how definite is our knowledge of this native American species and how clear is our information on its history. (See MacDougal, 1905, p. 7.)

Oenothera grandiflora Solander was discovered by William Bartram in 1776 near Tensaw, Alabama, on an expedition undertaken at the request of John Fothergill, M.D. Solander's original description in Aiton's Hortus Kewensis, 1789, from material grown at Kew, states that *O. grandiflora* was introduced by John Fothergill in 1778. A herbarium specimen in the British Museum from "Hort. Fothergill 1778" makes it evident that Bartram must have sent seed to Fothergill. The species still occupies its original station in Alabama, where it was rediscovered in 1904, and there is abundant herbarium material from this source; also, there are strains under cultivation by myself and others. As striking an American novelty as this large-flowered species would naturally become widely distributed, which explains its presence in Paris somewhat earlier than ?1798, when Lamarck's description was published. Escaping from the gardens, the plant has been reported as growing wild at various stations in England and France. Following in the wake of its distribution to European botanical centers came the inevitable description as new species of forms derived from the original. *Oenothera suaveolens* Desfontaines and Lamarck's plant, *Oenothera Lamarckiana* Seringe, were undoubtedly such derivatives and must be considered as forms of *Oenothera grandiflora* Solander.

The identification of Lamarck's plant with *Oenothera grandiflora* Solander has very greatly modified the problem of the origin of "*Oenothera Lamarckiana* De Vries." The problem has become far more tangible. I have recently (Davis, 1911, p. 226, and 1912, p. 379) criticized adversely the evidence that has been offered to show that *Lamarckiana* was known previous to 1778 when *grandiflora* was introduced into England. With Lamarck's plant assigned to *grandiflora* we pass from the eighteenth century to periods when we may hope for more direct evidence than that furnished by the old accounts and figures.

We know that as a cultivated plant handled by seedsmen *O. Lamarckiana* first appeared about 1860, when it was placed on the market by the firm of Carter and Company of London, who state that their seed came from Texas. The identification by Lindley of these plants with *O. Lamarckiana* Seringe was undoubtedly incorrect. I have recently described and figured (Davis, 1912, p. 417) certain well preserved specimens of an *Oenothera* in the Gray Herbarium from a plant grown at Cambridge, Massachusetts, by Dr. Asa Gray in 1862. Evidence is there given which indicates that this plant held a close genetical relationship to these same cultures of Carter and Company, perhaps not more than one or two generations removed from the original plants. These specimens show characters in part those of De Vries's *Lamarckiana* and in part like *grandiflora*. If this plant grown by Dr. Gray was representative of the cultures of Carter and Company their plants must have differed from the *Lamarckiana* of today in a number of important particulars. I regard this herbarium sheet as the most important now known bearing on the problem of the origin of *Oenothera Lamarckiana*. Its relation to the writer's working hypothesis that

Lamarckiana arose as a hybrid between *biennis* and *grandiflora* has been fully discussed in the paper mentioned above.

Although Carter and Company state that they received their seed from Texas, it must be borne in mind that we have at present no confirmatory evidence that such a plant as they describe or as that represented on the sheet in the Gray Herbarium is native in the southern or southwestern United States. Here is a problem that well deserves the attention of botanists in these regions, who should make every effort to bring such a type to light that seed may be sent to the workers in the experimental gardens. If such a form grew in Texas no further back than 1860 it may surely be expected there today.

It is possible that the cultures of Carter and Company arose in England and that their association with a Texan source may have been some mistake on the part of the seedsmen. We have several accounts of large-flowered Oenotheras in England at dates previous to 1860. The most important and the earliest is that in Smith's English Botany (**22**: 1534. 1806) with the excellent figure of Sowerby. This account describes at this early date (1806) very extensive growths of an interesting form on the sand banks along the coast a few miles north of Liverpool. At the present day "*Oenothera Lamarckiana* De Vries" and variants from this type are established and flourishing over extensive tracts in the same region north of Liverpool through the sand hills of Lancashire. It is not impossible that the *Lamarckiana* of Carter and Company may have come from such regions.

The problem of the origin of "*Oenothera Lamarckiana* De Vries" must be approached from two sides. The English botanists have the problem of the history of such an *Oenothera* flora as that of the Lancashire sand hills, and collections should be searched with the greatest thoroughness for herbarium sheets that may be of assistance in tracing its development. American botanists have the problem of the discovery and isolation by cultures of the large-flowered Oenotheras throughout the south and west, which might have a direct relationship to *Lamarckiana* or which might be one of the parents of a possible hybrid. A good beginning was made in the rediscovery of *Oenothera grandiflora* Solander but the search should be pushed further.

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The effect of guanidin on plants*

OSWALD SCHREINER AND J. J. SKINNER

INTRODUCTION

Guanidin has been found in some plants. It may arise from the oxidation of arginin. Arginin is a decomposition product of proteins and exists in plants, and it has also been found in soils.† Interesting in this connection is the appearance of guanidin in seedlings, as reported by Schulze,‡ which probably results by further changes from arginin. Guanidin can also be formed by the oxidation of guanin in the laboratory.

Guanidin was shown to be toxic to plants, first by Kawakita § and later in this laboratory.|| According to Shibata,¶ who studied the effect of *Aspergillus niger* on a number of nitrogenous compounds, this mold had no effect on guanidin. Hutchinson and Miller** include guanidin among the nitrogenous compounds assimilated by plants.

In the earlier experiments in this laboratory the guanidin carbonate was studied in various concentrations of distilled water. The wheat plants were killed in 9 days in solutions stronger than 100 parts per million. In all the lower concentrations, including 1 part per million, the wheat plants were seriously injured.

This harmful effect of guanidin has since then been more

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* Contribution from the Laboratory of Soil Fertility Investigations, Bureau of Soils.

† Schreiner, O., and Shorey, E. C. The presence of arginin and histidin in soils. Jour. Biol. Chem. 8: 381. 1910.

‡ Schulze, E. Ueber einige stickstoffhaltige Bestandtheile der Keimlinge von *Vicia sativa*. Zeit. Physiol. Chem. 17: 193. 1893.

§ Kawakita, I. On the behavior of guanidin to plants. Bull. Col. Agr. Tokio 6: 181. 1904–05.

|| Schreiner, O., Reed, H. S., and Skinner, J. J. Certain organic constituents of soils in relation to soil fertility. U. S. Dept. Agr. Bur. Soils Bull. 47. 1907.

¶ Shibata, K. Über das Vorkommen von Amide spaltenden Enzymen bei Pilzen. Hofmeister's Beiträge 5: 384. 1904.

** Hutchinson, H. B., and Miller, N. H. J. The direct assimilation of inorganic and organic forms of nitrogen by higher plants. Centralbl. Bakt. 30: 513. 1911.

thoroughly studied, and in this later work nutrient culture solutions, 66 in number, have been used, comprising all the combinations of potash, phosphate, and nitrate, as explained below.

EXPERIMENTAL METHODS

Wheat seedlings were grown in aqueous culture solutions containing the ordinary fertilizer salts, calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained calcium acid phosphate only, some sodium nitrate only, and some potassium sulphate only. Other solutions were composed of mixtures of two salts, sodium nitrate and calcium acid phosphate, sodium nitrate and potassium sulphate, and calcium acid phosphate and potassium sulphate. Still other solutions had all three constituents in various proportions. The concentration of all the solutions was 80 parts per million of the fertilizer ingredients, P_2O_5, NH_3, and K_2O. In cultures containing only one fertilizer salt, for instance calcium acid phosphate, the concentration was 80 parts per million of P_2O_5. If two salts were present, for instance calcium acid phosphate and sodium nitrate, the concentration was 80 parts per million of $P_2O_5 + NH_3$. If all three salts were present, the concentration was 80 parts per million of $P_2O_5 + NH_3 + K_2O$. The ratios of the constituents varied in 10 per cent stages. In all, there were 66 different cultures of nutrient solutions.

For a more detailed explanation of this triangular scheme and the principles involved in preparing culture solutions in definite progression of its constituents, the reader is referred to earlier publications.*

Two sets of cultures were prepared; to one set was added merely the nutrient salts, while to each culture of a similar set guanidin carbonate was added in amounts of 25 parts per million in addition to the nutrient salts. The culture solutions were contained in wide-mouth bottles, holding 250 c.c., and 10 wheat seedlings grown in each culture. The culture solutions were changed every three days, four changes being made in the course of the

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* Schreiner, O., and Skinner, J. J. Some effects of a harmful organic soil constituent. U. S. Dept. Agr. Bur. Soils Bull. 70. 1910. Ratio of phosphate, nitrate and potassium on absorption and growth. Bot. Gaz. 50: 1. 1910.

experiment. The solutions were analyzed for nitrates immediately after each change. The phosphate and potassium were determined on a composite solution of the four changes. Observations on the general development of the plants and the effect on root growth and appearance were made during the experiment, and photographs were taken.

For the purpose of preparing the 66 culture solutions needed in this investigation, stock solutions of the three salts, calcium acid phosphate, sodium nitrate, and potassium sulphate, were prepared separately. The salts were chemically pure salts and were dissolved in each case in physiologically pure water. For the calcium acid phosphate solution 1.776 grams of $CaH_4(PO_4)_2 \cdot H_2O$ per liter were used. This solution has a concentration of 1,000 parts per million of P_2O_5. The sodium nitrate solution was prepared by using 5,000 grams of $NaNO_3$ per liter. This solution is equivalent to a concentration of 1,000 parts per million of NH_3. The potassium sulphate solution was prepared by dissolving 1.852 grams of K_2SO_4 per liter. This solution has a concentration of 1,000 parts per million of K_2O. The amount of culture solution used in each culture bottle being 250 c.c., it follows that every 2 c.c. of these 1,000 parts per million stock solutions will represent 8 parts per million in the culture solution when this is diluted to the capacity of the bottle; i. e. the successive addition of 2 c.c. of the stock solution gives the 10 per cent differences desired in putting up the 66 solutions. In putting up the 66 cultures it was found desirable to calibrate each bottle for 250 c.c. capacity and to number them consecutively from 1 to 66. Bottles in which the 250 c.c. mark was either high or low were discarded, only those being used that brought the surface of the liquid from one-half to one centimeter from the top. These 66 bottles were then arranged in a triangular form, as illustrated by FIG. 1 and 2.

The necessary amount of the 1,000 parts per million stock solution above described was measured from a burette. For instance, in adding the requisite amount of nitrate to the set of culture bottles the line of bottles P to K in FIG. 2 received no nitrate solution, the next line of bottles received 2 c.c. each, the third line 4 c.c. each, and so on, increasing 2 c.c. with each successive line, the culture at N receiving 20 c.c. of the nitrate solution.

Likewise, in adding the requisite amount of potash, the cultures in the line P to N received none, the cultures in the next line received 2 c.c. each, in the third line 4 c.c. each, and so on up to the culture at K, which received 20 c.c. of the potash solution. The phosphate solution is added in the same manner, none to cultures in line K to N, 2 c.c. to cultures in the second line, and so on up to the culture at P, which received 20 c.c.

Each bottle received, therefore, a total of 20 c.c. of one, two, or three of the stock solutions, depending upon whether it was at the apex, along the sides, or in the interior of the triangle. All of the cultures were then diluted up to the 250 c.c. mark.

In this investigation, as already mentioned, the culture solution contained 25 parts per million of the guanidin carbonate. The amount of this carbonate to be added to each culture bottle of 250 c.c. was, therefore, 6.25 milligrams. Of the 250 c.c., 20 c.c. were already contained in the bottles in the form of the fertilizer salt solution. Therefore the solution with which the fertilizer salt solution in the bottles was to be diluted consisted of 6.25 milligrams of the compound dissolved in 230 c.c. of pure water or 27.17 milligrams per liter. A sufficient quantity of this strength of solution was prepared to fill the 66 bottles.

As a means of comparing the cultures grown in these solutions containing the guanidin, it was necessary to put up cultures prepared in exactly the same way, except that pure water was used.

In all of this work physiologically pure water was used. This was prepared by shaking ordinary distilled water with a highly absorptive carbon black, as described in earlier publications,* which removes from the water any injurious property it may possess.

The culture solutions were now ready to receive the plants, which were thereafter grown in a greenhouse under suitable conditions.

In this work it was necessary to have a large number, often several hundred, and sometimes thousands of uniform seedlings, i. e. seedlings of the same age and equal development and general vitality.

The manner of growing the seedlings and the method of inserting them in the above culture solutions were as follows:

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* Livingston, B. E., et al. Further studies on the properties of unproductive soils. U. S. Dept. Agr. Bur. Soils Bull. 36. 1907.

Perforated aluminum disks were floated, by means of a raft prepared from sealed glass tubing, in such a way that the disks were kept just at the surface of the water when loaded with seeds.

The wheat seeds, previously soaked in water, for about two hours, not longer, were spread evenly on the surface of the disks. The perforations in the 1.6 mm. thick aluminum were approximately 3.2 mm. in diameter and 2 mm. apart. The entire arrangement of raft and disks was floated in a porcelain-lined iron tank. The seedlings were used when the plumule was about 2 cm. high and just ready to emerge from the enveloping sheath. In this manner the 1,320 uniform seedlings required for each experiment were readily obtainable.

The bottles used in these cultures were made of flint glass and were stoppered by means of a soft flat cork about 12 mm. in thickness and notched for holding the seedlings. The method of notching these corks consisted in cutting 10 vertical, triangular wedges from the circumference of each. Each wedge after being cut out was truncated, so that when it was replaced, a small triangular opening was left through which the plumule of the seedling passed. This hole was large enough to hold the seedling firmly and yet not bruise or injure it in any way by pressure. Around the circumference of the cork, in the upper half, a groove had been made sufficiently large to hold a small rubber band. After the wedges were inserted, the band kept them in place and allowed the cork with the seedlings to be handled readily and put into or taken out of the bottle without disturbing the plants.

As already mentioned, these solutions were changed every three days. This was done by putting up other triangles of bottles similar in every respect to the ones just described. The corks with the plants were then transferred from the old solution to the corresponding new solution.

EFFECT OF GUANIDIN ON WHEAT

As already mentioned, two sets of the cultures were prepared; one was used as a control; to the other was added guanidin carbonate, 25 parts per million to each culture. The wheat seedlings grew from February 15 to February 27, 1911, the solutions being changed every three days.

For the first few days no difference was noticeable between the control and the guanidin set. About the fifth day bleached spots appeared in the leaves in some of the cultures, producing an effect like a plant disease. The diseased spots on the leaves spread and became larger and more numerous. The spots appeared first on a few cultures, but when the cultures were arranged in the order of their composition the reason for this became evident. The guanidin effect showed itself first in the cultures high in nitrate and then spread to those lower in nitrate, until the series of no nitrate content was reached. In this series the guanidin effect was scarcely discernible. As the plants grew older, the guanidin effect became more and more marked; the bleached spots coalesced and appeared most marked in the lower part of the leaves; the leaves broke finally, presenting on the whole an effect similar to that produced by a wilt disease and accompanied with considerable bleaching of the green parts of the plant. This, at least, was the effect in all of the cultures containing nitrate and was the more marked the higher the nitrate content. The series containing no nitrate whatever retained its green color and was not subject to collapse or wilting, although here and there some bleached spots appeared.

FIG. 1. Effect of guanidin on wheat plants; series *A* without guanidin, series *B* with guanidin.

In FIG. 1 are shown the two sets of cultures. *A* is the normal or control set and *B* the guanidin set. The distinctly destructive effect of the guanidin is apparent in the blighted appearance of set *B* in striking contrast to the fine growth in the control cultures, which is even more marked than the photograph can show because of the deep green color of the normal set contrasted with the bleached appearance of the guanidin set.

FIG. 2. Effect of guanidin on wheat plants. Nearer view of series *B* in FIG. 1.

In FIG. 2 a nearer and better view is had of this guanidin set. The plants are arranged according to the composition of their culture solutions, thus forming a triangle. By this arrangement the highest nitrate culture appears at *N*, the highest phosphate culture at *P*, and the highest potash culture at *K*. It is apparent that the poorest plant development occurs in those cultures high in nitrate but is distinctly noticeable in every culture except in the line of cultures from *P* to *K*, which is the series containing no nitrate. The plants in this line of cultures are firm and erect, as can be seen in the photograph. In actuality this difference is accentuated by the nearly normal green color of this series, whereas all other cultures, in addition to the dilapidated condition, had a decidedly bleached appearance.

The effect of the nitrate in increasing the harmful effect of guanidin is also shown by the weight of the tops taken at the termination of the experiment. In TABLE I the first column gives the series, the cultures of which have like nitrate content. The amounts of nitrate in each culture of these series are given in the second column. The third and fourth columns give the weight of the tops of the plants grown in the cultures without and with 25 parts per million of guanidin carbonate. It is at once apparent that the guanidin is very harmful to growth. The total green weight of the 66 cultures in the normal set was 151.2 grams against only 99.5 grams in the guanidin set. Placing the normal at 100, the growth in the guanidin set becomes 66. The last column gives the relative growth in each of the series of uniform nitrate content in the set. The culture that contained 80 parts per million NH_3 as nitrate gave a relative weight of only 31 or a decrease in growth of 69 per cent, whereas in the series of cultures that contained no nitrate the relative growth was 94, a decrease of only 6 per cent below the control. As shown in the table, the relative weight of tops obtained increased with decreasing nitrate content.

TABLE I

EFFECT OF GUANIDIN ON GROWTH AS INFLUENCED BY NITRATE

Culture series	NH_3 as nitrate in fertilizer mixture, parts per million	Green weight of cultures, grams		Relative growth. Control = 100
		Without guanidin	With 25 parts per million guanidin	
66	80	1.656	0.520	31
55–65	72	4.178	1.990	47
45–64	64	6.860	3.412	48
36–63	56	9.449	5.031	53
28–62	48	12.359	6.874	55
21–61	40	15.998	8.394	52
15–60	32	18.649	11.491	62
10–59	24	21.691	13.602	62
6–58	16	23.327	15.709	67
3–57	8	20.923	17.288	83
1–56	0	16.156	15.195	94

The effect of guanidin on growth, and especially the harmful influence of the nitrate, was considered so remarkable, particularly in the light of the previously observed beneficial effect of nitrate in conjunction with harmful compounds,* that the entire experiment was repeated, and it gave absolutely the same results.

The plants grew from March 17 to March 29. Again the effect of the guanidin did not appear until about five days had elapsed, and again it showed itself first, and later most marked, in the high nitrate solutions. Again the no nitrate cultures were left practically unharmed. The total green weight for the normal set was 163.9 grams, and in the guanidin set it was 116.3 grams, a relative green weight of 71. The weights of the tops in the different nitrate series are given in TABLE II, the arrangement being exactly the same as in TABLE I. The last column, giving the relative green weight of the different nitrate series, again shows the greater harmfulness of the guanidin in the series containing nitrate, which is especially marked in those high in nitrate.

TABLE II

EFFECT OF GUANIDIN ON GROWTH AS INFLUENCED BY NITRATE

Culture series	NH_3 as nitrate in fertilizer mixture, parts per million	Green weight of cultures, grams		Relative growth. Control = 100
		Without guanidin	With guanidin	
66	80	2.201	1.003	46
55–65	72	4.040	2.040	50
45–64	64	7.275	4.021	55
36–63	56	10.359	5.996	57
28–62	48	13.387	7.544	56
21–61	40	17.394	10.110	58
15–60	32	20.821	13.204	63
10–59	24	22.769	16.952	74
6–58	16	25.614	18.141	71
3–57	8	24.097	21.112	81
1–56	0	15.969	16.164	100

In the first experiment the solutions were also analyzed for phosphate, nitrate, and potash. The results show a marked decrease in the absorption of the nutrient salts on the part of the guanidin plants, although the roots themselves were not noticeably affected, as is apparent from the plants visible in FIG. 1 and 2.

The total phosphate, nitrate, and potash removed by the normal plants was 1,608.9 milligrams, against only 1,088.5 milli-

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* Schreiner, O., and Reed, H. S. The power of sodium nitrate and calcium carbonate to decrease toxicity in conjunction with plants growing in solution cultures. Jour. Amer. Chem. Soc. **30**: 185. 1908.—Schreiner, O., and Skinner, J. J. Some effects of a harmful organic soil constituent. Bot. Gaz. **50**: 161. 1910.

grams in the guanidin set. The phosphate removed was 427.3 milligrams in the control and 287.0 milligrams in the guanidin set; the potash was 723.7 milligrams for the control and 496.7 milligrams for the guanidin set; the nitrate was 457.9 milligrams for the control cultures and 304.8 milligrams for the guanidin cultures.

Tests of guanidin carbonate in quantities of 50 parts per million were also made in soil cultures. The physiological effect of the guanidin was again apparent in the spotting and bleaching of the leaves and was again most evident in the soils fertilized with nitrate.

EFFECT OF GUANIDIN ON OTHER PLANTS

The effect of guanidin was further studied by using plants other than wheat. In FIG. 3 is shown its effect on corn growing in culture solution no. 41, containing 16 parts per million phosphate, 32 parts per million nitrate, and 32 parts per million potash. FIG. 4 shows the effect of guanidin on cowpeas, the control and guanidin cultures being in duplicate. FIG. 5 shows its effect on the potato plant. In these tests guanidin was used in concentra-

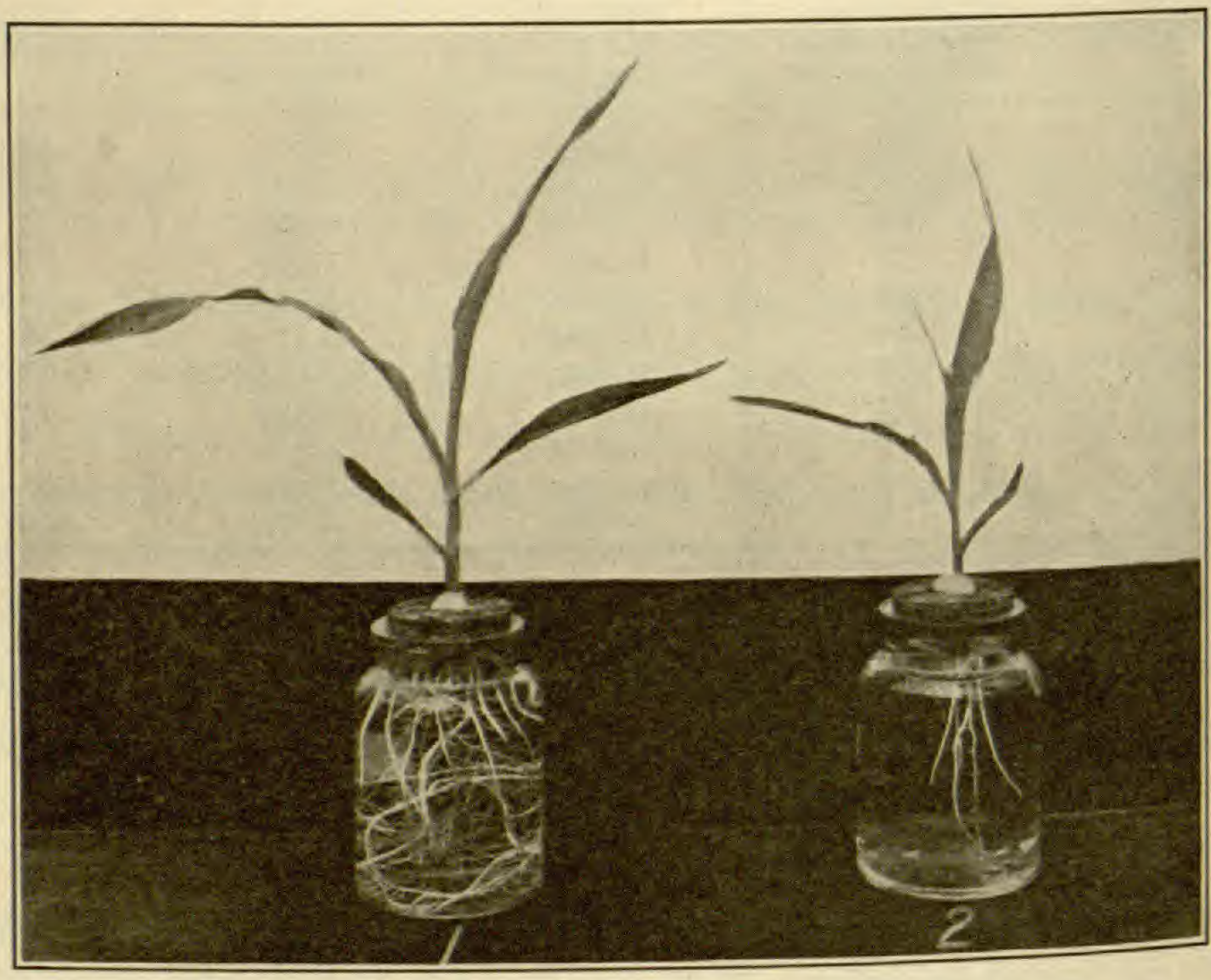

FIG. 3. Harmful effect of guanidin on corn; no. 1 without guanidin, no. 2 with guanidin.

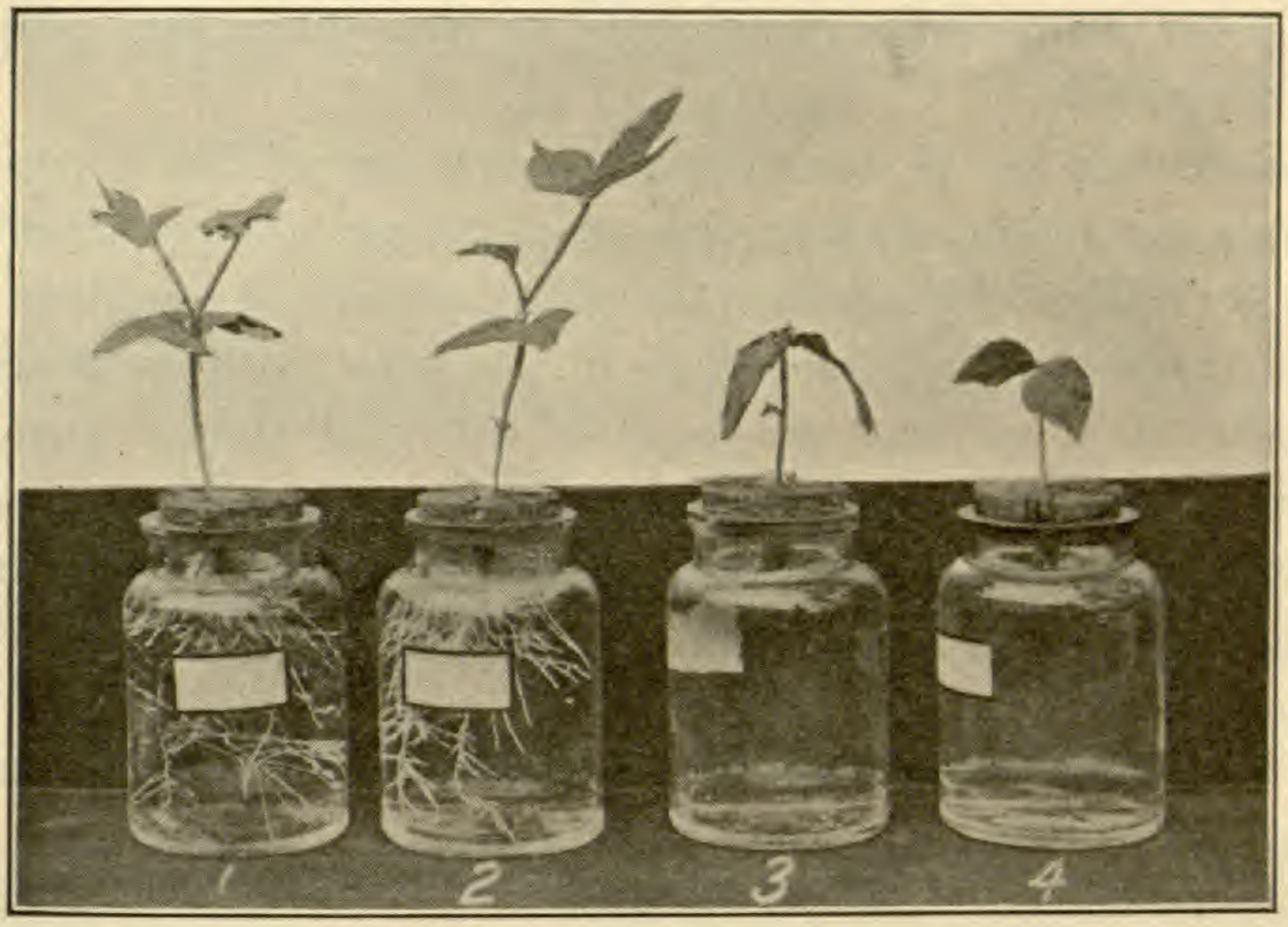

FIG. 4. Harmful effect of guanidin on cowpeas; no. 1 and 2 without guanidin, no. 3 and 4 with guanidin.

tions of 25 parts per million. With all these plants the harmful effect on growth is clearly shown and the same general physiological action was manifested as in the case of wheat.

FIG. 5. Harmful effect of guanidin on potatoes; no. 1 without guanidin, no. 2 with guanidin.

INFLUENCE OF ORGANIC NITROGENOUS COMPOUNDS

In regard to the influence of nitrate in increasing the harmfulness of guanidin some further studies were made which indicate that other nitrogenous compounds do not share this property with the nitrate.

To solution no. 41, containing 16 parts per million phosphate, 32 parts per million nitrate, and 32 parts per million potash, 25 parts per million of guanidin were added, and wheat seedlings were grown in this solution as well as in a control without guanidin. A similar set of cultures was prepared with and without guanidin, but with this difference that the nitrate was omitted entirely and an equivalent amount of nitrogen in the form of asparagin was added to the culture solution. The plants grew from March 10 to March 23, 1911.

The characteristic effects of guanidin were noticed in the culture containing nitrate but did not appear in the culture containing asparagin. The appearance of the cultures is shown in FIG. 6, where no. 1 is the control with nitrate and no. 3 the control with asparagin. No. 2 and 4 are the guanidin cultures to be compared with each other and with their respective controls. No. 2 shows the wilting effect of the guanidin as well as the decreased growth. The colors of the various cultures brought out the difference even more strikingly. The green weights given in TABLE III bear out the same point.

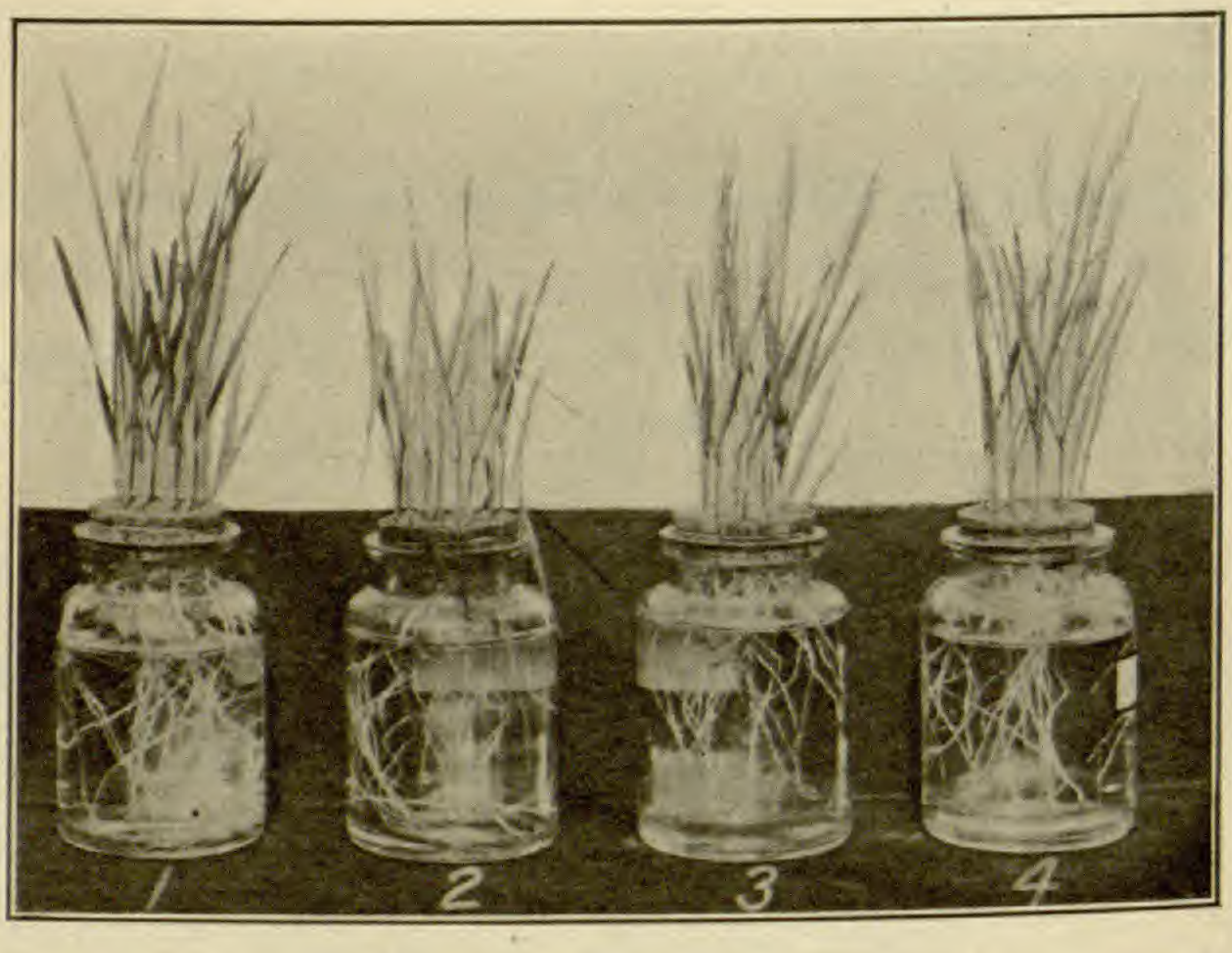

FIG. 6. Effect of guanidin with nitrogen in different forms; no. 1, nutrient solution containing sodium nitrate; no. 2, same plus guanidin; no. 3, nutrient solution containing asparagin; no. 4, same plus guanidin.

TABLE III

EFFECT OF GUANIDIN IN CULTURE SOLUTIONS CONTAINING NITROGEN AS NITRATE AND AS ASPARAGIN

Culture solution	Green weight, grams
$CaH_4(PO_4)_2$ $NaNO_3$ K_2SO_4	4.0
$CaH_4(PO_4)_2$ $NaNO_3$ + 25 parts per million guanidin K_2SO_4	2.5
$CaH_4(PO_4)_2$ Asparagin K_2SO_4	3.5
$CaH_4(PO_4)_2$ Asparagin + 25 parts per million guanidin K_2SO_4	3.3

Creatinin was also tried in this same manner. Creatinin was identified as a soil constituent in this laboratory* and also found to be a constituent in a number of plants.† Its effect on plants has been shown to be beneficial, its action being to replace nitrate in producing plant growth.‡ The results obtained by using creatinin as the source of nitrogen instead of sodium nitrate in conjunction with the guanidin are given in TABLE IV.

TABLE IV

EFFECT OF GUANIDIN IN CULTURES CONTAINING NITROGEN AS NITRATE AND AS CREATININ

Culture solution	Green weight, grams
$CaH_4(PO_4)_2$ $NaNO_3$ K_2SO_4	3.4
$CaH_4(PO_4)_2$ $NaNO_3$ + 25 parts per million guanidin K_2SO_4	2.4
$CaH_4(PO_4)_2$ Creatinin K_2SO_4	3.0
$CaH_4(PO_4)_2$ Creatinin + 25 parts per million guanidin K_2SO_4	3.0

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* Shorey, E. C. The isolation of creatinin from soils. Jour. Amer. Chem. Soc. **34**: 99. 1912.

† Sullivan, M. X. The origin of creatinin in soils. Jour. Amer. Chem. Soc. **33**: 2035. 1911.

‡ Skinner, J. J. The beneficial effect of creatinin and creatin on growth. Bot. Gaz. **54**: 152–163. *f. 1.* 16 Au 1912.

Again the characteristic effect of the guanidin was observed in the cultures containing nitrate, and the depressed growth is shown by the green weight in the table. With creatinin the effect of guanidin was not apparent either in appearance or in the green weight obtained.

SUMMARY

Guanidin, as carbonate, is shown to be harmful to wheat, corn, cowpeas, and potato plants. It produces an effect similar to a physiological disease. The plant is normal for a few days, then begins to show a spotted appearance on leaf and stem. This effect develops until the plant is bleached to a considerable extent, with final collapse.

This harmful effect of guanidin on plants is augmented by the presence of nitrate and increases with the amount of nitrate present.

Sources of nitrogen, other than nitrate, did not show this same effect. The organic nitrogenous compound asparagin, as well as the beneficial soil constituent creatinin, appeared in fact to be able to counteract the effect of guanidin itself.

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WASHINGTON, D. C.

Polycodium

C. B. Robinson

The statements by which Professor E. L. Greene* suggested the resuscitation of Rafinesque's name require quotation in full, as they bring up many points open to controversy.

"We have in the Eastern and Southern United States two groups of vacciniaceous shrubs either of which is at variance with all genuine *Vaccinium* in two important points of floral structure. The corollas in both groups are campanulate, while in both *Vaccinium* and *Gaylussacia* they are urceolate. The stamens also, in these campanulate-flowered shrubs, are of a structure so peculiar that, on the characters of this organ alone, a genus might reasonably be established, were concomitant characters wanting. *Vaccinium* and *Gaylussacia* are now everywhere admitted as distinct, yet, exclusive of the groups here under special notice, there is not the slightest difference of floral structure between the two. But these other shrubs depart widely from the characters of both *Vaccinium* and *Gaylussacia* not only in their open-campanulate corollas, but in respect to their stamens, which organs are doubly marked by extremely long and slender anther-tubes, and two prominent horn-like projections on the back; so that nothing approaching these characters is found in any other genera allied to *Vaccinium.*

"Twice in the early part of the century, botanists of first-class ability proposed the separation of these species from *Vaccinium.* Rafinesque in 1818, not distinguishing generic differences between those types represented by *V. stamineum* and *V. arboreum* respectively—perhaps not even knowing *V. arboreum*—proposed the *V. stamineum* group for a genus under the beautifully appropriate name of POLYCODIUM; and Nuttall in 1843, ignoring Rafinesque's earlier proposition—just as later pretenders to taxonomic autocracy suppressed Nuttall's work—sought to establish a new genus *Batodendron* with *V. arboreum* as typical, and *Picrococcus* with *V. stamineum* for its type.

"The characters of the two genera are well indicated by Nuttall, in the transactions of the American Philosophical Society, with the exception of one new and most significant peculiarity of the *V. stamineum* group which I alone seem to have observed.

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* Pittonia 3: 323. 1898.

It is this, that in this group the corollas are *open in the bud!* For from ten days to two weeks before the actual flowering, and even from the time that the buds are green and scarcely larger than a pin-head, the corolla is open and campanulate. This is another character otherwise unknown in the family of plants to which these belong. Certainly in *Vaccinium* and *Gaylussacia* the buds are tightly closed, in an imbricate aestivation, until the corollas are full-grown and the anthers mature."

Now of vacciniaceous plants found within the limits of the United States, the genera that are almost universally recognized are *Chiogenes*, *Gaylussacia*, and *Vaccinium*. Even regarding these there is some controversy. *Chiogenes* is readily distinguished by the position of the ovary, only slightly inferior in flower, distinctly inferior in fruit, and while American and British authors of recent years have agreed in placing it near *Vaccinium*, German authors on the other hand believe the closest affinity to be *Gaultheria;* and it can hardly be denied that its position is somewhat intermediate,

There is no doubt as to the identity of *Gaylussacia*, as it was published as monotypic, its type, *G. buxifolia* H. B. K., agreeing with many species now known from South America, in the possession of evergreen leaves and non-succulent fruit as well as of a 10-celled ovary. The only species described as a *Gaylussacia* from Mexico or Central America does not belong to the genus, all of the species so called in the United States have succulent fruit, and all but one have deciduous leaves. Niedenzu[*] has placed that one in the Vitis-Idaea section of *Vaccinium*, and the other North American species in the Cyanococcus section of *Vaccinium*, retaining the name *Gaylussacia* for South American species only.

Kuntze,[†] also, has taken up the name *Adnaria* Raf.[‡] for *Gaylussacia*, but the most positive thing that can be said about Robin's description,[§] upon which Rafinesque's was based, is that it does not agree with that of any species of the family found in America and in particular disagrees with *Gaylussacia* in the very character relied on for its differentiation, the number of cells in the ovary.

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[*] Engl. Bot. Jahrb. 11: 193. 1889.

[†] Rev. Gen. Pl. 382. 1891.

[‡] Fl. Ludov. 56. 1817.

[§] Voy. Int. Louisiana 3: 422. 1807.

Yet, taken on a summary of characters, there is probably no species found in Louisiana that is more likely to have been the basis for Robin's description than *Gaylussacia dumosa* (Andr.) A. Gray.

All of the remaining species of the family found north of the Mexican border are retained by many authors in *Vaccinium*. Generic or sectional segregation has been proposed on several characters, taken singly or in combination, the degree of union of the corolla, its aestivation, its shape, the presence or absence of awns on the anthers, the presence or absence of pubescence on the filaments, the presence or absence of false partitions in the ovary, the nature of the inflorescence, and tetramerous as contrasted with pentamerous flowers.

In the Thibaudieae, the other subfamily of Vacciniaceae, general agreement has been reached that the primary basis of differentiation should be sought in the stamens. There is much reason to believe that this is equally true with regard to the *Vaccinium* group, but it would be useless to belittle the fact that the weight of botanical opinion has been otherwise. The most popular segregate has been *Oxycoccus*, from which *Hugeria* has further been discriminated. They differ from the remainder of the group and from one another in the degree of division of the corolla. Possibly *Polycodium* will prove the most acceptable of the others. But on what grounds should it be retained? Professor Greene's claims for it are excessive, although indefinite, for he does not define "genuine *Vaccinium*." It has a campanulate corolla: so have *V. arboreum* Marsh.,* *V. Vitis-Idaea* L., *V. poasanum* Donn. Sm., *V. confertum* H. B. K., and others, differing from one another in various characters, and none except the first closely allied to *Polycodium*. The 10 stamens of *Polycodium* have pubescent filaments and 2-awned anthers: except in number they differ from the great majority of species of the eastern and southern United States, which have pubescent filaments but awnless anthers (section Cyanococcus), from most of those of the western States, which have 2-awned anthers but glabrous filaments (section Euvaccinium), but agree with many tropical American species,

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* No opinion is necessarily expressed in giving the name of this or any other species as *Vaccinium*.

such as *V. leucanthum* Schlecht., *V. stenophyllum* Steud., and *V. cubense* Griseb., none at all closely allied to *Polycodium.* This is not all, for in the United States no single character is as certain to ensure the instant identification of *Polycodium* as the long-exserted anthers; moreover, the tubes forming the prolongation of the anther cells are unusually long, both absolutely and relatively to the anther cells. But there is a Mexican species, *Vaccinium Kunthianum* Klotzsch, so closely related to *Polycodium stamineum* that neither Kunth nor Dunal* thought it worthy of specific rank. Its stamens were described as half-exserted, and figured as well exserted, but in no collection that I have seen, so identified by others or by myself, can they be considered as more than barely exserted, the anthers are shorter than in the other species, and the anther tubes only about one and a half times the length of the anther cells. In all other respects it is a perfectly good *Polycodium,* and if the genus is to be maintained, must be transferred to it, forming a section by itself, on the basis of the characters just stated.

Finally, the anther awns are often revolute, but too much emphasis should not be placed on this, as it is not always constant within a single flower; at least, however, they are divaricate, but so they are in species which no one has suggested separating from *Vaccinium,* such as *V. caespitosum* Michx.

The flowers of *Polycodium* are articulated with the pedicel; this is also true of certain species placed in *Vaccinium* by most authors, notably of the *Disterigma* species. That group, which does not come north of Mexico, was until recently treated by all authors as a section of *Vaccinium,* but Niedenzu† and Hörold‡ so far separate it from that genus that they place it in the Thibaudieae. On the basis of floral characters there seems to be no reason for so wide separation; indeed, unless *Vaccinium* is to be radically divided, I at least believe that there is as much reason for placing *V. Myrtillus* L. and its American allies in a different genus from *V. corymbosum* L. and its allies, as there is for so segregating *Disterigma* from the latter. Drude§ has placed considerable

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* H. B. K. Nov. Gen. & Sp. **3**: 267. *pl. 253.* 1819; DC. Prodr. **7**: 568. 1839.

† Engl. Bot. Jahrb. **11**: 209. 1889.

‡ Engl. Bot. Jahrb. **42**: 282. 1909.

§ Engler & Prantl, Die Nat. Pflanzenfam. **4**^{1}: 32. 1889.

emphasis on articulated pedicels as a means of distinguishing the Thibaudieae from the Vaccinieae but, unfortunately, has gone far beyond the facts.

One character remains to which Professor Greene has called particular attention, the open aestivation of the corolla. All evidence that has been obtained confirms his statement on this point for every species of *Polycodium*, including *V. Kunthianum*. This does seem of such importance that the genus may properly be maintained; the other characters previously mentioned may be treated as collateral, by one who is dealing with the species of America north of Mexico, but it must be remembered that not one of them can be relied on to distinguish *Polycodium* from all other genera, even within the limits of North America.

Rafinesque* published *Polycodium* thus: "67. The species of *Vaccinium* with campanulated corollas, must form a peculiar genus or subgenus, *Polycodium*. In fact the whole tribe of *Ericacea* or *Bicornia* must be newly modelled." And this is all, with one very important exception. The paragraph occurs in a review of Pursh's Flora Americae Septentrionalis and may fairly be interpreted by reference to that work. Pursh divided *Vaccinium*† primarily into species with deciduous leaves and those with evergreen leaves, dividing each of these in turn on the basis of campanulate as contrasted with urceolate corollas. His species with deciduous leaves and campanulate corollas were *V. stamineum*, *V. album*, *V. arboreum*, *V. dumosum*, *V. frondosum*, and *V. pallidum;* those with persistent leaves and campanulate corollas were *V. Vitis-Idaea*, *V. myrtifolium*, and *V. crassifolium*. *Vaccinium stamineum* thus comes first, and *V. album* Pursh is regarded by most authors as the same species. *Polycodium*, therefore, may be held to be typified by *Vaccinium stamineum* L., but Rafinesque's genus in its entirety was a mixture of widely differing elements, including representatives not only of *Batodendron* but of *Gaylussacia* and of different sections still included in *Vaccinium* by nearly all authors.

Picrococcus of Nuttall is based almost entirely on *Vaccinium stamineum* L. (including *V. elevatum* Banks & Soland.) with the

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* Am. Monthly Mag. 2: 266. 1818.

† Fl. Am. Sept. 1: 284–290. 1814.

addition of a second species, *Picrococcus floridanus*, certainly congeneric with the former, of which more hereafter.

Professor Greene is unduly critical of Nuttall for overlooking or disregarding such a publication as Rafinesque's of *Polycodium* for the genus containing *Vaccinium stamineum*, and Nuttall was not the first offender. In 1836 Rafinesque himself has the following:* "ADNARIA Raf. fl. lud. probably a subgenus of the *Codorolla* or Vacciniums with bell flowers, which see." But *Codorolla* does not appear again, and Rafinesque did not consider this reference worth indexing.

It is apparent that the adoption of *Polycodium* as a generic name, to be typified by *Vaccinium stamineum* L., is barely justified.

Before leaving the subject of generic subdivision in the *Vaccinium* alliance it is desired to amplify a statement above made with regard to the importance of characters derived from the stamens. The anthers may be 2-awned or awnless. In a solitary specimen, *Wright 2202*, referred to *Vaccinium Ramonii* Griseb., some anthers were found with a single central awn. Further examination showed that this was not a constant character, even within a single flower; but none of the anthers were awnless. The value of anther awns as a diagnostic character obviously depends upon the degree of their constancy, and final judgment will be influenced, consciously or unconsciously, by the nature of the grouping thus achieved.

Examination of the flowers of every species but one, found within the limits of North America, as well as of some extralimital material, gives this result. There are 3, or more likely only 2, species, *V. meridionale* Sw., of Jamaica, *V. consanguineum* Klotzsch, of Panama and Costa Rica, and *V. multiflorum* Benth., of Colombia, in which this character has to be handled with extreme caution. All of these are very closely allied; indeed, it is doubtful if the first two can be held distinct. In all of these the awns are very delicate and often closely appressed, to such an extent that they might escape detection, unless considerable care be taken in their search. Further, in *V. meridionale* they are often so reduced that they are practically wanting, yet other stamens in the same flower may possess them, slender and short

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* New Fl. 1: 65. 1836.

indeed, but certainly present. Moreover, *V. multiflorum* was described as having anthers alternately awned and awnless, yet a recent collection from near its type locality, *Pittier 1182*, agreeing otherwise with Bentham's description, has all the anthers of such flowers as were examined 2-awned, with awns as described and found for this and for *V. consanguineum*. The plate* of *V. meridionale* is wrong in this respect.

Yet, all these can be described as awned anthers, and on other grounds the alliance of the species is with those possessing awned anthers. Much search has failed to disclose a single other exception, not only within the limits of a species but within the limits of what appear to be groups of related species.

It may be added that the presence of pubescence, in whatever degree, on the filaments or the connectives—and when it occurs it is usually on both—is equally conclusive but of secondary importance. Thus, if a vacciniaceous plant be found in America north of Mexico with awnless anthers and glabrous filaments, no further information is needed for its determination as *Gaylussacia frondosa* (L.) T. & G., except by those who consider *G. nana* (A. Gray) Small and *G. tomentosa* (Pursh) Chapm. to be specifically distinct from that species. Each of the other three combinations of these two characters will describe large groups of species.

On the other hand, investigation of the relative length and degree of divergence of the awns and of the relative amount of pubescence on the filaments seems to indicate that these do not afford reliable characters except possibly in rare cases.

Up to the present the following have been ascribed to *Polycodium* as distinct species: *P. caesium* Greene, *P. candicans* (C. Mohr) Small, *P. elevatum* (Banks) Greene, *P. floridanum* (Nutt.) Greene, *P. Langloisii* Greene, *P. melanocarpum* (C. Mohr) Small, *P. neglectum* Small, *P. oblongum* Greene, *P. oliganthum* Greene, *P. revolutum* Greene, and *P. stamineum* (L.) Greene; it has already been stated that another species awaits transfer, *Vaccinium Kunthianum* Klotzsch. The last having been separated on the basis of its shorter anthers, not or barely exserted, the character depended on as of next importance is the relation between leaves or bracts and the inflorescence.

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* Sw. Ic. Ind. Occ. *pl. 12.* 1794.

In the *Vaccinium* group as a whole there is a transition in this respect, and *Polycodium* is merely one case of many. In certain species, such as *V. caespitosum* Michx., *V. scoparium* Rydb., and *V. Myrtillus* L., the flowers are few in number on a branch borne in the axils of what are apparently quite normal leaves as to size, shape, and texture. In others the inflorescence is quite clearly racemose, or by contraction fasciculate, the pedicels subtended by bracteoles quite different in appearance from the vegetative leaves. This includes nearly all the species of the eastern United States. There is yet a third group, which almost perfectly links the two, the inflorescence being perhaps best described as a leafy raceme. These are mostly tropical plants. Incidentally, these three groups follow rather closely the lines indicated by the stamens.

In the case of *Polycodium* there is a group "in which," to use Nuttall's expression* when describing *Picrococcus floridanus*, "the flowers appear truly axillar." Here also belong the names *Polycodium caesium* Greene, *P. oliganthum* Greene, and *P. revolutum* Greene. Nuttall's type seems to have perished, which will cause trouble to those who believe this group to contain more than one species, for he has no sufficient description for more definite determination. In the case of the other species duplicates of the type collections have been examined, and there seems no sufficient reason for holding them distinct. In separating *P. revolutum* from *P. caesium* Professor Greene† relies chiefly on the leaves of the former being more pubescent, more oval and obtuse, their margins revolute, the calyx lobes deeper, acute or acuminate instead of scarcely acute, and deeper corolla lobes. It is not possible to separate the series of specimens on these characters or any of them, those drawn from the leaves being especially unreliable, not even holding for the collections on which the species were based. There seems even less reason for segregating *P. oliganthum*.

Now, the same thing happens in *Polycodium* as in the *Vaccinium* group in general; the leaves, in the axils of which the flowers are borne, are often reduced in size but still retain the other characters of the typical leaves of the plant; yet again, they may

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* Trans. Am. Philos. Soc. II. 8: 262. 1843.

† Pittonia 3: 249, 250. 1897.

be very greatly reduced although sometimes differing considerably within the same inflorescence. *P. oliganthum* approaches the former condition but seems to have been referred correctly to the *P. floridanum* group. The linking material affords some justification for the view that specific lines should not be drawn on this character, but the corolla in the group thus separated is always smaller, one half to one third of the length of that of the remaining species, and it seems preferable to consider it as distinct and as forming a single species only. Its range is from South Carolina to Florida, all of the types of the species proposed having come from the latter state. If this view be accepted, there seems no reason why its name should not be *Polycodium floridanum* (Nutt.) Greene.

From the remainder it is exceedingly easy to separate *Polycodium neglectum* Small by means of its glabrous branchlets and leaves. These characters hold definitely for large series of collections, but there seem no others correlated with them, and the plants often grow side by side with those of *P. stamineum*. It is, therefore, a matter of opinion as to whether the two should be held distinct.

Polycodium melanocarpum was described by Mohr* as *Vaccinium stamineum melanocarpum* without a definite type specified. It was raised to specific rank by Kearney,† who expressly stated that his own collections were not typical. Mohr,‡ subsequently discussing it as a species, gives as the type locality "Mountain region of Alabama. More specifically, St. Clair County, near Ashville, July 1880." The ground for separation was the succulent nature of the fruit and its color. Mohr also proposed two varieties, *V. melanocarpum candicans* and *V. melanocarpum sericeum*. In Small's Flora§ the former variety becomes *P. candicans* (C. Mohr) Small, and *Polycodium melanocarpum* includes both the species and its variety *sericeum;* "hypanthium *usually* more or less pubescent." The seventh edition of Gray's Manual goes further: "calyx white-tomentose." Study of material in the herbarium of

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* Bull. Torrey Club **24**: 25. 1897.

† Bull. Torrey Club **24**: 570. 1897.

‡ Contr. U. S. Nat. Herb. **6**: 658. 1901.

§ Fl. SE. U. S. 894. 1903.

the New York Botanical Garden led to the conviction that *Vaccinium melanocarpum* of Gray's Manual is a good species, but that it is not identical with Mohr's species but with his variety *sericeum* only. On all sheets in the New York herbarium the character of pubescence on the hypanthium, always more or less definitely present on fruit as well, was accompanied by another character. The calyx lobes were accrescent in late flower or early fruit. This was easily evident to the eye, but on measuring, the balance of difference proved slight, the fruiting calyx being 1.5–2 mm. long in *P. stamineum* and 2.5–3 mm. long in the collections referable to *sericeum*. There was a single plant in which a glabrous hypanthium was accompanied by an accrescent calyx. This plant, on fine division, would be referred to *P. candicans* Small.

Examination of material from the United States National Herbarium shows that the same is true of the collections there. But the specimen that Mohr seems to have considered as the type of his species has a glabrous hypanthium, and the calyx is not accrescent. So far, then, as *Polycodium melanocarpum* (C. Mohr) Small is concerned, there is room for difference of opinion; if the character of succulent fruit is considered sufficient, it may be maintained as a species, but no other sufficient reason has been found for holding it specifically distinct from *P. stamineum*. But the evidence is otherwise as regards *V. melanocarpum sericeum*.

Typical forms of *P. candicans* (C. Mohr) Small differ notably from more typical *P. stamineum* in glaucescence, but the extremes are united by many intermediates, and no sharp line for separation has been found. Moreover, there is much reason for believing that this is a revival of *P. elevatum* Greene, the *Vaccinium album* of Pursh, although not the Linnaean species of the latter name, which does not belong to the family.

Two species have not been discussed, *P. oblongum* Greene and *P. Langloisii* Greene, of neither of which I have seen the types. Its author places the former in the *P. floridanum* group, but from the description and study of material which seems to match it I am inclined to refer it to *P. stamineum*, to which also *P. Langloisii* seems too closely related.

The following new combinations give effect to conclusions already stated.

Polycodium Kunthianum (Klotzsch) comb. nov.

Vaccinium stamineum β H. B. K. Nov. Gen. & Sp. **3**: 267. 1819.

Vaccinium elevatum β Dunal, in DC. Prodr. **7**: 568. 1839.

Picrococcus elevatus β Nutt. Trans. Am. Philos. Soc. II. **8**: 262. 1843.

Vaccinium Kunthianum Klotzsch, Linnaea **24**: 56. 1851.

Polycodium sericeum (C. Mohr) comb. nov.

Vaccinium melanocarpum sericeum C. Mohr, Contr. U. S. Nat. Herb. **6**: 658. 1901.

Vaccinium melanocarpum Robinson & Fernald, in Gray, Man. ed. 7. 639. 1908. Not *V. melanocarpum* C. Mohr, 1897.

NEW YORK BOTANICAL GARDEN.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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Alden, I. A contribution to the life history of *Uvularia sessilifolia.* Bull. Torrey Club **39**: 439–446. *pl. 34, 35.* 9 S 1912.

Arber, E. A. N. On *Psygmophyllum majus* sp. nov., from the Lower Carboniferous rocks of Newfoundland, together with a revision of the genus and remarks on its affinities. Trans. Linn. Soc. Bot. II. **7**: 391–407. *pl. 42–44* + *f. 1.* Jl 1912.

Banker, H. J. Type studies in the *Hydnaceae*—I. The genus *Manina.* Mycologia **4**: 271–278. 28 Au 1912.

Three new combinations are made.

Barnhart, J. H. Jacquin's Selectarum stirpium historia iconibus pictis. Jour. N. Y. Bot. Gard. **13**: 99, 100. Jl 1912.

Batchelder, C. F. Two grasses new to New Hampshire. Rhodora **14**: 175. 23 Au 1912.

Berger, A. *Agave marmorata.* Curt. Bot. Mag. IV. **8**: *pl. 8442.* Jl 1912.

From Mexico.

Berry, E. W. Contributions to the Mesozoic flora of the Atlantic coastal plain—VIII. Texas. Bull. Torrey Club **39**: 387–406. *pl. 30–32.* 16 Au 1912.

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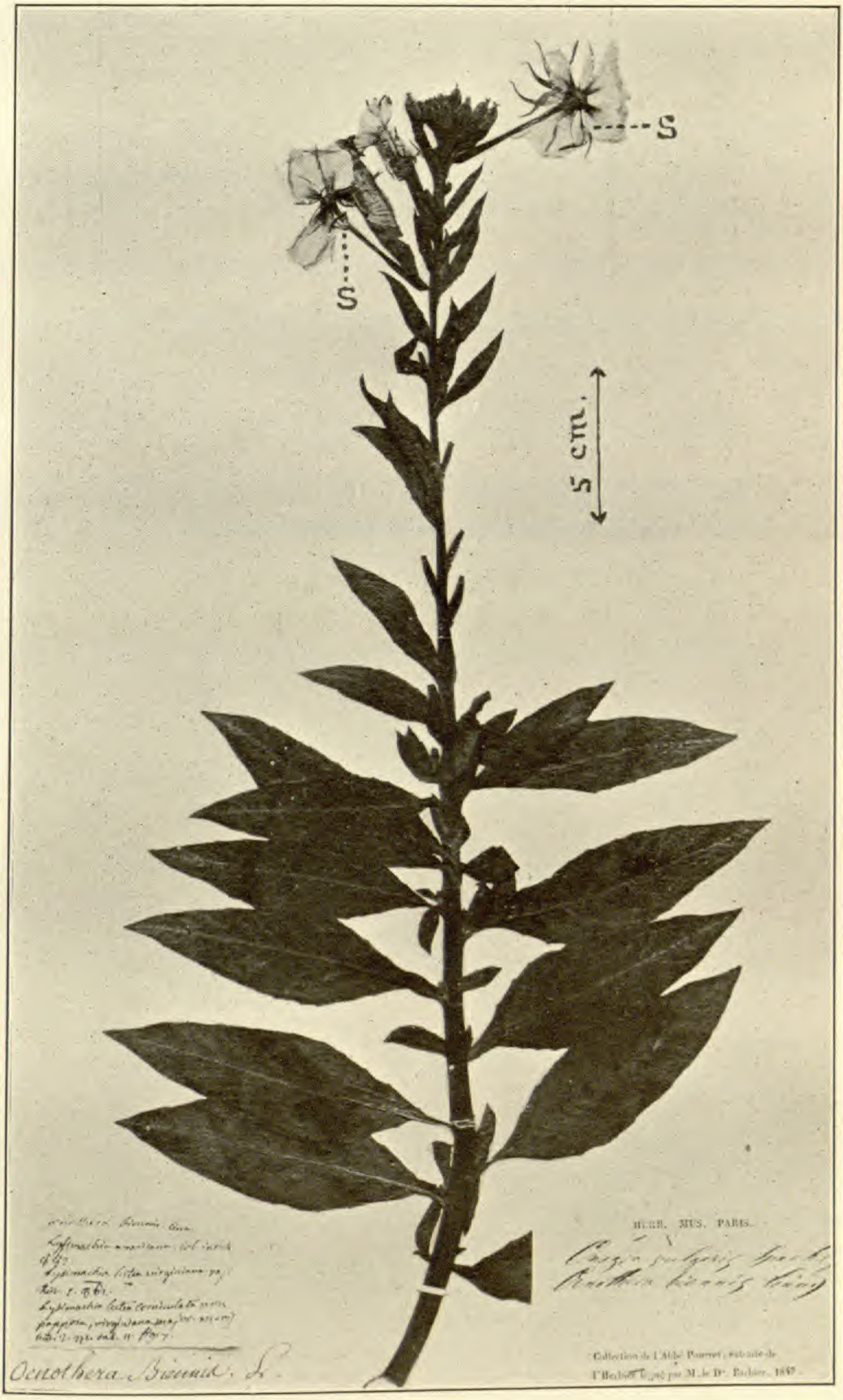

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CONTENTS

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BULLETIN

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TORREY BOTANICAL CLUB

DECEMBER 1912

A taxonomic study of the Pteridophyta of the Hawaiian Islands—II

WINIFRED J. ROBINSON

(WITH PLATES 40–44)

5. POLYPODIACEAE

Plants various in habit. Rootstock erect or creeping; leaves circinate in vernation, blades simple to quadripinnate; sporangia covering the lower surface in a uniform layer or arranged in linear, roundish, or oval sori; these indusiate or non-indusiate; sporangia stalked; annulus incomplete.

- Sporangia scattered over the under surface of the leaf blade in a uniform layer. 1. *Elaphoglossum*.
- Sporangia in definite sori.
  - Sori marginal or submarginal.
    - Indusium present.
      - Sori continuous or interrupted, indusium formed of the more or less modified leaf margin.
        - Indusium opening inward.
          - Sporangia arising from a continuous veinlike receptacle, connecting the ends of the veins.
            - Indusium single. 2. *Pteris*.
            - Indusium double. 3. *Pteridium*.
          - Sporangia arising from the unconnected ends of veins.
            - Leaf margin continuously reflexed in fertile leaflets.
              - Veins free. 4. *Pellaea*.
              - Veins anastomosing. 5. *Doryopteris*.

[The BULLETIN for November 1912 (**39**: 519–566. *pl. 37–39*) was issued 18 N 1912.

          - Separate lobes of leaf margin reflexed as indusia.
            - Leafstalks black, shining. 6. *Adiantum.*
            - Leafstalks brownish, dull.
              - Sori distinct in sinus of leaf. 7. *Hypolepis.*
              - Sori crowded. 8. *Schizostege.*
      - Indusium opening outward.
        - Pinnae strongly developed on anterior side.
          - Sori transverse on the expanded tips of free or anastomosing veins, segments dimidiate or cuneate. 9. *Diellia.*
          - Sori on the expanded tips of free veins with no intramarginal vein, pinnae only slightly developed on posterior side. 10. *Odontoloma.*
        - Pinnae developed on both sides of the midrib, though not equally.
          - Indusium attached only at the base; pinnae jointed to the midrib. 11. *Nephrolepis.*
          - Indusium attached on three sides.
            - Ultimate segments cuneate. 12. *Odontosoria.*
            - Ultimate segments not cuneate but toothed or lobed. 13. *Microlepia.*
  - Indusium absent; sporangia sunken in a marginal groove. 14. *Vittaria.*
- Sori dorsal, with or without indusia.
  - Indusium partly inferior, hood-shaped. 15. *Filix.*
  - Indusium superior or wanting.
    - Indusium wanting.
      - Sporangia following the veins.
        - Under surface covered with a waxy powder. 16. *Ceropteris.*
        - Under surface not covered with a waxy powder. 17. *Coniogramme.*
      - Sporangia in definite, roundish sori.
        - Leaves non-articulate. 18. *Dryopteris* (in part).
        - Leaves articulate.
          - Veins free. 19. *Polypodium.*
          - Veins anastomosing with free included veinlets.

- Veins indistinct, leaf blade simple. 20. *Phymatodes.*
- Veins distinct, leaf blade pinnatifid. 21. *Phlebodium.*
- Indusium present.
  - Sori roundish or oval.
    - Veins free.
      - Indusium circular, attached in the center. 22. *Polystichum.*
      - Indusium reniform or orbicular, attached at the side or in the sinus. 18. *Dryopteris* (in part).
    - Veins anastomosing.
      - Veins anastomosing regularly to form one or more areolae, with free included veinlets. 23. *Cyrtomium.*
      - Veins anastomosing copiously, with few included veinlets. 24. *Tectaria.*
  - Sori elongate, on the veins or crossing them.
    - Leaf blades simple. 25. *Neottopteris.*
    - Leaf blades pinnate to quadripinnate.
      - Veins free; sori oblique to the midrib.
        - Sori simple on the outer side of the veinlet or crossing it.
          - Sori usually straight. 26. *Asplenium.*
          - Sori usually curved, often crossing the veinlet. 27. *Athyrium.*
        - Sori double, usually opening outward. 28. *Diplazium.*
      - Veins anastomosing; sori parallel to the midrib.
        - Sori continuous. 29. *Sadleria.*
        - Sori interrupted. 30. *Doodia.*

1. ELAPHOGLOSSUM Schott, Gen. Fil. *pl. 14.* 1834

Mostly tropical plants found growing upon rocks or as epiphytes in the forests. Rootstock erect or creeping; leaves articulate, simple; blades of fertile leaves usually narrower than those of sterile leaves; veins usually free, occasionally anastomosing; sporangia covering the lower surface of the leaf, non-indusiate.

Type species: *Elaphoglossum conforme* (Sw.) Schott.

- Veins free.
  - Leaves densely covered with brown scales. *E. hirtum.*
  - Leaves smooth or bearing minute scattered scales.
    - Rootstock slender, 1–5 mm. in diameter.
      - Leaf blades oblong-lanceolate, acuminate. *E. micradenium.*
      - Leaf blades linear or linear-oblanceolate, acute or somewhat obtuse. *E. aemulum.*
    - Rootstock stout, 2–4 cm. in diameter; leaf oblanceolate, obtuse. *E. Wawrae.*
- Veins not free.
  - Veins anastomosing freely throughout. *E. reticulatum.*
  - Veins united by a marginal vein. *E. gorgonium.*

ELAPHOGLOSSUM HIRTUM (Sw.) C. Chr. Ind. Fil. 308. 1905

Acrostichum hirtum Sw. Jour. Bot. Schrad. **1800^2**: 10. 1801.

Acrostichum squamosum Sw. Jour. Bot. Schrad. **1800^2**: 11. 1801. Not Cav.

Acrostichum vestitum Lowe (*paleaceum* in plate); Hook. & Grev. Ic. Fil. **2**: 235. 1831. Not Schl. & Cham. Linnaea **5**: 605. 1830.

Elaphoglossum squamosum J. Sm. Jour. Bot. Hook. **4**: 148. 1841.

Elaphoglossum vestitum J. Sm. Ferns Brit. & For. 106. 1866.

Acrostichum micans Mett. in Kuhn, Linnaea **36**: 50. 1869.

TYPE LOCALITY: Azores (?)

DISTRIBUTION: Exposed ridges at 900–1,200 m. elevation, also on banks of streams in woods, tropical countries.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* C, N; *Robinson 272* V; *274* V; *283* V; Maui, *Lichtenthaler* N; *Heller 2688* C, N; Hawaiian Islands, *Baldwin 99* C, N; *Hillebrand* C; *Lindley* C; *Miss Sessions* C; ex Herb. John Donnell Smith N.

The description of *E. hirtum* by Swartz in Jour. Bot. Schrad. **1800^2**: 10. 1801 is inadequate but is amplified in Syn. Fil. 194. 1806.

ELAPHOGLOSSUM MICRADENIUM (Fée) Moore, Ind. Fil. 12. 1857

Acrostichum micradenium Fée, Mém. Foug. **2**: 43. 1845.

Elaphoglossum nitidum Brack. Fil. U. S. Expl. Exp. 70. 1854.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: On rocks and trees from 300 m. elevation upwards; Hawaiian Islands.

ILLUSTRATIONS: Fée, Mém. Foug. **2**: *pl. 8, f. 1.* 1845; Brack. Fil. U. S. Expl. Exp. *pl. 9, f. 3.* 1854.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; Maui, *Lichtenthaler* N; Oahu, *Robinson 49* V; *75* V; *110* V; *Safford 875* N; Kauai, *Heller 2621* C, N; Hawaiian Islands, *Baldwin 97* C, N; *Hillebrand* C; *Wilkes Expedition* C.

ELAPHOGLOSSUM AEMULUM (Kaulf.) Brack. Fil. U. S. Expl. Exp. 71. 1854

Acrostichum aemulum Kaulf. Enum. 63. 1824.
Olfersia aemula Presl, Tent. Pterid. 235. 1836.
Acrostichum Helleri Underw. in Heller, Minn. Bot. Stud. **1**: 771. 1897.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On trees at 900–1,200 m. elevation; Tropical America, Africa, India, Malaysia, and Australia.

ILLUSTRATION: Underw. in Heller, Minn. Bot. Stud. 1^2: 42. 1897.

SPECIMENS EXAMINED: Hawaii, *Robinson*; Oahu, *Chamisso* B; *Forbes* BM; Kauai, *Heller 2709* C, N; *Kuntze 23037* C; Hawaiian Islands, *Gaudichaud* C.

ELAPHOGLOSSUM WAWRAE (Luerssen) C. Chr. Ind. Fil. 318. 1906

Elaphoglossum aemulum Brack. Fil. U. S. Expl. Exp. 71. 1854. Not Kaulf. Enum. Fil. 63. 1824.
Acrostichum Wawrae Luerssen, in Wawra, Flora **58**: 420. 1875.

TYPE LOCALITY: Kauai.

DISTRIBUTION: In forests and on dry shaded rocks at 1,200 m. elevation; common; Hawaiian Islands.

ILLUSTRATION: PLATE 40.

SPECIMENS EXAMINED: Hawaii, District of Puna, *Wilkes Expedition* N; District of Waimea, *Wilkes Expedition* N; Mauna Loa, above 2,400 m., *Wilkes Expedition* N; Maui, *Lichtenthaler* N; *Mann & Brigham* N; *Robinson 309* V; *315* V; *355* V; Kauai, *Forbes 530* BM; *Heller 2808* C, N; Hawaiian Islands, *Bailey* C; *Baldwin 98* C, N; *Wilkes Expedition* C.

Brackenridge named his specimens of *Elaphoglossum Wawrae* *E. aemulum* and gave Kaulfuss's description of *Acrostichum aemulum* (Enum. 63. 1824), with slight changes, in his report, transferring the species from *Acrostichum* to *Elaphoglossum* (Brack.

Fil. U. S. Expl. Exp. 71. 1854). However, his specimens in the U. S. National Herbarium at Washington do not correspond with Kaulfuss's description of *A. aemulum* in dimensions or in other characters. The series of specimens noted above seems to represent but one species as indicated by the texture, uniform punctuations, and revolute margins of the leaves, and by the oblong-lanceolate scales of the rhizome. The dimensions of the leaves are fairly constant with the exception of a few plants, as *Baldwin 98* and *Wilkes Expedition*, Hawaii, District of Puna, which are smaller than the others.

ELAPHOGLOSSUM RETICULATUM (Kaulf.) Gaud. Voy. Bonite Bot. 1846

Acrostichum reticulatum Kaulf. Enum. 64. 1824.
Acrostichum crassifolium Gaud. Voy. Freyc. Bot. 303. 1828.
Hymenodium crassifolium Fée, Mém. Foug. **2**: 91. 1845.
Anetium reticulatum Presl, Epim. 176. 1849.
Hymenodium reticulatum Moore, Ind. Fil. 19. 1857.

TYPE LOCALITY: Oahu, Chamisso collector.

DISTRIBUTION: On trunks of trees and on rocks, common; Hawaiian Islands.

ILLUSTRATIONS: Fée, Mém. Foug. **2**: *pl. 63. f. 1.* 1845; Gaud. Voy. Bonite Bot. *pl. 79. f. 1–4.* 1846.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; Oahu, *Heller 2114* C, N; *Mann & Brigham 182* N; *Robinson 27* V; *106* V; *114* V; Kauai, *Heller 2567* C, N; *Robinson 436* V; Hawaiian Islands, *Baldwin 101* C; *Hillebrand 112* C; *Wilkes Expedition* C; ex Herb. John Donnell Smith N.

ELAPHOGLOSSUM GORGONIUM (Kaulf.) Brack. Fil. U. S. Expl. Exp. 74. 1854

Acrostichum gorgonium Kaulf. Enum. 63. 1824.
Olfersia gorgonea Presl, Tent. Pterid. 235. 1836.
Aconiopteris obtusa Fée, Mém. Foug. **2**: 80. 1845.
Olfersia obtusa Moore, Ind. Fil. **1**: 17. 1857.
Aconiopteris gorgonea J. Sm. Hist. Fil. 128. 1875.
Acrostichum pellucido-marginatum Christ, Verh. Nat. Ges. Basel **11**: 255. 1895.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On ground in wet woods at 600–700 m. elevation, Hawaiian Islands, Society Islands.

ILLUSTRATION: Fée, Mém. Foug. **2**: *pl. 41*. 1845.

SPECIMENS EXAMINED: Hawaii, *Mann & Brigham 286* N; Maui, *Lichtenthaler* N; *Robinson 303* V; Oahu, *Heller* C, N; *Robinson 4* V; *48* V; *Wilkes Expedition* N; Kauai, *Heller* C; *Robinson 833* V; Hawaiian Islands, *Baldwin 100* C; *Miss Sessions* C; ex Herb. Mt. Holyoke College C.

2. PTERIS L. Sp. Pl. 1073. 1753

A cosmopolitan genus of various habit. Rootstock usually creeping; leafstalk articulate; blades variously divided; sori marginal, linear, continuous upon a slender receptacle, connecting the tips of the free veins, indusiate.

Type species: *Pteris arborea* L.

Leaf blade broadly oblong, bipinnate; sterile pinnae broader than fertile pinnae, segments of former irregularly crenulate, segments of latter entire; midrib not winged. *P. excelsa.*

Leaf blade ovate to ovate-oblong, bipinnate to quadripinnate; midrib winged throughout or terminal pinnae decurrent.

- Midrib winged toward the apex, the terminal pinnae decurrent; leaf pinnate; pinnae linear-lanceolate, simple, or the lowest pair often bi-tripartite. *P. cretica.*
- Midrib winged throughout; leaf quadripinnate; pinnae varying from linear-lanceolate and entire to oblong and crenate-dentate. *P. irregularis.*

PTERIS EXCELSA Gaud. Voy. Freyc. Bot. 388. 1829

Pteris terminalis Wall. Cat. no. 101. 1828 (nomen).

Pteris owahuensis Presl, Tent. Pterid. 145 (nomen). 1836.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In damp gulches at elevations of 600–900 m.; Northern India, Malaysia, and Fiji Islands.

ILLUSTRATION: Hook. Sp. Fil. **2**: 136. 1846.

SPECIMENS EXAMINED: Hawaii, *Robinson 226* V; *235* V; Maui, *Bailey* C; *Robinson 306* V; Oahu, *Forbes* BM; *Hillebrand 407* V; *Robinson 104* V; Kauai, *Heller 2649*; Hawaiian Islands, *Baldwin 18; Wilkes Expedition 11* C; *Miss Sessions* C.

PTERIS CRETICA L. Mant. 130. 1767

Pteris nervosa Thunb. Fl. Jap. 332. 1784.

Pteris serraria Sw. Jour. Bot. Schrad. **1800**^{2}: 65. 1801.

Pteris pentaphylla Willd. Sp. Pl. **5**: 362. 1810.

Pteris triphylla Mart. & Gal. Mém. Acad. Brux. **15**: 51. *pl. 14. f. 1.* 1824.

Pteris scabripes Wall. Cat. no. 94. 1828.

Pteris melanocaulon Fée, Mém. Foug. **7**: 31. *pl. 19. f. 1.* 1857.

Pteris Treacheriana Baker, Jour. Bot. **17**: 65. 1879.

Pteris lomarioides Colenso, Trans. N. Z. Inst. **13**: 380. 1881.

TYPE LOCALITY: Crete.

DISTRIBUTION: On ground and on trees, tropical countries.

ILLUSTRATIONS: Mart. & Gal. Mém. Acad. Brux. **15**: 51. *pl. 14. f. 1.* 1824; Fée, Mém. Foug. **7**: 31. *pl. 19. f. 1.* 1857.

SPECIMENS EXAMINED: Maui, *Bailey* C; *Bishop* B; *Hillebrand* B; Oahu, *Heller 2782* C; *Hillebrand* B; *Robinson 22* V; *25* V; *42* V; Kauai, *Knudsen 39* B; Hawaiian Islands, *Baldwin 19* B, C.

PTERIS IRREGULARIS Kaulf. Enum. 189. 1842

Pteris alata Gaud. Voy. Freyc. Bot. 391. 1829.

Pteris regularis E. Bailey, Haw. Ferns 26. 1883.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In woods and shady gulches 300–900 m. elevation; Hawaiian Islands.

ILLUSTRATION: Gaud. Voy. Freyc. Bot. *pl. 19.* 1829.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B, K; Maui, *Bailey* C; *Hillebrand* B; *Wilkes Expedition* C; Oahu, *Bennett 85* B; *Chamisso* C; *Forbes* BM; *Gaudichaud* B; *Heller 2335* C; *Hillebrand* B; *79* B; *Lindley* K; *Macrae* B; *Mann & Brigham 162* C; *Meyen* B; *Nuttall* K; *Robinson 12* V; *56* V; *61* V; *65* V; *116* V; Kauai, *Knudsen 40* B; *41* B; *69* B; Hawaiian Islands, *Baldwin 17* B, C; *Douglas 31* K; *Gaudichaud 184* B; *Hillebrand* K; *Knudsen 29* B; *42* B; *Miss Sessions* C; *Wilkes Expedition* C.

Bailey (Haw. Ferns 25. 1883) believed that two species had been confused under the name *P. irregularis* and sought to clear up the difficulty by describing *P. regularis*. The variations shown by leaves growing upon the same plant permit placing the several forms in one species.

3. PTERIDIUM Gleditsch, in Scop. Fl. Carn. 169. 1760

Rootstock wide-creeping; leaves distant, not articulate, triangular to deltoid-ovate, ternately compound; sorus linear, following the vein which connects the tips of the otherwise free veins; indusium double, the outer formed from the incurved margin of the frond, the inner attached to the receptacle on the inner side and enclosed by the outer indusium, both ciliate at the margin.

Type species: *Pteris aquilina* L.

PTERIDIUM AQUILINUM (L.) Kuhn; v. Decken, Reisen Ost. Afr. Bot. 11. 1879

Pteris aquilina L. Sp. Pl. 1075. 1753.
Cincinalis aquilina Gled. Syst. Pl. 290. 1764.
Asplenium aquilinum Bernh. Jour. Bot. Schrad. **1799**[1]: 310. 1799.
Pteris psittacina Presl, Del. Prag. 185. 1822.
Pteris arachnoidea Kaulf. Enum. 190. 1824.
Allosorus aquilinus Presl, Tent. Pterid. 153. 1836.
Eupteris aquilina Newman, Phytologist **2**: 278. 1845.
Paesia aquilina Keyserl. Polyp. Cyath. Herb. Bung. 22. 1873.
Ornithopteris aquilina J. Sm. Hist. Fil. 298. 1875.

TYPE LOCALITY: Europe.

DISTRIBUTION: Common through tropics and North Temperate zones.

ILLUSTRATIONS: Diels, in E. & P. Nat. Pfl. **1**[4]: 296. 1899; Waters, Ferns 93. 1903.

SPECIMENS EXAMINED: Hawaii, *Baldwin 17;* Mauna Loa, *Wilkes Expedition* C; Maui, *Bailey 40* C; Kauai, *Heller 2416* C; *40* C; Hawaiian Islands, *Baldwin 20* C, N; ex Herb. John Donnell Smith *17*.

In the Olinda woods at 1,300 m. elevation on Mt. Haleakala, Maui, plants of *Pteridium aquilinum* attain such size that it seems hardly possible that they are of the same species as the dwarfed, leathery, and resistant forms that grow upon the exposed rocks at from 2,000 m. to 3,000 m. elevation. Further study may show that they are distinct species, but for the present their differences must be considered ecological rather than taxonomic.

4. PELLAEA Link, Fil. Sp. 59. 1841

Xerophilous plants, usually found upon rocks. Rootstock short, erect; leaves cespitose, articulate; blades consisting of 1 to 3 nearly uniform leaflets; sori marginal, borne upon the ends of unconnected veins; indusium formed by the reflexed margin of the leaf.

Type species: *Pteris atropurpurea* L.

PELLAEA TERNIFOLIA (Cav.) Link, Fil. Sp. 59. 1841

Pteris ternifolia Cav. Desc. Pl. Dem. 266. 1802.
Pteris peruviana Poir. in Lam. Encyc. **5**: 718. 1804. (Reduced to synonym in supplement.)
Pteris subverticillata Sw. Syn. Fil. 103. 1806.
Allosorus ternifolius Kunze; Klotzsch, Linnaea **20**: 339. 1847.
?*Pellaea Weddelliana* Fée, Mém. Foug. **8**: 4. 1857.
Cheilanthes ternifolia Moore, Ind. Fil. 255. 1861.
Nothochlaena ternifolia Keyserl. Polyp. Cyath. Herb. Bung. 30. 1873.

TYPE LOCALITY: Peru.

DISTRIBUTION: At elevations of 1,500 m. in dry exposed places in the mountains, Chile to Texas; Hawaiian Islands.

ILLUSTRATIONS: Hook. & Grev. Ic. Fil. **2**: *pl. 126.* 1829; Lowe, Ferns Brit. & Exot. **3**: *pl. 24b.* 1857.

SPECIMENS EXAMINED: Hawaii, *Lichtenthaler* N; *Mann & Brigham 262* N; *Safford 884* N; *Wilkes Expedition* N; Maui, *Bailey* C; *Robinson 312* V; Kauai, *Wilkes Expedition* C, N; Hawaiian Islands, *Baldwin 15* C, N; *Lindley* C; *Moore* C; *Remy 40* C; *Miss Sessions* C; ex herb. Kew Gardens C.

5. DORYOPTERIS J. Sm. Jour. Bot. Hook. 3: 404. 1841

Rootstock short, erect; leaves cespitose, palmate or pedate, coriaceous; petiole black, polished; veins free or anastomosing, indistinct; sori marginal; indusium usually revolute with age.

Type species: *Pteris hastata* Raddi.

Leaf blades broadly deltoid; ultimate segments lanceolate.	*D. decipiens.*
Leaf blades ovate-cordate; ultimate segments linear.	*D. decora.*

DORYOPTERIS DECIPIENS (Hook.) J. Sm. Hist. Fil. 289. 1875

Pteris pedata Hook. & Arn. Bot. Beech. 107. 1832. Not Willd.
Doryopteris pedata Brack. Fil. U. S. Expl. Exp. 403. 1854.
Pteris decipiens Hook. Sp. Fil. **2**: 209. 1858.
Litobrochia decipiens Moore, Ind. Fil. 342. 1862.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In crevices in rocks at 350 m. or more elevation, Hawaiian Islands.

ILLUSTRATION: Hook. Exot. Ferns *pl. 34*. 1858.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; Maui, *Bailey* C; *Lichtenthaler* N; Oahu, *Heller* C; *Mann & Brigham 136* N; *Wilkes Expedition* N; Hawaiian Islands, *Baldwin* C; *21* C; *Hillebrand* C; *Moore* C; ex Herb. John Donnell Smith *67* N.

DORYOPTERIS DECORA Brack. Fil. U. S. Expl. Exp. 103. 1854
Pteris decora Hook. Sp. Fil. **2**: 210. 1858.
Litobrochia decora Moore, Ind. Fil. 342. 1862.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: On exposed rocks at elevations of about 600 m., Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 13. f. 1*. 1854.

SPECIMENS EXAMINED: Hawaii, *Mann & Brigham* N; *Wilkes Expedition* N; Maui, *Bailey* C; *Safford 882* N; Kauai, *Heller 2654* C, N; *Heller* C; Lanai, *Hillebrand* N; Hawaiian Islands, *Baldwin 22* C, N; *Wilkes Expedition* C.

6. ADIANTUM L. Sp. Pl. 1094. 1753

Delicate ferns, inhabiting moist, shady localities. Rootstock creeping or suberect; leafstalks slender, usually dark and lustrous, not articulate; blades pinnate to pinnately decompound or tripinnate; sori terminal upon the free forking veins within the reflexed lobes (indusia) of the leaflets.

Type species: *Adiantum Capillus-veneris* L.

ADIANTUM CAPILLUS-VENERIS L. Sp. Pl. **2**: 1096. 1753
Adiantum Capillus Sw. Jour. Bot. Schrad. **1800**^{2}: 83. 1801.
Adiantum emarginatum Bory; Willd. Sp. Pl. **5**: 449. 1810.
Adiantum Wattii Baker, Jour. Linn. Soc. **18**: 381. 1881.
Adiantum Levingei Baker, Ann. Bot. **5**: 207. 1891.

TYPE LOCALITY: Southern Europe.

DISTRIBUTION: On ground or moist rocks in tropics and subtropics.

ILLUSTRATIONS: Hook. Brit. Ferns 41. 1861; Ettingsh. Farnkr. 44. *f. 5. 11–17*. 1865.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; Maui, *Bailey 41* C; Oahu, *Hitchcock* C; *Lichtenthaler* N; *Mann & Brigham* N; *Remy 241* B; *Robinson* V; *Safford 880* N; Kauai, *Forbes 306* BM; *Heller 2479* C, N; Hawaiian Islands, *Baldwin 14* B, C; *Moore* C; *Miss Sessions* C; *Wilkes Expedition 5* B.

SPECIES INQUIRENDA

Adiantum Bennettii Carruth. in Seeman, Fl. Vit. 346. 1873

Hillebrand states that a specimen of this plant collected by Lieut. Strickland is in the herbarium of the British Museum, but it cannot be found there at the present time (1911).

7. HYPOLEPIS Bernh. Neues Jour. Bot. Schrad. 1^2: 34. 1806

Rootstock slender, wide-creeping; leaves pinnate to quadripinnate, herbaceous, hairy; leafstalk not articulate; veins free; sori borne in the sinuses of the segments; indusium formed by the small reflexed marginal lobe of the leaf.

Type species: *Lonchitis tenuifolia* Forst.

Leaf blade quadripinnate; petiole brownish at base, stramineous above; intervals on rootstock between leaves about 12 cm.	*H. punctata.*
Leaf blade bipinnate; leafstalk purplish red; intervals on rootstock between leaves 4–6 cm.	*H. flaccida.*

HYPOLEPIS PUNCTATA (Thunb.) Mett. in Kuhn, Fil. Afr. 120. 1868

Polypodium punctatum Thunb. Fl. Jap. 337. 1784. Not Swartz.
Polypodium Paepigii Kunze; Klotzsch, Linnaea 9: 50. 1834.
Phegopteris punctata Mett. Ann. Lugd. Bat. 1: 222. 1864.
Phegopteris punctata var. *glabra* Hilleb. Fl. Haw. Is. 562. 1888.
Hypolepis tenuifolia Underw. in Heller, Minn. Bot. Stud. 1: 782. 1897.
Nephrodium punctatum Diels in E. & P. Nat. Pfl. 1^4: 177. 1899.

TYPE LOCALITY: Japan.

DISTRIBUTION: Japan, China, Malaysia, Polynesia, Australia, New Zealand, Hawaiian Islands.

SPECIMENS EXAMINED: *Heller 2778* C.

H. tenuifolia (Forst.) Bernh. and *H. punctata* Mett. may be synonyms, though the term "arborescens" in Forster's original description does not apply to the Hawaiian plant nor to the plants from Japan, China, and the South Pacific Islands, which are labeled "*Hypolepis tenuifolia*" in herbaria.

Hypolepis flaccida (Hilleb.) comb. nov.

Phegopteris punctata var. *flaccida* Hilleb. Fl. Haw. Is. 563. 1888.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Hawaiian Islands.

SPECIMENS EXAMINED: *Baldwin 80* C, V.

8. SCHIZOSTEGE Hilleb. Fl. Haw. Is. 631. 1888

Rootstock erect; leaves clustered, bipinnate at the base, bipinnatifid above, cyatheoid; sori oblong, marginal upon the T-shaped expansions of the veins, which occasionally anastomose; indusium coriaceous.

Type species: *Schizostege Lydgatei* Hilleb.

SCHIZOSTEGE LYDGATEI (Bak.) Hilleb. Fl. Haw. Is. 632. 1888

Cheilanthes Lidgatii Baker; Hook. & Baker, Syn. Fil. 475. 1874.

Pteris Lydgatei Christ, Farnkr. Erde 167. 1897.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On ground, Oahu and Maui, Hawaiian Islands.

ILLUSTRATION: PLATE 41.

SPECIMENS EXAMINED: Maui, Gulch of Waihee, *Hillebrand* B; Oahu, Valley of Wailupe, *Lydgate & W. F. Hillebrand* B; Koolaulua Mts., between Punahua and Kaipaupau, *Forbes* BM.

The specimens noted above are the only collections of this species that have been recorded, and an interval of about twenty-five years elapsed between the collections made upon Oahu.

The habit of *Schizostege* closely resembles that of *Pteris biaurita* L., but the relation is no closer than that of *Cheilanthes* to *Pteris* or of *Pellaea* to *Cheilanthes*.

Schizostege was a monotypic Hawaiian genus until Copeland (Philip. Jour. Sci. 1: Suppl. 2. 1906) described two Philippine species, *S. pachysora* and *S. calocarpa*, both of which he states resemble *Cheilanthes* to a greater extent than they resemble *Pteris*.

9. DIELLIA Brack. Fil. U. S. Expl. Exp. 217. 1854

Rootstock short; leaves cespitose; veins forking, uniting to form oblique areolae, free at the margin of the leaf or united by a transverse vein upon which the sporangia are borne; sori distinct; indusium linear-oblong, parallel to the margin of the leaf and opening outward.

Type species: *Diellia erecta* Brack.

- Leaf blades pinnate.
  - Leafstalk and midrib smooth.
    - Pinnae not more than 3 mm. broad, linear, zigzag from the alternate crenations of the margin. *D. centifolia.*
    - Pinnae more than 3 mm. broad.
      - Leaf 8–10 cm. high, coriaceous; pinnae rhomboid-ovate above, orbicular below. *D. pumila.*
      - Leaf more than 10 cm. high, chartaceous; pinnae lanceolate, auricular. *D. erecta.*
  - Leafstalk and midrib scaly.
    - Pinnae cut into cuneiform segments. *D. Alexandri.*
    - Pinnae not cut into cuneiform segments.
      - Pinnae lanceolate, acute, repand. *D. falcata.*
      - Pinnae deltoid-lanceolate, caudate, laciniate. *D. laciniata.*
- Leaf blades tripinnatifid to quadripinnate.
  - Blades tripinnatifid, 6–7-jugate. *D. Knudsenii.*
  - Blades quadripinnatifid, 40–50-jugate. *D. Mannii.*

Diellia centifolia (Hilleb.) comb. nov.

Lindsaya centifolia Hilleb. Fl. Haw. Is. 621. 1888.

TYPE LOCALITY: Halemanu, Kauai.

DISTRIBUTION: Known from type locality only.

ILLUSTRATION: Diels in E. & P. Nat. Pfl. 1^4: 211. *f. 114D.* 1899.

SPECIMENS EXAMINED: Kauai, *Knudsen 35* (type) B.

It seems possible that *Diellia centifolia* may have arisen from a cross between *Diellia falcata* and *Diellia Alexandri*, by which it inherited the position of the sori from the former parent and the modified form of the pinnae from the latter parent.

DIELLIA PUMILA Brack. Fil. U. S. Expl. Exp. 219. 1888

TYPE LOCALITY: Oahu.

DISTRIBUTION: In crevices of rocks, rare; Oahu, Hawaiian Islands.

SPECIMENS EXAMINED: Oahu, *Hillebrand* B; Nuuanu Valley, Oahu, *Hillebrand* B.

This species is represented at Kew by *Wilkes Expedition 2*, which is probably a cotype if not the type specimen.

DIELLIA ERECTA Brack. Fil. U. S. Expl. Exp. 218. 1854

TYPE LOCALITY: Mountain forest, Western division of Maui.

DISTRIBUTION: Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 31. f. 2.* 1854.

SPECIMENS EXAMINED: Maui, *Baker* C; *Baldwin* B; *Hillebrand* B; Kauai, *Van Ingen* C; Hawaiian Islands, *Baldwin 28* B; *Moore* B; ex Herb. Lindley C.

DIELLIA ALEXANDRI (Hilleb.) Diels in E. & P. Nat. Pfl. 1^4: 212. 1899

Lindsaya Alexandri Hilleb. Fl. Haw. Is. 622. 1888.

TYPE LOCALITY: Halemanu, Kauai.

DISTRIBUTION: Known from type locality only.

ILLUSTRATION: Diels in E. & P. Nat. Pfl. 1^4: 211. *f. 114G, H.* 1899.

SPECIMENS EXAMINED: Kauai, *Knudsen* B; Maui, *Baldwin* C, V; Hawaiian Islands, *Baldwin 12* C.

DIELLIA FALCATA Brack. Fil. U. S. Expl. Exp. 219. 1854

TYPE LOCALITY: Kaala Mountains, Oahu.

DISTRIBUTION: On dry, open ridges, Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 31. f. 1.* 1854.

SPECIMENS EXAMINED: Maui, *Hillebrand* B; Oahu, *Hillebrand* B; Kauai, *Van Ingen* C; Hawaiian Islands, *Baldwin 29* C.

Diellia laciniata (Hilleb.) comb. nov.

Lindsaya laciniata Hilleb. Fl. Haw. Is. 621. 1888.

TYPE LOCALITY: Halemanu, Kauai.

DISTRIBUTION: Known from type locality only.

ILLUSTRATION: Diels in E. & P. Nat. Pfl. 1^4: 211. *f. 114E, F.* 1899.

SPECIMENS EXAMINED: Halemanu, Kauai, *Knudsen* B.

Hillebrand's β variety *subbipinnata* has more symmetrical pinnae than the type. His variety γ, as represented in the Berlin herbarium, is a monstrosity.

Diellia Knudsenii (Hilleb.) Diels in E. & P. Nat. Pfl. 1^4: 212. 1899

Lindsaya Knudsenii Hilleb. Fl. Haw. Is. 623. 1888.

Type locality: Halemanu, Kauai.

Distribution: Known from Hawaiian Islands only.

Illustrations: Diels in E. & P. Nat. Pfl. 1^4: 212. *f. 114L–N.* 1899.

Specimens examined: Kauai, *Knudsen 19* (type) B.

Diellia Mannii (Hilleb.) comb. nov.

Microlepia Mannii D. C. Eaton in Mann, Proc. Am. Acad. **7**: 212. 1867.

Davallia Mannii Baker in Hook. & Baker, Syn. Fil. ed. 2. 471. 1874.

Lindsaya Mannii Hilleb. Fl. Haw. Is. 624. 1888.

Humata Mannii Diels in E. & P. Nat. Pfl. 1^4: 209. 1899.

Type locality: Kauai.

Distribution: Hawaiian Islands.

Specimens examined: Maui, *Bishop* B; Kauai, *Baldwin 10* B, C; *Forbes 333* BM; *Knudsen 38* B; *Mann & Brigham 546* B; Hawaiian Islands, *Baldwin* V.

10. ODONTOLOMA J. Sm. Jour. Bot. Hook. **3**: 415. 1841

Rootstock creeping, slender, scaly, much branching; leafstalk not articulate; blades membranaceous, dimidiate; veins forking, free or united in pairs at their apices; sori submarginal, discrete; indusium attached by a broad base, free laterally and apically, opening outward.

Type species: *Odontoloma pulchella* J. Sm.

Odontoloma Macraeanum (Hook. & Arn.) Brack. Fil. U. S. Expl. Exp. 226. 1854

Davallia Macraeana Hook. & Arn. Bot. Beech. Voy. 108. 1832.

Acrophorus repens Moore, Ind. Fil. 91. 1857.

Acrophorus Macraeanus Carruth. in Seeman, Fl. Vit. 336. 1869.

Type locality: Hawaiian Islands.

DISTRIBUTION: Hawaiian Islands, common.

ILLUSTRATION: Hook. & Grev. Ic. Fil. *pl. 143*. 1829.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* C; Maui, *Baldwin* B; *Baldwin 7* B; *Robinson 203* V; *367* V; *369* V; Oahu, *Forbes* BM; (Honolulu) *Hillebrand* C; (Konhuanui) *Hillebrand* B; (Nuuanu) *Hillebrand* B; *Macrae* B; *Robinson 163* V; *193* V; *613* V; *Wilkes Expedition* C; Kauai, *Robinson 427* V; *433* V; *437* V; *499* V; *Remy* C; Hawaiian Islands, *Baldwin* B; *Gaudichaud* B; *Wilkes Expedition* B.

Odontoloma Macraeanum differs from *Lindsaya repens* in that the sori are submarginal rather than marginal, as they are in the latter, and are discrete rather than confluent. Superficially they are much alike.

11. NEPHROLEPIS Schott, Gen. Fil. *pl. 3*. 1834

Terrestrial or epiphytic plants, mainly found in the tropics; rhizome creeping or suberect; leafstalk not articulate; blades pinnate, usually coriaceous, spreading or pendent; pinnae approximate, articulate; veins free, forked, each terminating in a punctiform apex, which bears a calcareous scale on the outer side; sori borne apically upon the upper branch of a vein, thus forming a single row parallel to the midrib; indusium circular or reniform.

Type species: *Nephrolepis exaltata* (L.) Schott.

Rootstock bearing tubers; indusium opening toward apex of pinna.	*N. cordifolia.*
Rootstock without tubers; indusium opening obliquely toward margin of pinna.	*N. exaltata.*

NEPHROLEPIS CORDIFOLIA (L.) Presl, Tent. Pterid. 79. 1836

Polypodium cordifolium L. Sp. Pl. 1089. 1753.
Aspidium cordifolium Sw. Jour. Bot. Schrad. **1800**^{2}: 32. 1801.
Aspidium undulatum Afz.; Sw. Jour. Bot. Schrad. **1800**^{2}: 32. 1801.
Aspidium tuberosum Bory in Willd. Sp. Pl. **5**: 234. 1810.
Nephrolepis tuberosa Presl, Tent. Pterid. 79. 1836.
Nephrolepis pendula J. Sm. Jour. Bot. Hook. **4**: 197. 1842.

TYPE LOCALITY: West Indies.

DISTRIBUTION: On ground and on trees; tropical countries, Japan, New Zealand.

ILLUSTRATIONS: Raddi, Pl. Bras. **1**: *pl. 46*. 1825; Diels in E. & P. Nat. Pfl. **1**^{4}: 205. *f. 111*. 1899.

SPECIMENS EXAMINED: Hawaii, *Robinson 225* V; *Forbes 291* BM.

Mr. J. F. Rock, botanist of the Forestry Station of the Hawaiian Department of Agriculture, reports having found *N. cordifolia* (L.) Presl [*N. tuberosa* (Bory) Presl] on Punaluu Trail above Kaliiuao, Oahu, on Mr. James Castle's place. He also says that he has specimens of the same plant in his herbarium, which were collected by Mr. Lyons, a missionary on the islands, about fifty years ago.

N. cordifolia, introduced into the Hawaiian Islands from Japan, is used as a border plant in gardens.

NEPHROLEPIS EXALTATA (L.) Schott, Gen. Fil. *pl. 3.* 1834
Polypodium exaltatum L. Syst. ed. 10^2: 1326. 1759.
Aspidium exaltatum Sw. Jour. Bot. Schrad. 1800^2: 32. 1801.
Nephrodium exaltatum R. Br. Prod. Fl. N. Holl. 148. 1810.
Aspidium Schkuhrii Bl. Enum. Fil. Jav. 147. 1828.
Nephrolepis cultrifolia Presl, Tent. Pterid. 79. 1836.

TYPE LOCALITY: Jamaica.

DISTRIBUTION: Epiphytic on trees; common in tropical countries.

ILLUSTRATIONS: Plumier, Fil. Am. *pl. 63.* 1703; Sloane, Hist. Jam. 1: *pl. 31.* 1707; Schkuhr, Krypt. Gew. *pl. 32b.* 1809 (not Mett. Fil. Hort. Lips. *pl. 26. f. 1–5.* 1856); Raddi, Pl. Bras. 1: *pl. 46.* 1825.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* C; Maui, *Robinson 305* V; Oahu, *Chamisso* B; *Heller 1987* C; *Macrae* B; *Meyen* B; Kauai, *Heller 2873* C; *Kuntze 23041* C; *Robinson 6* V; *154* V; *423* V; *425* V; Hawaiian Islands, *Baldwin 73* C; *Gaudichaud* B, C; *Miss Sessions* C.

12. ODONTOSORIA Presl, Tent. Pterid. 129. 1836

Rootstock short, creeping; leafstalks not articulate; blades 2–3-pinnate; ultimate divisions cuneate, usually truncate; veins simple or forked, if sterile, punctiform at the apex. Sori apical or subapical; indusium semiorbicular, attached at the base and sides, truncate at the apex.

Type species: *Davallia biflora* Kaulf.

ODONTOSORIA CHINENSIS J. Sm. Bot. Voy. Herald 430. 1857

Trichomanes chinensis L. Sp. Pl. 1099. 1753.
Adiantum chusanum L. Sp. Pl. 1095. 1753.
Adiantum chinense Burm. Fl. Ind. 236. 1768.
Trichomanes cuneiforme Forst. Prod. 330. 1786.
Davallia chinensis J. E. Sm. Mém. Acad. Turin **5**: 414. 1793.
Davallia chusana Willd. Sp. Pl. **5**: 414. 1793.
Davallia tenuifolia Sw. Jour. Bot. Schrad. **1800**^{2}: 88. 1801.
Adiantum tenuifolium Poir. in Lam. Encyc. **1**: 44. 1810.
Davallia remota Kaulf. Enum. 223. 1824.
Microlepia tenuifolia Mett. Fil. Lips. 104. 1856.
Stenoloma tenuifolium Fée, Gen. Fil. 330. 1852.
Lindsaya chinensis Mett. in Kuhn, Fil. Afr. 67. 1868.

TYPE LOCALITY: Bojei, Mauritius.

DISTRIBUTION: Tropical countries.

ILLUSTRATIONS: Mett. Fil. Lips. *pl. 27. f. 1–4.* 1856.

SPECIMENS EXAMINED: Hawaii, *Kuntze 1904* C; *23089* C; *Robinson* V; Maui, *Bailey* C; Oahu, *Capt. Haines* B, C; *Heller 2327* C; *2328* C; *Robinson 3* V; *25* V; *165* V; *Knudsen 16* B; *Wilkes Expedition 13* B; Kauai, *Kuntze 23034* C; Molokai, *Hillebrand* B; Hawaiian Islands, *Baldwin 11* B, C; *Chamisso* B; *Gaudichaud* B; *Miss Sessions* C; *Wilkes Expedition* C.

13. MICROLEPIA Presl, Tent. Pterid. 124. 1836

Rootstock slender, creeping; leafstalk not articulate; blades various in size and texture; veins free, once or more than once forked; sori cup-shaped, upon a tooth or a sinus; indusium membranaceous, attached at sides and base, opening outward.

Type species: *Microlepia brasiliensis* Presl.

Leaf blade bipinnate, coriaceous, paleaceous.	*M. strigosa.*
Leaf blade tripinnate, chartaceous, glabrate.	*M. Speluncae.*

MICROLEPIA STRIGOSA (Thunb.) Presl. Epim. 95. 1849

Trichomanes strigosum Thunb. Fl. Jap. 339. 1784.
Dicksonia strigosa Thunb. Trans. Linn. Soc. **2**: 341. 1794.
Dicksonia japonica Sw. Jour. Bot. Schrad. **1800**^{2}: 92. 1801.
Davallia polypodioides Don, Prod. Fl. Nepal. 10. 1825.
Microlepia cristata J. Sm. Jour. Bot. Hook. **3**: 416. 1841.

Davallia strigosa (Sw.) Kunze, Bot. Zeit. **6**: 542. 1848.
Microlepia Khasiyana Presl, Epim. 95. 1849.
Microlepia japonica Presl, Epim. 95. 1849.
Davallia Khasiyana Hook. Sp. Fil. **1**: 173. 1856.
Dennstaedtia strigosa J. Sm. Hist. Fil. 265. 1875.

TYPE LOCALITY: Japan.

DISTRIBUTION: Tropics and subtropics, common.

ILLUSTRATIONS: Hook. Sp. Fil. **1**: *pl. 47A, 57A*. 1856.

SPECIMENS EXAMINED: Hawaii, *Robinson 253* V; *261* V; Maui, *Baldwin* B; *Robinson 356* V; Oahu, *Beechey* C; *Heller 2012* C; *2327* C; *Meyen* B; *Wilkes Expedition* B, C; Kauai, *Forbes 423* BM; *Heller 2480* C; *2803* C; Molokai, *Hillebrand* B; Hawaiian Islands, *Baldwin 8* B, C; *Miss Sessions* C.

The specimens vary as to the amount of pubescence, those collected in certain very moist localities, such as the Olao woods (*Robinson 253* V, *261* V), being much more furfuraceous than those collected in drier localities, as *Heller 2803*. The variation from narrowly to broadly lanceolate is not correlated with this, nor is there any correspondence in size with the greater size of *Microlepia hirta*, hence Hillebrand's variety *hirta* may be disregarded.

MICROLEPIA SPELUNCAE Moore, Ind. Fil. 93. 1857

Polypodium Speluncae L. Sp. Pl. 1093. 1753.
Davallia flaccida R. Br. Prod. Fl. N. Holl. 157. 1810.
Aspidium Speluncae Willd. Sp. Pl. **5**: 269. 1810.
Microlepia polypodioides Presl, Tent. Pterid. 125. 1836.
Microlepia flaccida J. Sm. Jour. Bot. Hook. **1**: 427. 1842.
Davallia Speluncae Baker in Hook. & Baker, Syn. Fil. 100. 1867.

TYPE LOCALITY: India.

DISTRIBUTION: Tropics and subtropics.

ILLUSTRATION: Pluk. Phytog. *pl. 244. f. 2*. 1692.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; Maui, *Bailey* C; Oahu, *Heller 2072* C; *Hillebrand* B; *Robinson* V; Kauai, *Heller 2650* C; Hawaiian Islands, *Baldwin* B, C; *Miss Sessions* C.

14. VITTARIA J. E. Smith, Mém. Acad. Turin **5**: 413. *pl. 9. f. 5*. 1793

Epiphytic plants of tropical regions; rootstock slender, creeping, scaly; leaves clustered, linear, grasslike, sessile or short-stalked, articulate; veins anastomosing to form a single row of areolae on either side of the midvein; sorus upon a linear receptacle formed by a marginal or intramarginal groove on each side of the leaf, non-indusiate.

Type species: *Pteris lineata* L.

VITTARIA RIGIDA Kaulf. Enum. 193. 1824

TYPE LOCALITY: Oahu.

DISTRIBUTION: On trees, Polynesia.

SPECIMENS EXAMINED: Hawaii, *Robinson 204* V; *252* V; Oahu, *Chamisso* B; *Heller 2054* C; *2532* C; *Robinson 152* V; *521* V; *522* V; Kauai, *Kuntze 23039* C; Hawaiian Islands, *Baldwin 96* C; *Lindley* C; *Wilkes Expedition 3* C; *Moore* C.

This is the species wrongly referred by Hillebrand to *V. elongata* Sw. (Hilleb. Fl. Haw. Is. 551. 1888), the type of which is from India. In the Indian plants the ventral lip of the sorus is shorter than the lateral lip, so that the sporangia are invisible, and the leaves are nearly three times as long as those of the Hawaiian plants.

15. FILIX Adans. Fam. Pl. 20. 1763

Delicate rock ferns, found mainly in temperate regions. Rootstock short, erect; leaves clustered, not articulate; sori medial, subglobose; indusium attached by a broad base on the inner side, free above, soon reflexed.

Type species: *Polypodium bulbiferum* L.

Filix Douglasii (Hook.) comb. nov.

Cystopteris Douglasii Hook. Sp. Fil. 1: 200. 1846.

Cystopteris sandwichensis Brack. Fil. U. S. Expl. Exp. 234. 1854.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Hawaiian Islands.

ILLUSTRATION: Hook. Cent. Ferns *pl. 55*. 1854.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N, Herb. D. C. Eaton; Maui, *Wilkes Expedition* N; *Hillebrand* B; *Lichtenthaler* N; *Mann & Brigham* N; Oahu, *Hillebrand* B; Hawaiian Islands, *Baldwin* C; *Brackenridge* N.

16. CEROPTERIS Link, Fil. Sp. 141. 1841

Rootstock creeping or short oblique, covered with brown, linear-lanceolate scales; leaves cespitose; leafstalks not articulate; blades bipinnate to tripinnate, covered below with a waxy powder; veins free; sori following the course of the veins, non-indusiate.

Type species: *Acrostichum calomelanos* L.

Leaf blades bipinnate with a pinnatifid apex; powder on lower surface yellow.	*C. ochracea.*
Leaf blades tripinnate; powder on lower surface white.	*C. calomelanos.*

Ceropteris ochracea (Presl) comb. nov.

Gymnogramme tartarea var. *β* Hook. & Baker, Syn. Fil. 384. 1867.

TYPE LOCALITY: South America.

DISTRIBUTION: In moist thickets, tropical America, Costa Rica, Natal, and Hawaiian Islands.

SPECIMENS EXAMINED: Oahu, *Forbes* BM; *Robinson* V.

Mr. C. N. Forbes notes: "I find the species to be widely spread over the whole group (Hawaiian Islands), especially along the irrigation ditches. The golden variety is much less common than the silver."

This fern has been reported from the Philippines, where it has been thought to be an escape.

CEROPTERIS CALOMELANOS (L.) Link, Fil. Sp. 141. 1841.
(As *C. calomelaena*)

Acrostichum calomelanos L. Sp. Pl. 1072. 1753.

Gymnogramma calomelanos Kaulf. Enum. Fil. 76. 1824.

Neurogramme calomelanos Diels in E. & P. Nat. Pfl. 1^4: 264. 1899.

TYPE LOCALITY: West Indies.

DISTRIBUTION: In open places, in wet ground, West Indies, South America, Hawaiian Islands.

ILLUSTRATIONS: Plumier, Traité Foug. *pl. 40.* 1705; Sloane Hist. Jam. *pl. 30. f. 2.* 1735.

SPECIMENS EXAMINED: Oahu, *Forbes 1* BM; *Robinson* V.

17. CONIOGRAMME Fée, Mém. Foug. 5: 167. 1852

Mostly terrestrial plants. Rootstock creeping; leaves not articulate, pinnate or bipinnate, light green, glabrous, or slightly pubescent beneath, chartaceous; veins free, 1–3-forked; sori linear, continuous upon the veins and forking with them, non-indusiate.

CONIOGRAMME FRAXINEA (Don) Diels in E. & P. Nat. Pfl. 1^4: 262. 1899

Diplazium fraxineum Don, Prod. Fl. Nepal. 12. 1825.

Gymnogramme pilosa Brack. Fil. U. S. Expl. Exp. 22. 1854. Not Mart. & Gal. 1842.

Gymnogramme javanica Hook. Syn. Fil. 381. 1867. Not Blume 1828.

TYPE LOCALITY: Nepal.

DISTRIBUTION: In wet woods at 900–1,200 m. elevation, Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 4. f. 1.* 1854.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; *Robinson 200* V; *Wilkes Expedition* N; Maui, *Bishop 68* B; *Hillebrand* B; *Mann & Brigham 486* N; *Robinson 314* V; *358* V; Oahu, *Robinson 44* V; *53* V; Kauai, *Forbes* BM; *Heller 2637* C, N; *Knudsen 100* B; *Lichtenthaler* N; Hawaiian Islands, *Baldwin 95* C, N; *Wilkes Expedition* N.

18. DRYOPTERIS Adans. Fam. Pl. 2: 20. 1763

Rootstock erect or creeping, usually short; leafstalk not articulate; blade pinnate to quadripinnate; veins free or those in adjacent lobes connate; sori round to elliptical; indusium, if present, usually reniform, with narrow sinus.

Type species: *Polypodium Filix-mas* L. Sp. Pl. 1090. 1753.

- Veins free.
  - Indusium present.
    - Leaf blades bipinnatifid; basal pinnae reduced.
      - Under surface paleaceous with whitish hairs mingled with resinous dots. *D. globulifera.*
      - Under surface densely covered, at least as to leafstalk and midribs, with linear-lanceolate, long-acuminate scales.
        - Blades coriaceous; scales light brown; veins more than once forking. *D. paleacea.*
        - Blades chartaceous; scales dark brown; veins simple or once forking. *D. fusco-atra.*
    - Leaf blades bipinnate to quadripinnatifid; basal pinnae not reduced.

- Under surface smooth.
  - Blades bipinnate above, tripinnatifid below, deltoid. *D. nuda.*
  - Blades tripinnate above, quadripinnatifid below, deltoid-ovate. *D. glabra.*
- Under surface glandular or scaly.
  - Under surface glandular.
    - Blades cordate-ovate (20–40 cm. × 16–32 cm.); sori marginal. *D. latifrons.*
    - Blades oblong-lanceolate (10–25 cm. × 4.5–8 cm.); sori medial. *D. parvula.*
  - Under surface scaly.
    - Blades bipinnate; paleaceous with light brown scales.
      - Leafstalk and midrib densely covered with ferruginous scales, leaf deltoid. *D. squamigera.*
      - Leafstalk and midrib sparsely covered with brown, membranaceous scales, leaf lanceolate. *D. hawaiiensis.*
    - Blades tripinnate; paleaceous with dark brown or black linear scales. *D. rubiginosa.*

Indusium wanting.

- Blades tripinnatifid to tripinnate.
  - Midribs covered with abundant dark fibrillose scales.
    - Blades coriaceous, punctate, with scattered resinous granules on their lower surfaces. *D. honolulensis.*
    - Blades chartaceous with no resinous granules. *D. crinalis.*
  - Midribs smooth or merely pubescent with whitish hairs.
    - Pinnules linear-lanceolate, acuminate, 1 cm. or more apart; leafstalk stramineous. *D. Keraudreniana.*
    - Pinnules oblong, obtuse, closely set; leafstalk reddish brown. *D. rubiformis.*
- Blades quadripinnatifid to quadripinnate.
  - Ultimate segments sharply toothed, primary and secondary midribs purplish, scaly. *D. acutidens.*
  - Ultimate segments entire or with appressed teeth, midribs stramineous, smooth or fibrillose.
    - Basal scales of leafstalk mahogany-colored, spreading; sori submarginal. *D. unidentata.*
    - Basal scales of leafstalk pale, appressed; sori medial. *D. sandwicensis.*

Veins connate.

- Leaf blades pinnate, under surface covered with resinous glands; sori submarginal; indusium present. *D. propinqua.*

Leaf blades pinnate to bipinnatifid, under surface without resinous glands; sori variously placed; indusium present or wanting.
  Indusium present.
    Leaf blades bipinnatifid; basal pinnae reduced; under surface paleaceous with whitish hairs; sori medial upon secondary veins. *D. parasitica.*
    Leaf blades pinnate; basal pinnae not reduced; under surface smooth; sori at base of secondary veins, forming a row on either side of primary veins. *D. cyatheoides.*
  Indusium absent or fugacious.
    Indusium absent; leaf blades pinnate; under surface hairy as to veins and sori. *D. stegnogrammoides.*
    Indusium fugacious; leaf blades bipinnatifid; under surface not hairy. *D. truncata.*

DRYOPTERIS GLOBULIFERA (Brack.) Kuntze, Rev. Gen. Pl. **2**: 812. 1891

Lastraea globulifera Brack. Fil. U. S. Expl. Exp. 194. 1854.
Nephrodium globuliferum Hook. Sp. Fil. **4**: 96. 1862.
Aspidium globuliferum Hilleb. Fl. Haw. Is. 573. 1888.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: At elevations of 1,200–1,500 m., Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Robinson 607* V; *Wilkes Expedition* N; *Hillebrand* B, C; Maui, *Bailey* C; *Bishop* B; *Hillebrand* B; Oahu, *Lichtenthaler* N; *Robinson 67* V; *89* V; *525* V; Hawaiian Islands, *Baldwin 67* C, N; *Gaudichaud* B; *Hillebrand* C; Kauai (var. *bipinnata*), *Hillebrand 53* B.

Dryopteris paleacea (Sw.) comb. nov.

Aspidium paleaceum Sw. Syn. Fil. 52. 1806.
Aspidium parallelogrammum Kunze, Linnaea **13**: 146. 1839.
Dichasium parallelogrammum Fée, Mém. Foug. **5**: 303. *pl. 23*. 1852.
Lastraea truncata Brack. Fil. U. S. Expl. Exp. 195. *pl. 27*. 1854.

TYPE LOCALITY: Peru, South America.

DISTRIBUTION: On ground at lower elevations; Mexico to Peru; Hawaiian Islands.

ILLUSTRATION: Fée, Mém. Foug. **5**: *pl. 23*. 1852.

SPECIMENS EXAMINED: Hawaii, *Robinson 618* V; *Wilkes Expe-*

dition; Maui, *Bailey* C; *Hillebrand* B; *Robinson 385* V; Oahu, *Gaudichaud* B; *Lichtenthaler* N; Kauai, *Bishop* BM; *Forbes 444* BM; *Heller 2749* C, N; Hawaiian Islands, *Baldwin 65* C, N.

Dryopteris paleacea is closely allied to the widely distributed *Dryopteris Filix-mas*, but the crowded pinnae, the truncate form of the pinnules, the form and number of the scales of the rachis distinguish it from the more lax and open form of the latter.

Dryopteris fusco-atra (Hilleb.) comb. nov.

Aspidium Filix-mas var. *fusco-atrum* Hilleb. Fl. Haw. Is. 575. 1888.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: At high elevations, Hawaiian Islands.

ILLUSTRATION: PLATE 42.

SPECIMENS EXAMINED: Maui, *Hillebrand 24* B; Oahu, *Forbes* BM; Kauai, *Bishop* B; *Heller 2589* C, N; *2746* C; *Hillebrand* C; Hawaiian Islands, *Baldwin* B; *Hillebrand 24* B; *Mann & Brigham 255* N; *Miss Sessions* C.

The lax character of the leaves and the dark color of the scales are excellent field marks by which to distinguish this fern from *Dryopteris paleacea*.

DRYOPTERIS NUDA Underw. in Heller, Minn. Bot. Stud. **1**: 780. 1896

Aspidium glabrum Hilleb. Fl. Haw. Is. 576. 1888. (Not Mett.)

TYPE LOCALITY: Kauai.

DISTRIBUTION: Hawaiian Islands.

ILLUSTRATION: PLATE 43.

SPECIMENS EXAMINED: Hawaii, *Robinson 251* V; Maui, *Bishop* B; *Hillebrand* B; *Robinson 335* V; *339* V; *393* V; Oahu, *Baldwin* B; *Hillebrand* B; *Robinson 198* V; Kauai *Heller 2750* (type) C; *Hillebrand* B; *Robinson 818* V.

This fern strongly resembles *Dryopteris spinulosa* but is a much more compact, rigid form and has more acute ultimate divisions.

DRYOPTERIS GLABRA (Brack.) Kuntze, Rev. Gen. Pl. **2**: 812. 1891

Lastraea glabra Brack. Fil. U. S. Expl. Exp. 200. 1854.

Aspidium glabrum Mett. Aspid. 59. 1858.

Aspidium glabrum var. *quadripinnatum* Hilleb. Fl. Haw. Is. 576. 1888.

TYPE LOCALITY: Hawaii.

DISTRIBUTION: High forests, Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; *Robinson 268* V; *627* V; Maui, *Bailey* C; *Lindley* C; *Robinson 374* V; *397* V; Oahu, *Halerman 63* B; Kauai, *Robinson 421* V.

Wilkes's specimen in the National Herbarium is labeled "sp. nov.," hence it is probably a cotype if not his type of Brackenridge's *Lastraea glabra*.

This is a much more graceful fern than *Dryopteris nuda*, which has been confused with it by some authors.

DRYOPTERIS LATIFRONS (Brack.) Kuntze, Rev. Gen. Pl. 2: 813. 1891

Lastraea latifrons Brack. Fil. U. S. Expl. Exp. 196. 1854.

Nephrodium latifrons Hooker, Sp. Fil. 4: 138. 1862.

Aspidium latifrons Mann, Proc. Am. Acad. 7: 217. 1868.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Common at elevations of 600–1,200 m., Hawaiian Islands.

SPECIMENS EXAMINED: Maui, *Bailey* C; Lanai, *Hillebrand* B; Molokai, *Hillebrand* B; Oahu, *Forbes 1082* BM; *Heller 2899* C, N; *Lichtenthaler* N; *Mann & Brigham 189, 195, 196* N; *Macrae* C; *Robinson 93* V; *172* V; *182* V; *Wilkes Expedition* N; Hawaiian Islands, *Baldwin 69* B, C, N; *129* B; *Gaudichaud* B; *Van Ingen* C; ex herb. Kew C; ex Herb. John Donnell Smith *623* N; *624* N.

Dryopteris parvula sp. nov.

Aspidium glabrum var. *pusillum* Hilleb. Fl. Haw. Is. 577. 1888. Not *Dryopteris pusilla* (Mett.) Kuntze.

Caudex short, oblique, covered with linear-lanceolate, light brown scales 7–10 mm. long; leafstalk slender, 6–7 cm. long, grooved ventrally; blade chartaceous, ovate-oblong, 12–20 cm. long, bipinnate; lobes of pinnae spinulose, marginal cells transparent; both surfaces of blade and stipe covered with globular glands; veins free, simple or once forking; sori borne dorsally on the veins; indusium reniform; sporangia biconvex; spores reniform, rugose.

TYPE LOCALITY: Kauai, at 1,600–2,000 m. elevation.

DISTRIBUTION: Hawaiian Islands.

ILLUSTRATION: PLATE 44.

SPECIMENS EXAMINED: Kauai, *E. Johnson* (type) B; Hawaiian Islands, *Hillebrand* C.

This very delicate fern is a miniature *Dryopteris glabra* (Brack.) Kuntze in form but is easily distinguished from this plant by its glandular exterior in addition to its small size.

DRYOPTERIS SQUAMIGERA (Hook. & Arn.) Kuntze, Rev. Gen. Pl. 2: 813. 1891

Nephrodium squamigerum Hook. & Arn. Bot. Beech. 106. 1832.
Lastraea squamigera Brack. Fil. U. S. Expl. Exp. 198. 1854.
Aspidium squamigerum Mann, Proc. Am. Acad. 7: 217. 1868.

TYPE LOCALITY: Kaala Mountains, Oahu.

DISTRIBUTION: At elevations of 600–1,200 m., Hawaiian Islands, Viti Islands, Society Islands; rare.

ILLUSTRATION: Hook. Sp. Fil. 4: 270. 1862.

SPECIMENS EXAMINED: Oahu, *Wilkes Expedition* N; Kauai, *Heller 2841* C, N; Lanai, *Lichtenthaler* N; Hawaiian Islands, *Baldwin 70* C, N.

Dryopteris hawaiiensis (Hilleb.) comb. nov.

Aspidium hawaiiense Hilleb. Fl. Haw. Is. 575. 1888.
Dryopteris Filix-mas C. Chr. Ind. Fil. 265. 1905.

TYPE LOCALITY: Mauna Kea, Hawaii.

DISTRIBUTION: Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, Mauna Kea, *Hillebrand* (type) B; Hawaii, Hamakua, *Hillebrand* B; Maui, *Robinson 390* V; *395* V; Oahu, *Lichtenthaler* N; Hawaiian Islands, ex Herb. John Donnell Smith N.

DRYOPTERIS RUBIGINOSA (Brack.) Kuntze, Rev. Gen. Pl. 2: 813. 1891

Lastraea rubiginosa Brack. Fil. U. S. Expl. Exp. 201. 1854.
Nephrodium rubiginosum Hook. Sp. Fil. 4: 143. 1862.
Aspidium rubiginosum Mann, Proc. Am. Acad. 7: 217. 1868.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; *Robinson 285* V; *621* V; *Wilkes Expedition* (type) N; Molokai, *Hillebrand* B;

Lichtenthaler N; Oahu, *Hillebrand* B; *Robinson 136* V; *Safford 909;* Kauai, *Hillebrand* B.

Dryopteris fijiense (Hook.) C. Chr. is a closely related species but may be distinguished from *D. rubiginosa* (Brack.) Kuntze by its more open divisions, by the ciliated margin of its pinnules, and by its ciliated indusia, in contrast to the compact form and entire margins of the pinnules and indusia of *D. rubiginosa.* Compare Hook., A 2d Century of Ferns *pl. 67.* 1861; also Hook. Sp. Fil. **4**: 143. 1862.

DRYOPTERIS HONOLULENSIS (Hook.) C. Chr. Ind. Fil. 271. 1905
Polypodium honolulense Hook. Sp. Fil. **4**: 288. 1862.
Polypodium Hillebrandii Hook. Sp. Fil. **4**: 254. 1862. (Not **4**: 228. 1862.)
Phegopteris honolulense Mann, Proc. Am. Acad. **7**: 218. 1867.
Phegopteris Hillebrandii Hilleb. Fl. Haw. Is. 566. 1888.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On ground at elevations of 700–1,300 m., Hawaiian Islands.

SPECIMENS EXAMINED: Kauai, *Robinson 383* V; Lanai, *Hillebrand* B, C; Molokai, *Hillebrand* B, C; Oahu, *Hillebrand* B, C; *Remy* B; *Robinson 170* V; Kauai, *Hillebrand* B; *Robinson 821*; Hawaiian Islands, *Baldwin 77* B, C; *Lydgate* B.

There is a strong superficial resemblance between *Dryopteris honolulensis* (Hook.) C. Chr. and *Dryopteris latifrons* Brack., but the small submarginal, naked sori distinguish the former.

DRYOPTERIS CRINALIS (Hook. & Arn.) C. Chr. Ind. Fil. 259. 1905
Polypodium crinale Hook. & Arn. Bot. Beech. 105. 1841.
Phegopteris crinalis Mann, Proc. Am. Acad. **7**: 218. 1867.

TYPE LOCALITY: Oahu.

DISTRIBUTION: Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B, C; Molokai, *Hillebrand* B; Kauai, *Forbes 269* BM; *Johnson* B; *Heller 2587* C; *Robinson 412* V; Hawaiian Islands, *Baldwin 75* C; *Baldwin* B; *Baldwin* V.

Young specimens of *D. crinalis* are gray green in color, while mature specimens are rusty in appearance owing to the leathery texture and scaly under surface of the leaves.

DRYOPTERIS KERAUDRENIANA (Gaud.) C. Chr. Ind. Fil. 272. 1905

Polypodium Keraudrenianum Gaud. Voy. Freyc. Bot. 362. 1829.

Phegopteris Keraudreniana Mann, Proc. Am. Acad. **7**: 218. 1867.

Nephrodium Keraudrenianum (Gaud.) Diels in E. & P. Nat. Pfl. 1^4: 177. 1899.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In forests, Hawaiian Islands.

ILLUSTRATION: Gaud. Voy. Freyc. Bot. *pl. 7*. 1829.

SPECIMENS EXAMINED: Hawaii, *Robinson 336* V; *Wilkes Expedition* C; Maui, *Hillebrand* B; Molokai, *Hillebrand* B; Kauai, *Forbes 96* BM; Hawaiian Islands, *Baldwin 78* C; *Baldwin* V; *Gaudichaud* (type) B; *Hillebrand* B, C.

Although *Dryopteris Keraudreniana* and *Dryopteris rubiformis* are very similar in habit, they may be easily distinguished by the stramineous midrib and broad lanceolate pinnae of the former in contrast with the reddish midrib and narrow linear pinnae of the latter. Both support their weight by the attachment of the tips of the leaves to other plants, in a vinelike coil. If the leaf curves so that the end finally reaches the soil, it does not take root.

Hillebrand's variety *tripinnata* (Hilleb. Fl. Haw. Is. 562. 1888) has toothed segments in its pinnules, but this difference is too slight to warrant its separation from the species.

Dryopteris rubiformis nom. nov.

Polypodium procerum Brack. Fil. U. S. Expl. Exp. 14. 1854. Not *Dryopteris procera* (Baker) Kuntze.

Phegopteris Keraudreniana var. *procera* Hilleb. Fl. Haw. Is. 562. 1888.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In open places on the mountain sides, Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 3*. 1854.

SPECIMENS EXAMINED: Maui, *Hillebrand* B; Kauai, *Robinson 423* V; *829* V; Hawaiian Islands, *Baldwin 94* C; *Wilkes Expedition* C.

The reddish stem and midrib of this fern, together with its tendency to curve and rest its weight upon other plants in a thicket, suggest the appearance of blackberry vines by the roadside.

The type was collected upon the U. S. Exploring Expedition of 1854.

DRYOPTERIS ACUTIDENS C. Chr. Ind. Fil. 250. 1906

Phegopteris spinulosa Hilleb. Fl. Haw. Is. 566. 1888. Not *Dryopteris spinulosa* (Müll.) Kuntze.

Polypodium spinulosum Baker, Ann. Bot. **5**: 459. 1891.

TYPE LOCALITY: Southern slope of Haleakala, Maui.

DISTRIBUTION: Along banks of streams, at elevations of 400–1,400 m., Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B, C; Oahu, *Robinson 177* V; Maui, *Hillebrand* B, C; *Robinson 384* V; *604* V; *614* V; Kauai, *Heller 2874* C; Hawaiian Islands, *Baldwin 76* C; *Hillebrand* B; *Lydgate* B.

There is a marked superficial resemblance between *D. acutidens* C. Chr. and the North American *D. dilatata* (Hoffm.) A. Gray, but there is no trace of an indusial covering for the sorus in the youngest specimens of *D. acutidens*.

DRYOPTERIS UNIDENTATA (Hook. & Arn.) C. Chr. Ind. Fil. 299. 1905

Polypodium unidentatum Hook. & Arn. Bot. Beech. 105. 1832.

Phegopteris unidentata J. Sm. Ferns Brit. & For. 170. 1866.

Nephrodium unidentatum Diels in E. & P. Nat. Pfl. 1^4: 174. 1899.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In forests at 600–1,200 m. elevation, Hawaiian Islands.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; Maui, *Hillebrand* B, C; Molokai, *Hillebrand* B, C; Oahu, *Robinson 194* V; Kauai, *Hillebrand* B, C; Hawaiian Islands, *Baldwin 79* B, C; *Gaudichaud* B; *Hillebrand* B; *Baldwin* V.

Hillebrand's variety *paleacea* of this fern is apparently a form that has arisen from ecological causes rather than a stable variation; thus the tall habit and light color are characteristic of the plants growing in the deep forest at higher elevations than that of the dark green plants with short caudex.

DRYOPTERIS SANDWICENSIS (Hook. & Arn.) C. Chr. Ind. Fil. 290. 1905

Polypodium sandwicense Hook. & Arn. Bot. Beech. 105. 1832.
Phegopteris sandwicensis Mann, Proc. Am. Acad. **7**: 218. 1867.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: In forests, Hawaiian Islands, Viti Islands, and Pitcairn Island.

SPECIMENS EXAMINED: Hawaii, *Hillebrand* B; Maui, *Hillebrand* B; Lanai, *Hillebrand* B; Molokai, *Hillebrand* B, C; Oahu, *Hillebrand* B, C; Kauai, *Heller 2838* C; *Hillebrand 66* B; Hawaiian Islands, *Baldwin 79a* B; *Hillebrand* B; *Knudsen 158* B; *159* B; *160* B; *Lydgate* B.

DRYOPTERIS PROPINQUA (R. Br.) Gilb. Bull. Torrey Club **23**: 454. 1896

Aspidium unitum Sw. Jour. Bot. Schrad. **1800**^{2}: 32. 1801. Not *Dryopteris unita* (L.) Kuntze.
Nephrodium propinquum R. Br. Prod. Fl. N. Holl. 148. 1810.
Aspidium resiniferum Kaulf. Enum. 237. 1824.
Aspidium propinquum Sw. Adnot. 67. 1829.
Nephrodium resiniferum Hook. & Arn. Bot. Beech. 105. 1832.
Aspidium Ecklonii Kunze, Linnaea **10**: 546. 1836.
Nephrodium Ecklonii Presl, Epim. 49. 1849.

TYPE LOCALITY: Australia.

DISTRIBUTION: Very common in swamps in tropical countries.

ILLUSTRATION: Schkuhr, Krypt. Gew. *pl. 33b.* 1809.

SPECIMENS EXAMINED: Oahu, *Beechey* C; *Robinson 90* V; Maui, *E. Bailey* C; Kauai, *Forbes 37* BM; *Heller 2594* C; *Robinson 465* V; *467* V; *474* V; Hawaiian Islands, *Baldwin 66* B, C; *Gulick* B; *Hillebrand* B.

Dryopteris propinqua has caused much confusion because certain transitory characters, such as the hairs on the surface of the leaf and at the margin of the indusium, have been considered as specific.

This species is rarely in fruit though it grows abundantly in the roadside ditches from sea level to 1,500 m. elevation.

DRYOPTERIS PARASITICA (L.) Kuntze, Rev. Gen. Pl. **2**: 811. 1891

Polypodium parasiticum L. Sp. Pl. 1090. 1753.

Polypodium dentatum Forsk. Fl. Aeg.-arab. 185. 1775.
Polypodium nymphale Forst. Prod. 81. 1786.
Polypodium molle Jacq. Coll. Bot. **3**: 188. 1789. (Not Schreb. 1771 nor All. 1785.)
Aspidium molle Sw. Jour. Bot. Schrad. **1800**^{2}: 34. 1801.
Aspidium parasiticum Sw. Jour. Bot. Schrad. **1800**^{2}: 35. 1801.
Aspidium patens Sw. Jour. Bot. Schrad. **1801**^{1}: 280. 1803.
Aspidium nymphale Schkuhr, Krypt. Gew. **1**: 36. *pl. 34.* 1806.
Nephrodium molle R. Br. Prod. Fl. N. Holl. 149. 1810.
Nephrodium parasiticum Desv. Mém. Soc. Linn. **6**: 258. 1827.
Nephrodium nymphale Desv. Mém. Soc. Linn. **6**: 258. 1827.
Polystichum molle Gaud. Voy. Freyc. Bot. 326. 1828.
Aspidium violascens Link, Hort. Berol. **2**: 115. 1833.
Nephrodium violascens Fée, Mém. Foug. **5**: 305. 1852.

TYPE LOCALITY: India.

DISTRIBUTION: In open places between 1,400–1,600 m. elevation. Tropics, subtropics, and New Zealand.

ILLUSTRATIONS: Rheede, Hist. Hort. Malab. **12**: 17. 1753; Schkuhr, Krypt. Gew. *pl. 34.* 1806.

SPECIMENS EXAMINED: Hawaii, *Robinson 223* V; Oahu, *Heller 2011* C; *Robinson 170* V; *188* V; *192* V; Kauai, *Robinson 800* V; *805* V; *811* V.

There is a marked superficial resemblance between *Dryopteris parasitica* and *D. globulifera*, but the former is distinguished by its hairy epidermis and indusia in addition to the short lobes of its pinnae, while the latter has glands upon its epidermis and indusia, and its pinnae are deeply cut.

DRYOPTERIS CYATHEOIDES (Kaulf.) Kuntze, Rev. Gen. Pl. **2**: 812. 1891

Aspidium cyatheoides Kaulf. Enum. Fil. 234. 1824.
Polystichum Dubrueilianum Gaud. Freyc. Voy. Bot. 333. 1828.
Nephrodium Dubrueilianum Hook. & Arn. Bot. Beech. 105. 1832.
Nephrodium cyatheoides Presl, Tent. Pterid. 81. 1836.
Aspidium cyatheoides Mett. Aspid. 110. 1858.

TYPE LOCALITY: Oahu.

DISTRIBUTION: On ground in the lower forests and along rivers, Hawaiian Islands, New Guinea, Sumatra.

ILLUSTRATIONS: Gaud. Voy. Freyc. Bot. *pl. 9.* 1828; Presl, Tent. Pterid. *pl. 2. f. 5.* 1836; Hook. Sp. Fil. 4: *pl. 241.* 1862.

SPECIMENS EXAMINED: Hawaii, *Robinson 232* V; *Wilkes Expedition* C; Molokai, *Hillebrand* B; Oahu, *Anderson* B; *Bennett 11* B; *Bennett* B; *Chamisso* B; *Heller 1991* C, N; *Lichtenthaler* N; *Macrae* B; *Meyen* B; *Remy 13* C; *Robinson 21* V; *Wilkes Expedition* N; Kauai, *Heller 2857* C; *Hillebrand 85* B; *87* B; *Mann & Brigham 152* N; *Wilkes Expedition* N; Hawaiian Islands, *Baldwin* B, C; *63* C; *Beechey* C; *Wilkes Expedition* C; *Gaudichaud* B; *Lindley* C; *Miss Sessions* C; *Wilkes Expedition* B; ex herb. Kew Gardens 2 specimens C.

The tips of young leaves of this fern are eaten by the Hawaiian natives as a salad.

There is an interesting superficial resemblance between *Dryopteris cyatheoides* and *D. stegnogrammoides.*

DRYOPTERIS STEGNOGRAMMOIDES (Baker) C. Chr. Ind. Fil. 294. 1905

Polypodium polycarpon Hook. & Arn. Bot. Beech. 104. 1832. Not Swartz.

Stegnogramma sandwicense Brack. Fil. U. S. Expl. Exp. 26. *pl. 4.* 1854. Not *Dryopteris sandwicensis* C. Chr.

Polypodium sandwicense Hook. Sp. Fil. 5: 5. 1864. (Not 4: 267. 1862.)

Polypodium stegnogrammoides Baker, Syn. Fil. 317. 1867.

Phegopteris microdendron D. C. Eaton in Mann, Proc. Am. Acad. 7: 218. 1867.

Nephrodium polycarpon Diels in E. & P. Nat. Pfl. 1^4: 179. 1899.

TYPE LOCALITY: Hawaiian Islands.

DISTRIBUTION: Hawaiian Islands.

ILLUSTRATION: Brack. Fil. U. S. Expl. Exp. *pl. 4.* 1854.

SPECIMENS EXAMINED: Hawaii, *Robinson 617* V; Molokai, *Hillebrand* B; *Lindley* C; *Macrae* B; Kauai, *Forbes 239* BM; Hawaiian Islands, *Baldwin* B; *Gaudichaud* B.

Hillebrand (Fil. Haw. Is. 560. 1888) describes the caudex of *Dryopteris stegnogrammoides* as erect, but the specimens collected by the writer had prostrate rootstocks. His variety *depauperata* probably owes its decreased size and pubescence to its exposed situation upon the rocks, a theory which seems the more tenable from his statement that a corresponding form of *Dryopteris cyatheoides* is associated with this variety of *D. stegnogrammoides* in such localities.

DRYOPTERIS TRUNCATA (Poir.) Kuntze, Rev. Gen. Pl. **2**: 814. 1891

Polystichum truncatum Gaud. Voy. Freyc. Bot. 332. *pl. 10.* 1828.
Nephrodium truncatum Presl, Tent. Pterid. 81. 1836.
Nephrodium Hudsonianum Brack. U. S. Expl. Exp. 189. *pl. 25.* 1854.
Aspidium Hudsonianum Mann, Proc. Am. Acad. **7**: 217. 1867.

TYPE LOCALITY: Brazil.

DISTRIBUTION: Malaysia, Polynesia, Ceylon, Northern India, Brazil.

ILLUSTRATIONS: Gaud. Voy. Freyc. Bot. *pl. 10.* 1828; Brack. Fil. U. S. Expl. Exp. *pl. 25.* 1854.

SPECIMENS EXAMINED: Hawaii, *Wilkes Expedition* N; Oahu, *Heller 2334* C, N; *Mann & Brigham* N; *Robinson 152* V; *192* V; *522* V; *523* V; *Safford 869* N; *870* N; Maui, *Bailey* C; Kauai, *Heller 2843* C, N; *Hillebrand* B; Hawaiian Islands, *Baldwin 64* B; C; *65* B; (*Baldwin*) V; *Gaudichaud* B.

Poiret gives the habitat of *Dryopteris truncata* as Brazil. Baker (Syn. Fil. 295. 1874) gives a range of distribution through the subtropics, which Christensen follows. The representation of this genus in the herbarium of the New York Botanical Garden does not indicate that this is so cosmopolitan a species.

New West Indian Lejeuneae—II

ALEXANDER W. EVANS

(WITH PLATE 45)

In the first paper of this series, published in the BULLETIN for August 1908, six species of *Lejeuneae* from various islands of the West Indies were described and figured. One of these species, *Leiolejeunea grandiflora*, was proposed as the type of a new genus; the others belonged to genera that had been more or less fully discussed by the writer in a series of papers on the Hepaticae of Puerto Rico.* In the present paper three additional species are considered, all from the island of Jamaica. The genera to which they belong, *Diplasiolejeunea*, *Leptocolea*, and *Rectolejeunea*, are likewise among those discussed in connection with the Puerto Rico Hepaticae. The type specimens of the new species are preserved in the herbarium of the writer at New Haven, Connecticut.

Diplasiolejeunea Johnsonii sp. nov.

Pale green or yellowish, growing in depressed mats: stems 0.12 mm. in diameter, abundantly but irregularly branched, the branches obliquely spreading, similar to the stem but usually with smaller leaves: leaves of stems and leading branches closely imbricated, the lobe obliquely to widely spreading, distinctly convex, the margin usually revolute in apical and postical portions, orbicular-ovate, 1.1–1.5 mm. long, 1–1.2 mm. wide, antical margin rounded at the base and arching across the axis, outwardly curved to the broad and rounded apex, postical margin also curved; lobule inflated in carinal portion, otherwise more or less appressed to the lobe, obovate, 0.75 mm. long, 0.4 mm. wide, keel arched, forming a continuous line with the revolute portion of the lobe, free margin scarcely involute except at the very base, apical tooth obliquely spreading, triangular, acute or obtuse, tipped by a single conical or rounded cell, rarely by two superimposed cells, mostly four or five cells long and three to five cells wide at the base, proximal tooth obtuse and much shorter, usually consisting of a single projecting cell reinforced by a second cell coalescent with

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* Bull. Torrey Club 29: 496. 1902. Et seq.

the inner surface of the lobule, hyaline papilla usually distal; cells of lobe averaging about 18μ at the margin and 30 × 25μ in the median and basal portions, walls more or less thickened, with small but distinct triangular trigones and occasional intermediate thickenings: underleaves contiguous or subimbricated, broadly cuneate, about 0.3 mm. long (0.15 mm. to the bottom of the sinus) and 0.45 mm. wide, bifid about one half with broad and rounded obliquely spreading divisions and an acute sinus: inflorescence autoicous: ♀ inflorescence borne on a leading branch or on a more or less abbreviated branch, the innovation usually simple and sterile but sometimes bearing a second female flower; bracts obliquely spreading, sharply complicate, the keel with a very narrow wing, bifid about one fourth, the lobe narrowly oblong-obovate, 0.75 × 0.18 mm., rounded at the apex, lobule a little shorter and narrower, 0.68 × 0.15 mm., rounded at the apex; bracteole ovate, 0.68 mm. long, 0.3 mm. wide, bifid about one eighth with erect rounded to obtuse divisions and a broad obtuse sinus; perianth oblong-obovate, 1.1 mm. long, 0.6 mm. wide, truncate at the apex and with a very short beak, more or less compressed and sharply five-keeled: ♂ inflorescence occupying a short branch, not proliferating; bracts mostly in from four to six pairs, imbricated, inflated, subequally bifid with a strongly arched keel and rounded divisions; bracteoles oblong-quadrate, bifid about one third with rounded divisions: mature sporophyte not seen. (PLATE 45, FIGURES 1–6.)

On bark of trees. Jamaica: Cinchona, *D. S. Johnson* (*14*), April 1903; *Evans* (*250* in part), July 1903. No. 14 may be designated the type.

It can not be stated with certainty whether *D. Johnsonii* is gemmiparous or not. A few young gemmae were observed on the lower surface of a single lobe, but they may not have developed in this situation. The species is characterized by the strongly convex lobes with the apical and postical margins tending to be revolute, by the peculiar teeth of the lobules, by the broad and rounded divisions of the underleaves, by the autoicous inflorescence, and by the rounded divisions of the perichaetial bracts and bracteoles. The revolute portion of the lobe usually involves the junction of the lobe with the lobule, one effect being that the end of the sinus is displaced to the lower surface of the lobe. The apical tooth of the lobule is in the form of a triangle about as broad as high, and the apex is sometimes slightly curved to one side. The proximal tooth looks at first as if it were composed of a single projecting cell. Closer inspection, however, shows that the conditions are more complicated, and that a second cell on the inner surface of the lobule is coalescent with this projecting cell and with the two cells at its base. In other words the lobule is two cells thick where the proximal tooth is situated, a peculiarity which has not yet been recorded in any other member of the genus. The divisions of the underleaves often attain a width of from ten to twelve cells.

Five species of *Diplasiolejeunea* are now definitely known from Jamaica, the others being *D. pellucida* (Meissn.) Schiffn., *D. brachyclada* Evans, *D. unidentata* (Lehm. & Lindenb.) Schiffn., and *D. Rudolphiana* Steph. Since these species occur also in Puerto Rico, they have been described and figured by the writer.* Two of them, *D. brachyclada* and *D. Rudolphiana*, agree with *D. Johnsonii* in being autoicous, while the two others are definitely dioicous. In *D. Rudolphiana* and *D. unidentata*, which seem to be closely related to the new species, the lobes of the leaves, although convex, are not revolute in the vicinity of the keel, so that the end of the sinus is not displaced. The underleaves in these two species have much in common with those of *D. Johnsonii*, and their divisions are fully as broad; they show, however, a distinct narrowing toward the apex. Their lobular teeth show much more striking differences. In *D. Rudolphiana* the apical tooth is remarkably long and slender and is usually subparallel with the axis instead of being broadly triangular and spreading obliquely. In *D. unidentata* the tooth is oblique and about as long as in *D. Johnsonii*, but it is more slender and is usually tipped with two superimposed cells, a condition rarely found in the new species. The most important differences in the proximal teeth have already been mentioned. In the material collected by the writer *D brachyclada* grows mixed with *D. Johnsonii*, but the two species are amply distinct. The underleaves of *D. brachyclada* have narrow and sharply pointed divisions, the apical teeth of the lobules are often truncate or t-shaped and are usually only one cell broad, the perichaetial bracts and bracteoles are more deeply bifid, and the divisions of the latter are acute. Similar differences

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* Bull. Torrey Club **39**: 209–225. *pl. 16, 17.* 1912.

will separate *D. Johnsonii* from *D. pellucida*, which latter, moreover, almost invariably grows on leaves.

Leptocolea appressa sp. nov.

Pale green, growing in closely appressed mats: stems 0.05 mm. in diameter, sparingly and irregularly pinnate, the branches obliquely spreading, similar to the stem but with somewhat smaller leaves: stem leaves imbricated, the lobe widely spreading, falcate, ovate-oblong, 0.5–0.6 mm. long, 0.3–0.4 mm. wide, broad and rounded at the apex, antical margin arching considerably beyond the axis, strongly outwardly curved from base to apex, postical margin straight or slightly curved, forming a rounded indentation with the keel, margin very minutely crenulate from projecting verruculae; lobule inflated throughout, ovate, 0.14 mm. long, 0.08 mm. wide, keel arched, apical tooth consisting of two cells in a row, proximal tooth shorter, consisting of a sharp or blunt projecting cell, teeth separated by a very narrow sinus containing a marginal hyaline papilla; stylus (at base of lobule) consisting of a papilla; cells of lobe averaging 5μ at the margin, 9 × 7μ in the middle, and 20 × 7μ at the base, wall more or less uniformly thickened but without distinct trigones except in median and basal regions, each cell bearing a median verrucula on the free outer wall except in the basal portion of the leaf; ocelli usually four, arranged in a short median row and averaging about 35 × 23μ: inflorescence autoicous (but many plants apparently unisexual): ♀ inflorescence borne on a more or less elongated branch, innovating on one side, the innovation usually short and sterile; bracts obliquely spreading, complicate, keel sharp but without a wing, lobe oblong-obovate, 0.45 mm. long, 0.25 mm. wide, rounded at the apex, margin as in the leaves, ocelli several, forming an elongated patch several cells wide, lobule obovate, 0.25 mm. long, 0.2 mm. wide, rounded and irregularly dentate at the apex; perianth about one fourth exserted, obovate, 0.45 mm. long, 0.4 mm. wide, truncate at the apex with a distinct beak, five-keeled in the upper part, the lateral keels sharp, antical keel low and short, postical keels obtuse but extending almost to the base, lateral keels minutely and irregularly denticulate from projecting cells, surface otherwise smooth or nearly so: ♂ inflorescence (so far as observed) borne on a leading branch; bracts in one to three pairs, monandrous, similar to the leaves but smaller and more obliquely spreading or even suberect: mature sporophyte not seen. (PLATE 45, FIGURES 7–16.)

On bark of trees. Jamaica: John Crow Peak, *Evans* (*104*), July 1903; Clyde Valley, *Evans* (*270*), July 1903. No. 104 may be considered the type.

Although *L. appressa* is fairly large it is not conspicuous because both stems and leaves are firmly appressed to the bark. The ocelli form a striking feature of the species and are almost always arranged in a row of four, extending from the base of the lobe outward and thus simulating a short nerve (FIGURE 8). The contrast in size between the ocelli and the adjacent leaf cells is usually marked but sometimes, especially on the carinal side of the row, one or two series of cells are distinctly elongated and form a sort of transition between the ocelli and the ordinary cells. Occasionally similar elongated cells are to be observed in small number near the outer extremity of the row. The peculiar contents of the ocelli, however, will serve to distinguish them in case of doubt.

The new species produces gemmae in greater or less abundance, and these agree in method of development and in general structure with those found in other members of the genus.* Each consists at maturity of a flat broadly orbicular disk, about 0.07 mm. long and 0.09 mm. wide (FIGURE 16). The margin is very vaguely crenulate from projecting cells, there are three organs of attachment, and each half of the gemma shows twelve cells, their relative position indicating that the apical quadrants in the young gemma cut off four segments apiece. The gemmae bear a marked resemblance to those of *Leptocolea scabriflora* (Gottsche) Evans, a widely distributed species in the American tropics.

A close relative of *L. appressa* is **Leptocolea floccosa** (Lehm. & Lindenb.) comb. nov.,† a species originally described from the Philippines but since reported from both Java and Japan. In this species, which grows on leaves, the plants are closely appressed, just as in *L. appressa*, the ocelli (usually four in number) form a short false nerve, and the outer surfaces of the leaves are minutely roughened by rounded verruculae borne singly on the cells. The East Indian plant, however, is somewhat smaller, the lobes measur-

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* For a discussion of the genus *Leptocolea* see Evans, Bull. Torrey Club **38**: 251–286. *pl. 11, 12.* 1911.

† = *Jungermannia floccosa* Lehm. & Lindenb. in Lehmann, Pug. Plant. 5: 26. 1832. *Lejeunea floccosa* Lehm. & Lindenb. in G. L. & N. Syn. Hep. 324. 1845. *Lejeunea* (*Colo-Lejeunea*) *floccosa* Steph. Hedwigia **29**: 18. 1890. *Cololejeunea floccosa* Schiffn. Conspect. Hepat. Archip. Indici 243. 1898.

ing about 0.35 × 0.25 mm. or even less, the lobes are less falcate and spread more obliquely, the leaf cells are a little larger, averaging about 12 × 8μ in the middle of the lobe, the margin is entire, and the lobes are bordered by a smooth band from three to five cells wide except near the end of the keel, where it is narrower. According to Schiffner the lobule in *L. floccosa* is unidentate, but the specimens from Japan, which agree in all other respects with Schiffner's description and figures,* show bidentate lobules as in most members of the genus. The proximal tooth is remarkable in being the longer of the two, measuring from two to four cells in length and two or three cells in width at the base. It is sharply acute or even acuminate and is either straight, when it continues the free margin, or else it is more or less strongly curved toward the end of the keel. An exceedingly short indentation separates the proximal from the apical tooth. The latter consists normally of two cells, as in *L. appressa*, but is sometimes reduced to a single cell. Instead of spreading widely from the margin it extends toward the proximal tooth, thus tending to fill up the indentation between them and making it difficult to demonstrate. The hyaline papilla could not be clearly made out in the fragmentary material examined by the writer.

Two other species which are apparently close to *L. appressa* are *Lejeunea* (*Colo-Lejeunea*) *platyneura* Spruce,† of Brazil, and *Cololejeunea peraffinis* Schiffn.,‡ of Java. Both are known to the writer by description only but should probably be referred to the genus *Leptocolea*. They are distinguished by false nerves composed of ocelli, but these are arranged in two or more rows instead of in a single row. *Lejeunea platyneura* grows on leaves, its leaf cells are considerably larger than in *L. appressa*, measuring in the middle of the lobe 25–33μ (according to Spruce), and there are further differences in the bracts. In *C. affinis* the median leaf cells measure about 14 × 8μ (according to Schiffner), and the lobular teeth are more complex than in *L. appressa*.

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* Nova Acta Acad. Caes. Leop.-Carol. **60**: 242. *pl. 9. f. 11–13.* 1893.

† Hep. Amaz. et And. 299. 1884.

‡ Nova Acta Acad. Caes. Leop.-Carol. **60**: 242. *pl. 9. f. 8–10.* 1893.

Rectolejeunea Maxonii sp. nov.

Pale green, becoming whitish or yellowish with age, growing in depressed mats: stems 0.05 mm. in diameter, copiously and irregularly branched, the branches widely spreading, usually similar to the stem but occasionally microphyllous: leaves loosely imbricated, the lobe plane, widely spreading, slightly falcate, broadly ovate, 0.5 mm. long, 0.4 mm. wide, antical margin more or less rounded at the base, then strongly outwardly curved to the broad and rounded apex, postical margin slightly curved or straight, forming a continuous line with the keel or slightly indented at the junction, margin slightly and irregularly crenulate from projecting cells; lobule usually well developed, inflated, broadly ovate, 0.1 mm. long, 0.09 mm. wide, keel more or less arched, free margin involute to the apex, apical tooth short and straight, hyaline papilla in a shallow indentation, sinus slightly lunulate; cells of lobe plane or more or less convex, averaging about 12μ at the margin, 22μ in the middle, and 27 × 22μ at the base, apparently uniformly thickened but showing upon careful focusing minute trigones and rare intermediate thickenings; ocelli none: underleaves distant, orbicular, about 0.17 mm. long, bifid about one half with erect, usually obtuse or rounded divisions and an obtuse to acute sinus, cuneate at the base, margin entire or vaguely and irregularly crenulate from projecting cells: inflorescence dioicous: ♀ inflorescence sometimes borne on a leading branch, sometimes on a more or less abbreviated branch, innovating on one side, the innovation sometimes simple and sterile but often soon again floriferous; bracts obliquely spreading, complicate, the keel sharp but not winged, lobe plane or nearly so, oblong-ovate to oblong-obovate, 0.5–0.6 mm. long, 0.35 mm. wide, rounded at the apex or very obtusely pointed, lobule ovate to oblong, 0.3 mm. long, 0.15 mm. wide, obtuse to rounded at the apex, margin of bracts as in the leaves; bracteole free from the bracts, ovate to obovate, 0.45 mm. long, 0.3 mm. wide, bifid about one third with rounded to subacute divisions and a narrow acute sinus; perianth about half exserted, obovate, 0.75 mm. long, 0.55 mm. wide, slightly emarginate at the apex with a short but distinct beak, the upper angles rounded, cuneate at the base, compressed, antical keel low and short, postical keel long, two-angled, surface smooth or (especially along the keels) slightly and irregularly roughened from projecting cells: ♂ inflorescence at first terminal on a more or less elongated branch but soon becoming intercalary through apical proliferation; bracts mostly in from two to six pairs, slightly imbricated, strongly inflated with an arched keel, shortly bifid with rounded divisions, the lobule a little shorter than the lobe; bracteoles similar to the underleaves but smaller, restricted to the base of the inflorescence: capsule about 0.3 mm. in diameter; spores greenish, minutely verruculose, irregular in form, about 12μ in short diameter; elaters about 9μ in diameter, with a single spiral. (PLATE 45, FIGURES 17–27.)

On bark of trees. Jamaica: Cinchona, *L. M. Underwood* (*495*), February 1903; *W. R. Maxon* (*1361*), April 1903; *Evans* (*143* in part), July 1903. No. 1361 may be regarded as the type.

The microphyllous branches mentioned in the description are not abundant in the material examined, and little can be said in regard to their significance. In typical cases a branch of this character (FIGURE 18) exhibits the peculiarities associated with the genus *Microlejeunea.* The lobes of the leaves are ovate and suberect and measure only 0.18 × 0.11 mm., while the lobules are relatively large and measure about 0.13 × 0.1 mm. Such leaves are not very different from the rudimentary leaves found at the base of an ordinary branch, and it is possible that a microphyllous branch is simply one in which juvenile characters persist. Although similar branches have not yet been observed in other members of the genus, their occurrence would not be surprising.

A short time ago the writer proposed a new species of *Rectolejeunea* from the Bahama Islands, under the name *R. Brittoniae,** and pointed out its close relationship to the widely distributed *R. phyllobola* (Nees & Mont.) Evans.† The new plant from Jamaica belongs in the same group of species. In its dioicous inflorescence it agrees with *R. Brittoniae* and differs from *R. phyllobola;* in the restriction of its perigonial bracteoles to the base of the spike it agrees with *R. phyllobola* and differs from *R. Brittoniae.* Vegetative reproduction is apparently of rare occurrence in *R. Maxonii.* When it takes place it is by means of caducous leaves, just as in the other known members of the genus, but these leaves are not borne on specialized shoots. In this respect, as well as in most of the characters drawn from the leaves, leaf cells, and perianths, it agrees further with *R. Brittoniae* and *R. phyllobola.* The underleaves, however, afford a few additional differences.

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* Bull. Torrey Club **38**: 209. *pl. 9. f. 1–12.* 1911.

† For a discussion of the genus *Rectolejeunea* see Evans, Bull. Torrey Club **33**: 1–16. *pl. 1, 2.* 1906.

They are somewhat smaller than those of *R. Brittoniae* but resemble them more closely in other respects than they do those of *R. phyllobola*. Their divisions are broad and triangular and are usually tipped with a single cell, making them obtuse (FIGURE 22), in rarer cases they are distinctly rounded at the apex (FIGURE 23), while in still rarer cases they are acute and tipped with two superimposed cells (FIGURE 24). This last condition, it will be remembered, is the usual one in *R. phyllobola*.

YALE UNIVERSITY.

Explanation of plate 45

The figures were drawn by the writer, and most of them were prepared for publication by Mr. Stanley C. Ball.

Diplasiolejeunea Johnsonii Evans. 1. End of a vigorous shoot, postical view, ×25. 2. Apical tooth of a lobule, ×200. 3. Proximal tooth of the same lobule, ×200. 4. Apex of an underleaf division, ×200. 5, 6. Bract and bracteole from a single involucre, ×35. The figures were all drawn from the type specimen.

Leptocolea appressa Evans. 7. Stem bearing a female branch with a perianth, postical view, ×35. 8. A leaf, antical view, ×35. 9. Cells from middle of lobe, ×265. 10. Cells from margin of lobe, ×265. 11. End of a row of ocelli with neighboring cells, ×265. 12. Apex of lobule, ×265. 13, 14. Bracts from a single involucre, ×45. 15. Transverse section of perianth in upper third, ×45. 16. Gemma, ×265. The figures were all drawn from the type specimen.

Rectolejeunea Maxonii Evans. 17. Part of a plant with two female inflorescences and a perianth, postical view, ×35. 18. Part of a microphyllous branch, postical view, ×35. 19. Cells from middle of lobe, ×265. 20. Cells from margin of lobe, ×200. 22. Apex of an underleaf division, typical structure, ×200. 23, 24. Apices of underleaf divisions, deviations from the typical structure, ×200. 25, 26. Bract and bracteole from a single involucre, ×35. 27. Transverse section of a perianth near apex, ×35. The figures were all drawn from the type specimen.

INDEX TO AMERICAN BOTANICAL LITERATURE

(1912)

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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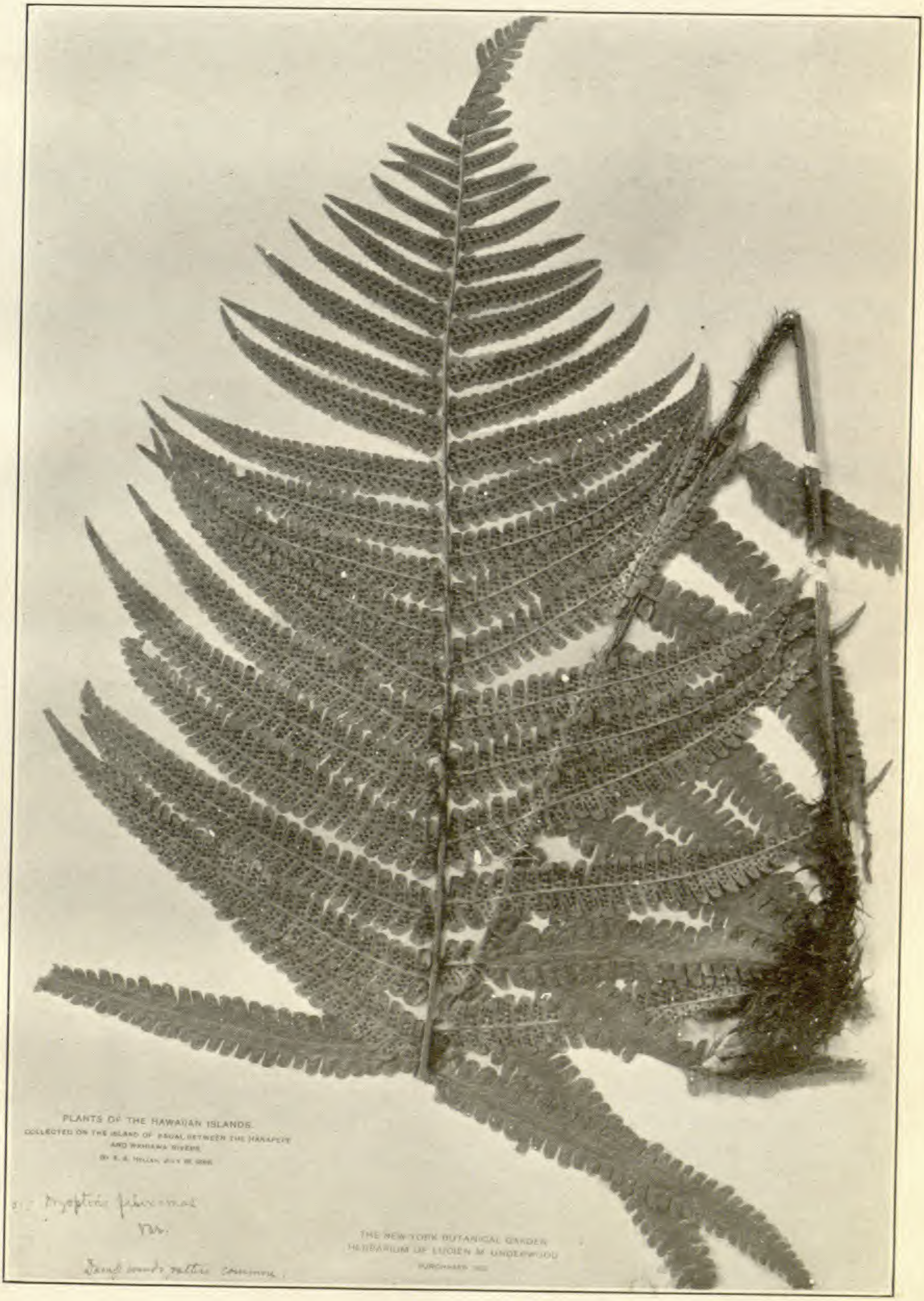
ELAPHOGLOSSUM WAWRAE (Luerssen) C. Chr.

SCHIZOSTEGE LYDGATEI Hilleb.

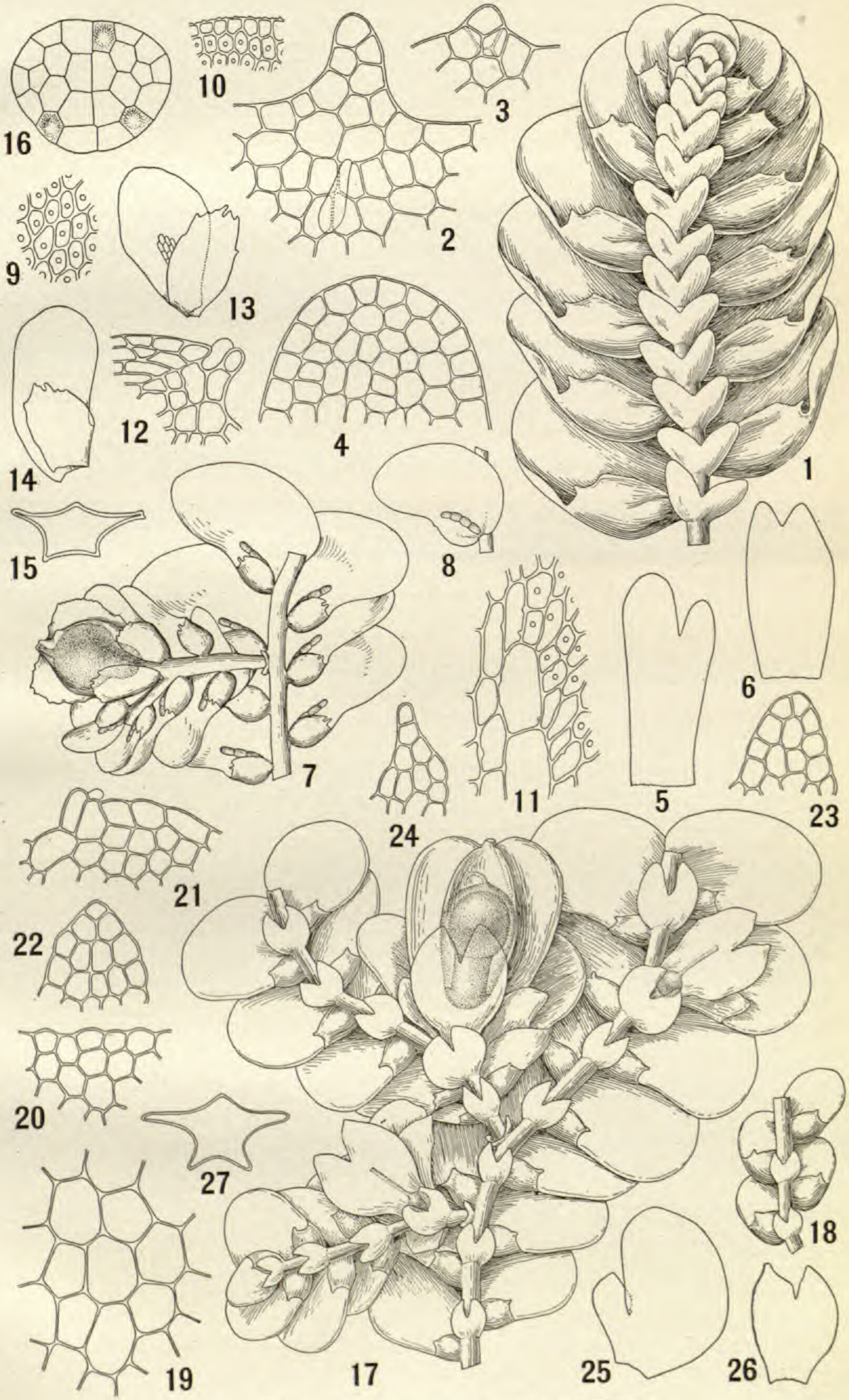
Apex and basal pinna



DRYOPTERIS FUSCO-ATRA (Hilleb.) W. J. Robinson

DYOPTERIS NUDA UNDERW.

DRYOPTERIS PARVULA W. J. Robinson



1–6. DIPLASIOLEJEUNEA JOHNSONII Evans
7–16. LEPTOCOLEA APPRESSA Evans
17–27. RECTOLEJEUNEA MAXONII Evans