BOTANICAL GAZETTE

THE
BOTANICAL GAZETTE

EDITORS:

JOHN MERLE COULTER AND CHARLES REID BARNES

VOLUME XL

JULY—DECEMBER, 1905

WITH SIXTEEN PLATES, ONE MAP, AND ONE HUNDRED AND TWO FIGURES

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BRIEFER ARTICLES—

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DATES OF PUBLICATION.

No. 1, July 18; No. 2, August 16; No. 3, September 15; No. 4, October 18; No. 5, November 15; No. 6, December 20.

ERRATA.

VOLUME XXXIX.

P. 371, line 3 from below, for Nobbes's read Nobbe's.
P. 381, line 13, for *M*/100 read *m*/100.
P. 384, line 12 from below, for Theophile read Théophile.
P. 386, line 15, for *amabole* read *amabile.*
P. 410, line 14, for MgGuigan read McGuigan.
P. 422, line 11, for eedlings read seedlings.
P. 425, line 18, for Allen read ALLEN.
P. 425, line 8 from below, and P. 426, line 25 for GREGOIRE read GRÉGOIRE.
P. 426, line 21, should read "There is no regularity in their number in relation to the chromatic segments which are formed later."
P. 426, lines 20 and 21 from below, and page 427, line 7, for fusion read fission.
P. 427, line 7, from below, for zooglaea read zoogloea.
P. 427, last line, for flagellae read flagella.

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P. 12, line 6 from below, for were read are.
P. 23, line 13, for cup read cap.
P. 35, line 13, for Wolf's read Wolff's.
P. 40, line 3, for curve read curved.
P. 43, reference 7, to Untersuch add ungen.
P. 44, reference 25, for JANCE read JANSE.
P. 49, line 3 from below for *figs. 1, 2b.* read *figs. 1, 3b.*
P. 53, line 17, for *h*, head read *b*, beard.
P. 69, line 7, for of read on.
P. 69, line 12, for PEACK read PENCK.
P. 70, line 9, for direction read directing.
P. 70, line 14 from below, insert comma after algae.
P. 70, line 9 from below, insert parenthesis after etc.
P. 71, lines 7 and 19, for imperial read Imperial.
P. 71, line 15, for Systematischen read systematischen.
P. 71, line 20, for seed-control read Seed-control.
P. 71, line 13 from below delete special.
P. 71, line 10 from below, for Commission read commission.
P. 72, line 3, for for read from.
P. 72, line 6, delete a before new.
P. 72, line 2 from below, for Commission of read Commission on.
P. 100, line 9 from below, for second in read on.
P. 103, line 6 from below, and p. 104, line 1, for axial read axile.
P. 113, line 2, for on read in.
P. 113, line 4, for infold read unfold.

P. 113, line 11, delete sentence "Experiments, etc." *Cf.* line 2.
P. 115, line 3, after with insert water.
P. 128, line 3, for biruet read biuret.
P. 152, line 21 from below, for Iosetes reads Isoetes.
P. 156, line 13, insert the word geotropic before response.
P. 157, line 22, for cell read wall.
P. 180, line 7 from below, for former read latter.
P. 236, line 24, after paper read on geotropism.
P. 384, line 10, for *Cystisus* read Cytisus.
P. 479, for R. C. read R. G.

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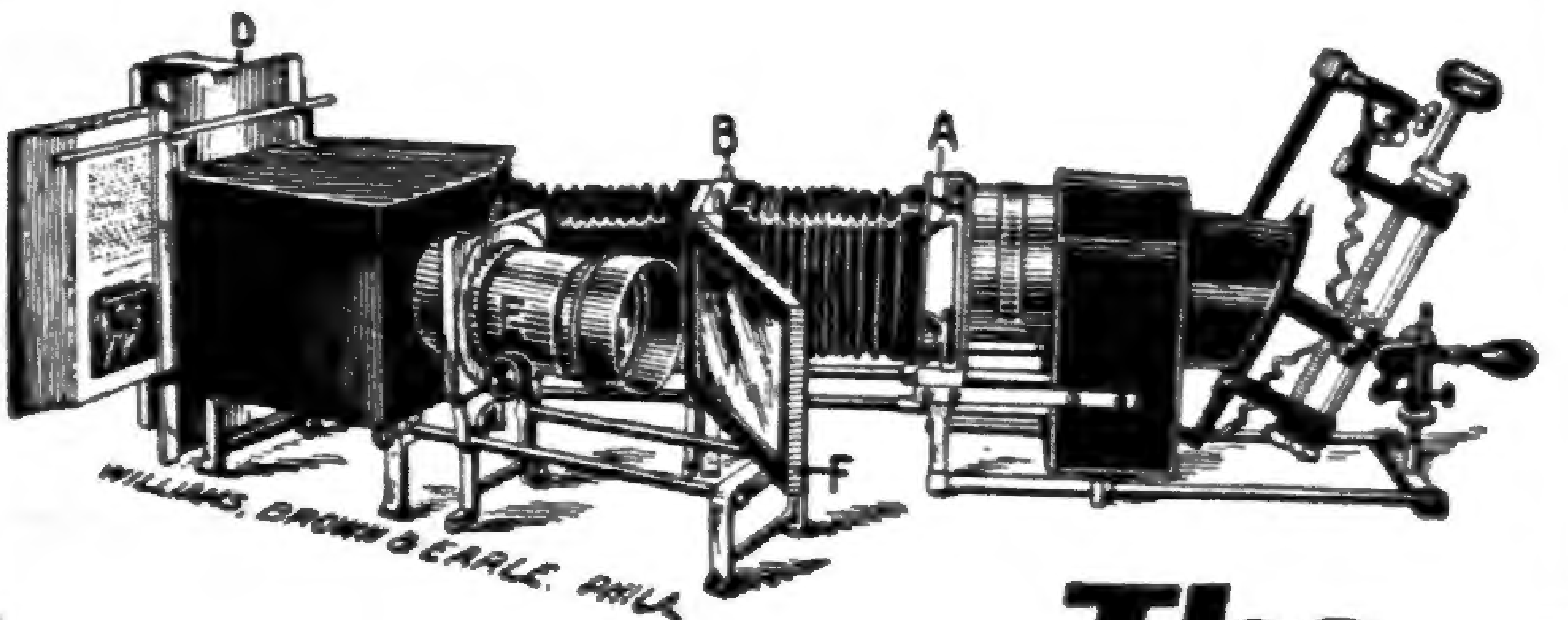
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BOTANICAL GAZETTE

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UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXVII.[1]

JOHN DONNELL SMITH.

Porcelia stenopetala Donn. Sm.—Folia maxima obovato-oblonga vel oblonga subcaudato-acuminata basi obtusiuscula vel rotundata supra glabra subtus pubescentia, nervis crebris parallelis subrectis. Pedunculi ex ligno vetere prorumpentes fasciculati vel approximati. Petala linearia multoties longiora quam latiora.

Arbor, ramulis petiolis gemmis pedunculis floribus fusco-velutinis. Folia papyracea, juniora obovato-oblonga, provectiora oblonga 26–31$^{\mathrm{cm}}$ longa 8–9$^{\mathrm{cm}}$ lata basi saepius rotundata, nervis lateralibus utrinque 15–17, petiolis vix 5$^{\mathrm{mm}}$ longis. Inflorescentia tantum in trunco (*de Tuerckheim* in schedula) vel in ramis crassis defoliatis obvia, pedunculis 8–15-subaggregatis 1.5–2$^{\mathrm{cm}}$ longis. Sepala deltoidea vix 3$^{\mathrm{mm}}$ longa patentia intus glabra. Petala imbricata aequalia utrinque pubescentia atropurpurea 6–6.5$^{\mathrm{cm}}$ longa 4–5$^{\mathrm{mm}}$ lata acuta. Stamina numerosissima cuneato-quadrata 1$^{\mathrm{mm}}$ longa compressa. Torus hemisphericus. Ovaria 9–12 oblonga 3–4$^{\mathrm{mm}}$ longa inflata sericea, stigmate sessili capitato, ovulis biseriatis 8–12. Bacca ignota.—Ad *P. Nicaraguensem* Benth. et Hook. staminibus ovariisque arcte accedens inflorescentia petalisque longe distat.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350$^{\mathrm{m}}$, Mart. 1904, *von Tuerckheim*, n. 8496 ex Pl. Guat. etc., quas ed. Donn. Sm.

Ionidium Thiemei Donn. Sm.—Fruticosum nanum pubescens. Stipulae minutae. Folia alterna ovalia apice rotunda in petiolum angustata crenulata. Pedunculi singuli foliis breviores uniflori. Petalum inferum sepalis subaequalibus integris altero tanto longius, lamina suborbiculari.

Caulis e rhizomate prostrato ascendens 3–6$^{\mathrm{cm}}$ altus lignosus parce ramosus cum petiolis pedunculisque ferrugineo-pubescens. Folia approximata 23–27$^{\mathrm{mm}}$ longa 17–19$^{\mathrm{mm}}$ lata supra pilis conspersa subtus nervatione pubescentia, petiolis

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[1] Continued from BOT. GAZ. **37**: 423. 1904.

circa 5^{mm} longis, stipulis lineari-lanceolatis 1–2^{mm} longis persistentibus. Pedunculi capillacei 12–16^{mm} longi. Sepala ovato-lanceolata 3^{mm} longa pubescentia. Petalum inferum 6^{mm} longum basi gibbosum, lamina unguem oblongam aequante, ceteris oblongis nervosis. Antherae subsessiles in annulum connatae, membrana terminali semiorbiculari. Capsula glabra.

San Pedro Sula, Depart. Santa Bárbara, Honduras, alt. 400^{m}, Jun. 1888, *C. Thieme*, n. 5628 ex Pl. Guat. etc., quas. ed. Donn. Sm.

Rourea Hondurensis Donn. Sm. (§DALBERGIOIDEAE Planch.)—Folia 4–5-juga, foliolis discoloribus marginatis supra glabris subtus pubescentibus obovato- vel elliptico-oblongis apice rotundis vel subacuminatis basi rotundis vel acutiusculis, infimis orbiculari-ovalibus. Paniculae folia subaequantes breviter parceque ramosae, pedicellis brevissimis. Capsula castaneo-velutina bis longior quam crassior.

Frutex scandens ut videtur, ramis petiolis paniculis ferrugineo-pubescentibus. Petiolus 2–3.5^{cm} longus, folii rhachi 6–8^{cm} longa, foliolis subcoriaceis aequilateralibus ad costam et nervos laterales utrinque 6–9 subtus ferrugineis, terminali obovato-oblongo 4.5–7^{cm} longo 2–3^{cm} lato brevissime acuminato basi acuto, lateralibus oppositis per paria deorsum decrescentibus 3.5–5^{cm} longis 1.5–2^{cm} latis utrinque rotundis vel basi subacutis, infimis 22^{mm} longis 17^{mm} latis. Paniculae singulae aut binae 8–13^{cm} longae, ramis simplicibus 0.5–1.5^{cm} longis. Calyx fructiferus glaber partitus pedicellum subaequans, laciniis ovatis 3^{mm} longis. Capsula valde arcuata 1.5^{cm} longa, semine optime ovali quam arillus bis longiore. Flores deficiunt.

Ad ripas rivuli prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 240).

Machaerium Verapazense Donn. Sm. (§RETICULATA Benth.)—Scandens inerme. Folia petiolo subdimidio longiora, foliolis 5 rotundo-ovatis vel ovalibus utrinque obtusis supra glabrescentibus subtus puberulis. Racemi solitarii petiolos subaequantes, pedicellis pluri-fasciculatis quam flores parum brevioribus. Stamina monadelpha. Ovula 2–4.

Caulis ramosus cum petiolis glabrescens, stipulis aristulato-lanceolatis 2–3^{mm} longis. Folia petiolo 3–6^{cm} longo addito 8–15^{cm} longa, foliolis papyraceis discoloribus costa excurrente mucrunculatis 6–7-penninerviis subtus tenuiter reticulatis, lateralibus oppositis 4–5.5^{cm} longis 2–3.5^{cm} latis basi rotundis vel levissime retusis, petiolulis incrassatis 3^{mm} longis, foliolo terminali maximo 5–6.5^{cm} longo 3–4.5^{cm} lato basi obtusiusculo, petiolulo 1–1.5^{cm} longo. Racemi axillares simplices fulvo-pilosi e basi floriferi 3–7^{cm} longi, pedicellis 3–12-nis 4–5^{mm} longis, bracteolis lineari-lanceolatis 2–3^{mm} longis, floribus violaceis, ut videtur, 6–7^{mm} longis. Calyx ecalyculatus pubescens hemisphericus 2^{mm} altus truncatus mucrunculo-denticulatus. Petala subaequilonga unguibus ciliata, vexillo orbiculari extus cano-sericeo. Stamina omnia in vaginam totam fissam usque ad duas partes connata 5^{mm} longa, antheris versatilibus. Ovarium cano-sericeum clavato-lineare 5^{mm} longum in stipitem 1^{mm} longam disco brevi circumdatam attenuatum, dimidio inferiore 2-vel 3-vel plerumque 4-ovulato, dimidio superiore applanato vacuo, stylo decurvo 2^{mm} longo. Legumen ignotum.—Species ovulis anormalis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1904, *von Tuerckheim*, n. 8508 ex Pl. Guat. etc., quas ed. Donn. Sm.

Pithecolobium macrandrium Donn. Sm. (§CHLOROLEUCON Benth.) —Pinnae 10–17-jugae, foliolis 16–40-jugis. Pedunculi ad axillas singuli ad apicem ramulorum racemosi et fasciculati spicis elongatis densissimis parum longiores. Stamina corollam calyce quinquies longiorem 5–6-plo superantia usque ad medium connata.

Arbuscula 5-metralis, ramulis angulatis uti rhachis foliorum et pedunculi glabrescentibus fuscis, aculeis stipularibus binis rectis 4–10^{mm} longis. Folia petiolo 3–8^{cm} longo addito 16–46^{cm} longa, glandula inter pinnas scutelliformi inter foliola stipitata, pinnis 5–12^{cm} longis, foliolis subsessilibus 9–18^{mm} longis oblongis apice obtuso apiculatis basi subtus glanduligera semicordatis supra praeter costam glabris subtus glaucis. Pedunculi 5–12^{cm} longi, spicarum rhachi 4–8^{cm} longa et floribus pubescentibus, bracteolis ovatis 2^{mm} longis intus glabris induratis spinula apiculatis calycem campanulatum triangulari-denticulatum aequantibus. Corolla infundibuliformis 1^{cm} longa usque ad primam tertiam partem lobata, lobis ovatis acutis. Stamina alba indefinita, antheris eglandulosis. Ovarium sessile pubescens. Legumina (juvenilia tantum suppetentia) oblonga leviter curvata plana.—Stamina magnitudine ea fere omnium aliarum specierum superant *Calliandram* referentia.

In silvis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1902, Nov. 1904, *von Tuerckheim*, nn. 8193, 8667 ex Pl. Guat. etc., quas ed. Donn. Sm.

Miconia Hondurensis Donn. Sm. (§TAMONEA Naud.)—Fere glabra. Folia opaca lucida lanceolato-elliptica contracto-acuminata basi acuta integerrima triplinervia, venis transversalibus simplicibus rectis. Calyx subsessilis obconico-oblongus limbo subintegro dilatatus. Stamina glabra.

Ramuli ad apicem versus obtuse tetragoni cum gemmis petiolis pedunculis leviter fusco-furfuraceis. Folia subcoriacea in sicco utrinque viridia apice ipso obtusiuscula disparia, altero 13.5–15^{cm} longo 5–5.5^{cm} lato, altero 8–10.5^{cm} longo 3.5–4.5^{cm} lato, venis subtus conspicuis, venulis supra obsoletis subtus grosse reticulatis, petiolis canaliculatis 1–1.5^{cm} longis. Thyrsus terminalis et subterminalis paniculiformis pedunculo 2.5–4.5^{cm} longo adjecto folia subaequans laxiflorus, pedicellis vix ullis minute bibracteolatis, floribus saepius ternis 5-meris. Calyx viridis vix pulverulentus 3.5^{mm} longus 10-costatus, limbo membranaceo undulato 0.5^{mm} lato. Petala siccitate simul flavicantia et rubescentia extus vix pulverulenta obovato-quadrata 4^{mm} longa retusa reflexa. Stamina disparia 7–9^{mm} longa, antheris filamenta paulo excedentibus falcatis, connectivo infra loculos haud producto basi antice biauriculato et ibidem rubiginoso-glanduloso. Ovarium pauciovulatum, stylo 8–10^{mm} longo, stigmate capitato. Bacca nondum visa.—*M. aureae* Naud. proxima.

Prope Puerto Sierra, Honduras, Febr. 1903, *Percy Wilson* (n. 575).

Miconia oinochrophylla Donn. Sm. (§SERIATIFLORAE Naud.)—Glabra. Folia lanceolata vel lanceolato-elliptica superne subsensim acuminata basi acuta subtus vinicoloria et cretaceo-punctulata adjecto nervulo utroque submarginali 5-nervia margine denticulato setulifera. Thyrsi rami semel 2–3-fidi, floribus sessilibus.

Ramuli obtuse tetragoni. Folia in eodem jugo paulo inaequalia 6–25^{cm} longa medio 5–9^{cm} lata, setulis marginalibus rigidis, petiolis 2.5–6^{cm} longis. Thyrsus terminalis 8–10^{cm} altus, ramis primariis decussatis praeter infimos trifidos bifidis, secundariis divaricatis, fructiferis 1.5–2.5^{cm} longis sulcatis purpurascentibus, bracteolis deltoideis 1^{mm} longis ciliolatis, floribus secundis 5-meris. Calyx teretiusculus 2.5^{mm} diametiens ecostatus, ore subintegro. Petala late oblonga 3^{mm} longa asymmetrica apice saepius emarginata. Antherae lineares 2^{mm} longae filamenta aequantes uniporosae. Ovarium apice tantum liberum 5-loculare, stylo crassiusculo 3^{mm} longo. Bacca nigra 4^{mm} diametiens.

Prope Livingston, Depart. Livingston, Guat., Febr. 1905, *von Tuerckheim*, n. 8684 ex Pl. Guat. etc., quas ed. Donn. Sm.

HAMELIA PATENS Jacq., var. **coronata** Donn. Sm.—Calycis segmenta patentia oblonga 4^{mm} longa tubum aequantia obtusa ciliata ceterum glabra. Fructus segmentis calycinis paulo auctis persistentibus coronatus.

Folia plerumque quaterna glabrescentia axillis subtus barbata. Stipulae setaceae.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Aug. 1903, *von Tuerckheim*, n. 8532 ex Pl. Guat. etc., quas ed. Donn. Sm.

Hoffmannia calycosa Donn. Sm.—Glabrescens. Folia inter minora lanceolato-elliptica deorsim sensim superne contractius acuminata. Cymae aggregatae petiolo breviores densiflorae, pedunculis pedicellisque brevissimis. Calycis segmenta linearia tubo bis et ultra longiora patentia. Corolla rotata, segmentis calycem subaequantibus.

Suffrutex, ramis teretibus, novellis bifariam puberulis. Stipulae triangulares contracto-acuminatae 1^{mm} longae. Folia nascentia nervis subtus puberula, provectiora glabra 9–15^{cm} longa 3.5–5.5^{cm} lata, nervis utrinsecus 6–8, petiolis glabrescentibus 8–15^{mm} longis. Cymae 6–10^{mm} longae, pedunculis pedicellisque 1–2^{mm} longis crassiusculis pilosiusculis, floribus tetrameris. Calycis pilosiusculi tubus obpyramidatus 2^{mm} altus tetragonus, segmenta 4–5^{mm} longa acuta carinata, sinubus parce glanduligeris. Corollae glabrae segmenta lineari-lanceolata. Stamina ori corollae inserta, antheris subsessilibus segmenta corollina fere aequantibus. Ovarium biloculare, stigmatis lobis liberis vix 0.5^{mm} longis. Bacca desideratur.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Maj. 1901, *von Tuerckheim*, n. 7912 ex Pl. Guat. etc., quas ed. Donn. Sm.

Hoffmannia lineolata Donn. Sm.—Rami crassi teretes glabrescentes. Folia maxima oblanceolato-elliptica acuminata in petiolum gracilem longe attenuata membranacea utrinque lineolata praeter nervos subtus ferrugineo-puberulos glabra. Cymae aggregatae petiolo 2–3-plo breviores pedunculatae cincinnales, pedicellis brevibus. Corolla rotata. Stamina sinubus corollinis inserta, antheris sessilibus.

Frutex, ramis digitum crassis fistulosis. Stipulae deciduae. Folia opposita 24–30^{cm} longa 6–12^{cm} lata discoloria cystolithis linearibus farcta subtus passim nigro-punctulata, nervis lateralibus utrinsecus 14–17, petiolis 3–7^{cm} longis. Cymae 1.5–2.5^{cm} longae quandoque semel vel bis dichotomae cum floribus 4-meris ferrugineo-puberulae. Calyx 2^{mm} altus pedicellum subaequans, limbo sinuato-dentato. Corollae tubus cylindricus 2^{mm} longus, segmenta lineari-oblonga 4^{mm} longa acuta. Antherae 3^{mm} longae. Ovarium biloculare, styli antheras paulo superantis lobis connatis 1^{mm} longis. Fructus globularis rubro-punctatus, seminibus rubellis.

Cubilquitz, Depart. Verapaz, Guat., alt. 350^{m}, Maj. 1902, *von Tuerckheim*, n. 8227 ex Pl. Guat. etc., quas ed. Donn. Sm.

Psychotria pleuropoda Donn. Sm. (§MAPOURIA Benth.)—Praeter stipulas bracteas bracteolas ferrugineo-ciliolatas glaberrima. Folia lineari-lanceolata internodiis multoties longiora. Stipulae majusculae connatae bifidae, laciniis lineari-setaceis. Pedunculus axillaris gracillimus. Cyma pedunculi dimidium subaequans pyramidalis, ramis ramulisque quaternis, floribus confertis. Corollae lobi tubo subaequilongi.

Suffrutex metralis dichotomo-ramosus, internodiis 1–3^{cm} longis. Folia 12–18^{cm} longa 2–2.5^{cm} lata utrinque deorsum autem longius attenuata, venulis subobsoletis, petiolis 5–10^{mm} longis. Stipulae utrinque solitariae in vaginam plus minus connatae 10–13^{mm} longae, parte inferiore ovata herbacea laciniis fuscis parum longiore. Pedunculi ex axillis perpaucis orti 7–8^{cm} longi, fructiferi reflexi. Cymae rami complanati, infimi 1.5^{cm} longi, pedicellis 0.5–1.5^{mm}

longis, bracteis bracteolisque minutis, floribus 5-meris glabris. Calyx bracteolatus campanulatus ultra ovarium productus 2^{mm} altus, lobis ovatis 0.5^{mm} longis. Corollae tubus cylindricus rectus 3^{mm} longus, lobis oblongis 2.5–3^{mm} longis reflexis apice cucullatis. Stamina annulo cano-pubescenti 1^{mm} infra orem corollae inserta, antheris subsessilibus 1.5^{mm} longis. Stylus 5^{mm} longus. Fructus ovalis 5–6^{mm} longus, pyrenis 4-carinatis facie ventrali haud sulcatis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Aug. 1903, *von Tuerckheim*, n. 8529 ex Pl. Guat. etc., quas ed. Donn. Sm.

Otopappus syncephalus Donn. Sm.—Folia perelongate oblongo-ovata acuminata basi subtruncata vel rotundata subtus setulosa. Paniculae pleistocephalae, capitulis discoideis inter minora 3–6-aggregatis sessilibus.

Rami validi cum petiolis paniculis capitulis leviter puberulis. Folia crassa subintegra 12–17^{cm} longa 4.5–6^{cm} lata supra scabrida subtus setulis scabriuscula, petiolis 1.5–2^{cm} longis. Paniculae foliis breviores, capitulis 5–6^{mm} altis et diametientibus 15–20-floris, involucri 3^{mm} alti bracteis 4-seriatis ovalibus obtusis scariosis, paleis oblongis acuminatis exappendiculatis parce puberulis, corollae 3^{mm} longae limbo semifido tubum bis superante, acheniis unialatis, pappo paleaceo.—*O. robusto* Hemsl. proximus.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Apr. 1904, *von Tuerckheim*, n. 8694 ex Pl. Guat. etc., quas ed. Donn. Sm.

Echites Cobanensis Donn. Sm.—Folia lineari-lanceolata basi rotundata vel retusa subtus incano-tomentosa, nervis lateralibus crebris. Pedicelli graciles, bracteis minutis. Corolla calyce multoties longior, faucibus tubo bis brevioribus paulo latioribus. Antherarum appendiculae obtusae adnatae. Discus lobatus.

Folia discoloria supra uti caulis et racemi fusco-puberula 8–10^{cm} longa 1.5^{cm} lata superne sensim acuteque angustata, nervis lateralibus utrinsecus 18–22, petiolis 6–8^{mm} longis. Racemi 6–10^{cm} longi, pedicellis 1.5^{cm} longis, bracteis subulatis 2^{mm} longis. Calycis intus basi pluriglandulosi segmenta ovata 3^{mm} longa. Corolla 2^{cm} longa, tubo 16^{mm} longo, faucibus leviter ampliatis.

Cobán, Depart. Alta Verapaz, Guat., alt. 1400^{m}, Aug. 1904, *von Tuerckheim*, n. 8709 ex Pl. Guat. etc., quas ed. Donn. Sm.

Echites Rosana Donn. Sm.—Glabra. Folia subsessilia lanceolata cordata subtus albicantia et fusco-reticulata, nervulis basalibus utroque latere binis. Racemi foliis longiores, pedicellis gracilibus bracteas calycemque subaequantibus. Corolla hypocraterimorpha, tubo laciniis calycinis bis fere longiore medio staminifero. Antherarum appendiculae obtusae adnatae. Disci squamae distinctae.

Folia 7–12^{cm} longa 1.5–3^{cm} lata superne sensim acuteque attenuata vel sursum nervulis basalibus brevissimis, petiolis 3–4^{mm} longis. Racemi 12–16^{cm} longi, pedicellis 9–11^{mm} longis, bracteis lineari-lanceolatis. Calyx intus basi glandulosus, laciniis lineari-lanceolatis 7^{mm} longis. Corolla 2^{cm} longa, tubo subaequaliter cylindrico.

Buena Vista, Depart. Santa Rosa, Guat., alt. 1000^{m}, Apr. 1893, *Heyde et Lux*, n. 4540 ex Pl. Guat., etc., quas ed. Donn. Sm.

Rhabdadenia macrantha Donn. Sm.—Glaberrima. Folia coriacea oblonga apice rotunda et cuspidata basi acuta. Pedunculus gracilis biflorus. Calyx pedicello paulo brevior, segmentis oblongis apiculatis. Corolla amplissima, tubo calycem sesquiaequante faucibus bis breviore. Antherae acutae dorso superne barbatae. Disci squamae semiconnatae rotundatae.

Volubilis ut videtur, internodiis 2–5^{cm} longis. Folia juniora glaucescentia aetate provectiore nitida 7–9.5^{cm} longa 3–3.5^{cm} lata abrupte minuteque cuspidata, nervis supra impressis subtus tenuibus subarcuatis, venis minute reticulatis, petiolis 1.5–2^{cm} longis. Pedunculus ex axilla suprema ortus 3–4.5^{cm} longus, pedicellis binis 10–14^{mm} longis, bracteolis minutis triangularibus, floribus glabris. Calycis segmenta eglandulosa 9–10^{mm} longa 3.5^{mm} lata obtusa nervata reticulata. Corolla in herbario aurantiacea, tubo cylindrico 18^{mm} longo ad apicem plaga staminifera cano-hirsuto in fauces 3.5^{cm} longas sensim ampliata, lobis dolabriformibus 2^{cm} longis. Antherae lanceolato-linearis 4–5^{mm} longae, filamentis complanatis paulo longioribus quam latioribus. Disci squamae carnosae 1.5^{mm} longae ovaria sejuncta orbicularia aequantes, stylo 2.5^{cm} longo, stigmatibus apice penicillatis, membrana reflexa 1.5^{mm} longa. Folliculi ignoti. —*R. biflorae* Muell. Arg. affinis.

Ad ripas rivuli prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 244).

Marsdenia laxiflora Donn. Sm.—Glaberrima. Folia subcoriacea nitida lanceolata vel lanceolato-oblonga sensim vel abruptius acuminata ad basin obtusam supra pluriglandulosa. Inflorescentia uniaxillaris folia subaequans laxe cymosa, pedunculo ramis pedicellis filiformibus. Corolla subrotata. Coronae squamae gynostegium aequantes.

Suffruticosa volubilis ramosa. Folia 7–12^{cm} longa 1.5–3.5^{cm} lata, nervis lateralibus utrinsecus 7–9, petiolis 5–10^{mm} longis. Cymae flexuosae pauciflorae, pedunculis 4–6^{cm} longis, ramis 2–4^{cm} longis, pedicellis 2–4-nis basi minute pluribracteolatis 1–2^{cm} longis, floribus totis praeter calycis corollaeque margines ciliolatos glabris. Calyx prope sinus uniglandularis, segmentis ovatis obtusis 2^{mm} longis. Corollae tubus 2^{mm} longus, segmenta leviter obtegentia oblonga

7^{mm} longa obtusa. Coronae squamae planae membranaceae sejunctae oblongo-ellipticae obtusae ad quartam partem liberae 3^{mm} longae basi auriculatae. Pollinia erecta ovoidea. Discus stylinus pulvinatus. Folliculi ignoti.—Inflorescentia laxissima hanc speciem bene significat.

Ad Río Dolores, Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Aug. 1903, *von Tuerckheim*, n. 8558^{B} ex Pl. Guat. etc., quas ed. Donn. Sm.

Ipomoea Tuerckheimii (Vatke ined.) Donn. Sm. (§STROPHIPOMOEA, *Integrifoliae, Hastatae.* Peter in Engl. et Prantl Nat. Pflanzenfam. IV. 3^{a} 30.)—Folia longe acuminato-cordiformia, lobis basalibus brevibus rotundatis, sinu acuto, margine subintegro vel sinuato-dentato. Pedunculi cymoso-pluriflori. Sepala aequalia dorso tuberculata. Corolla parva, limbo caeruleo.

Caulis cum petiolis et foliis novellis pubescens. Folia aetate provectiore praeter marginem glabrescentia $6–8^{cm}$ longa $3.5–4.5^{cm}$ lata mucrunculo apiculata usque ad quintam partem bilobata, petiolis $3.5–6^{cm}$ longis. Pedunculi $2.5–3^{cm}$ longi 2–7-flori. Sepala oblongo-ovata 4.5^{mm} longa glabra, costa extus tuberculis rubris prominente. Corollae circa 2^{cm} longae limbus fide cl. repertoris in vivo caeruleus. Capsula ovoidea 1^{cm} longa breviter cuspidata bilocularis quadrivalvis, seminibus 4 vix puberulis.

Cobán, Depart. Alta Verapaz, Guat., alt. 1400^{m}, Nov. 1886, *von Tuerckheim*, n. 386 ex Pl. Guat. etc., quas ed. Donn. Sm.—Cl. *Hallier* in Durand et Pitt. Prim. Fl. Cost. Fasc. III. 203 exemplum Tuerckheimianum sub nomine *I. Tweediei* Hook. incaute ut videtur citavit.

Brachistus physocalycius Donn. Sm.—Folia dimorpha, altero lanceolato-oblongo alterum ovale multoties superante. Flores gemini. Calyx subinteger, fructifer valde auctus. Corolla infundibularis quarta parte lobata. Filamenta filiformia antheris longiora. Bacca calyce tota inclusa.

Fruticosus. Folia disticha membranacea supra glabra subtus cum ramis petiolisque pubescentia, majore $16–22^{cm}$ longo $5–6.5^{cm}$ lato inaequilaterali sursum subsensim longeque acuminato basi inaequali plus minus acuto, petiolo $0.5–1.5^{cm}$ longo, folio minore $1.5–6^{cm}$ longo $1–3.5^{cm}$ lato utrinque obtusiusculo, petiolo vix ullo. Pedunculi cernui $4–6^{mm}$ longi. Flores toti glabri 12^{mm} longi. Calyx campanulatus sub anthesi 3^{mm} altus mucrunculo denticulatus. Corolla alba e basi paullatim ampliata, lobis ovatis erectis. Stamina 2^{mm} supra basin corollae affixa, filamentis 3^{mm} longis basi haud dilatatis, antheris oblongis 2^{mm} longis. Stylus 9^{mm} longus. Bacca globosa 7^{mm} diametiens, seminibus complanatis suborbicularibus 2^{mm} diametientibus in utroque loculo circiter 16.—*B. oblongifolio* Miers proximus differt insigniter calyce augescente *Athenaeam* simulante.

In silvis udis umbrosis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Oct. 1903, *von Tuerckheim*, n. 8553 ex Pl. Guat. etc., quas ed. Donn. Sm.

Columnea calotricha Donn. Sm. (§STYGNANTHE Benth. et Hook.)—Undique pilosa. Folia leviter disparia oblongo-elliptica utrinque acuta subintegra. Pedunculi petiolis breviores. Calycis segmenta sejuncta spathulato-oblonga. Corolla subclavato-tubulosa calyce 3-plo longior. Disci glandula unica.

Fruticulus saprogenus e basi repente ascendens in exemplis suppetentibus 5–16^{cm} altus simplex caule petiolis foliis nascentibus floribus crinito-hirsutus, pilis articulatis rubro-tinctis. Folia subtus vinicoloria utrinque pilosa margine ciliata 5–8.5^{cm} longa 2–3^{cm} lata, petiolis 11–14^{mm} longis, internodiis 5–15^{mm} longis. Flores solitarii 40–42^{mm} longi, pedunculis 6–8^{mm} longis. Calycis segmenta subaequalia 13–15^{mm} longa obtusa. Corolla rubiginosa recta e basi gibbosa paullatim leviterque ampliata faucibus haud constricta ore subobliqua, lobis 4^{mm} longis inaequilatis. Bacca rubra ovalis 16^{mm} longa.—*C. moestae* Poepp. et Endl. proxima differt autem inter alias notas glandula disci solitaria.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1903, *von Tuerckheim*, n. 8542 ex Pl. Guat. etc., quas ed. Donn. Sm.

Adenocalymna macrocarpum Donn. Sm. (§HANBURYOPHYTON Bur. et K. Sch.)—Glabrum. Folia conjugata, cirrho simplice vel plerumque deficiente, foliolis ellipticis vel oblongo-ellipticis apice subabrupte acuminatis basi acutis penninerviis subtus glandulari-punctulatis. Thyrsi densiflori, rhachide pedunculum altero tanto excedente. Corolla anguste infundibularis. Stamina medium corollae vix attingentia. Capsula linearis perelongata, seminibus latissime alatis, nucleo tenui.

Frutex scandens, caule verrucoso ceterum glabro. Foliola 7–11^{cm} longa 3.5–4.5^{cm} lata coriacea supra sicco saturate viridia subtus pallidiora pallidius marginata basi complicata, nervis lateralibus utrinque circiter 5, petiolis 12–16^{mm} longis, petiolulis 8–12^{mm} longis utrinque incrassatis supra canaliculatis. Thyrsi axillares et terminales bracteis foliaceis 1.5–2^{cm} longis suffulti glabri, pedunculo 3–4^{cm} longo, rhachide 6–8^{cm} longa, ramis primariis oppositis 1.5–2^{cm} longis erecto-patentibus dichasia gerentibus, bracteolis linearibus minutis, pedicellis 0.5–1^{cm} longis. Calyx eglandulosus pulverulentus campanulatus 6^{mm} altus mucrunculis denticulatus. Corolla flava pulverulenta 6–6.5^{cm} longa e tubo basilari cylindrico 7–8^{mm} longo subsensim ampliata ad 6^{mm} supra basin staminigera et ibidem pubescens, lobis inaequalibus 1–1.5^{cm} longis. Stamina majora 21^{mm} longa, minora 16^{mm} longa, staminodio 5^{mm} longo, antheris divaricatis nudis linearibus 3^{mm} longis. Discus pulvinatus 2^{mm} altus 3^{mm} latus. Ovarium lineare teres 6^{mm} longum puberulum, stylo 2.5^{cm} longo, stigmatis lobis lanceolatis

3^{mm} longis. Capsula generis adhuc longissima $29–52^{cm}$ longa 1.5^{cm} lata valde compressa eglandularis apice attenuata basi obtusa, valvis crasse coriaceis planis, nervo mediano percursis seminibus biseriatis pro loculo 20–25 alis hyalinis adjectis $4.5–5.5^{cm}$ latis 1.5^{cm} altis, nucleo 1^{cm} diametiente valde compresso.

Tecoluca, Depart. San Vincente, El Salvador, alt. 70^{m}, Jan. 1893, *Shannon*, n. 5055 ex Pl. Guat. etc., quas ed. Donn. Sm.—Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, ann. 1900, *von Tuerckheim*, n. 7759 ex Pl. Guat. etc., quas ed. Donn. Sm.—Eandem plantam in ditionibus Mexicanis collegit *Pringle* (n. 3898).—Haec exempla omnia sub *Cydista aequinoctiali* Miers, var. (*Bignonia sarmentosa* Bertol.), olim distributa sunt.

Cornutia cymosa Donn. Sm.—Ramuli teretes. Folia ampla ovalia vel suborbicularia utrinque rotundata. Cyma dichotoma corymbiformis latissima. Drupa generis adhuc maxima depresso-globosa, putamine osseo profunde exsculptato lacuna basali bifido.

Arbor, coma rotunda (*Tonduz* in schedula), ramulis petiolis cymae axibus pubescentibus vel glabrescentibus, gemmis ferrugineo-pilosis. Folia $14–27^{cm}$ longa $13–20^{cm}$ lata utrinque minute strigillosa siccitate bullata, costa nervisque validis, his utrinsecus 7–10 patulis sub margine junctis, venis transversis parallelis, venulis minute reticulatis, petiolis $2.5–4^{cm}$ longis. Pedunculus $3–10^{cm}$ longus, cyma sexies–decies dichotoma $10–14^{cm}$ alta $16–23^{cm}$ lata laxe floribunda, axibus robustis subangulatis, pedicellis $2–5^{mm}$ longis. Calyx fructifer pubescens planiusculus $6–7^{mm}$ latus, lobis ovatis. Drupa transversim leviter compressa $8–12^{mm}$ longa $10–15^{mm}$ lata, putamine sulcato et foveato a basi usque ad medium versus excavato abortu biloculari, seminibus lineari-oblongis. Flores ignoti.

In pascuis ad La Palma, Prov. San José, Costa Rica, alt. 1460^{m}, Sept. 1898, *Tonduz*, n. 7383 ex Pl. Guat. etc., quas ed. Donn. Sm. (n. 12555 herb. nat. Cost.).

Trophis macrostachya Donn. Sm.—Folia maxima oblongo-elliptica longe tenuiterque caudato-acuminata basi rotunda vel acuta supra medium repando-denticulata vel subintegra. Spicae masculinae dichotomae, femininae longissimae, perianthio fructifero sessili vel breviter pedicellato.

Arbor, ramulis novellis cum petiolis stipulis spicis pubescentibus. Folia coriacea supra glabra subtus nervis venisque pubescentia $15–22^{cm}$ longa $6–9^{cm}$ lata, acumine caudiformi $2–3^{cm}$ longo, nervis lateralibus utrinsecus 12–14 juxta marginem junctis, petiolis $1–2^{cm}$ longis, stipulis ovato-lanceolatis convolutis $5–6^{mm}$ longis. Spicae masculinae bis furcatae continuatim densiflorae 5.5^{cm} longae, perianthii segmentis imbricatis 2^{mm} longis bracteolas et stamina aequantibus. Spicae femininae plerumque binae, floriferae $4–6^{cm}$ longae, fructiferae $10–13^{cm}$ longae, bracteolis rotundis 0.5^{mm} longis ciliatis, perianthiis floriferis compactis, fructiferis laevibus pubescentibus ovalibus vel ovoideis $8–10^{mm}$ longis, pedicellis interdum $1–3^{mm}$ longis raro ramosis, fructu apice ipso tantum libero, semine 6^{mm} longo.

In pascuis ad Las Vueltas, C. R., Nov. 1898, *Tonduz*, n. 8124 ex Pl. Guat. etc., quas ed. Donn. Sm. (n. 12802 herb. nat. Cost.).—In silvis ad Palmar, Costa Rica, Mart. 1892, *Tonduz* (n. 6751).—Tuís prope Turrialba, Prov. Cartago, Costa Rica, alt. 620^{m}, Jul. 1897, *Pittier* (n. 11266).—In silvis ad Tuís, Prov. Cartago, C. R., alt. 650^{m}, Oct. 1897, *Tonduz* (n. 11357).

Sahagunia urophylla Donn. Sm.—Praeter perianthium glabra. Folia integra oblongo-elliptica vel late ovalia caudato-acuminata basi acutiuscula vel rotunda, nervis lateralibus utrinsecus 6–8. Pedunculi feminini solitarii aut gemini. Perianthium fructui pendulo infra apicem adnatum, pericarpio cartilagineo.

Folia subcoriacea supra saltem in sicco obscura subtus viridia, nunc 13–20^{cm} longa in medio 5.5–8.5^{cm} lata basi subacuta, nunc 6–8^{cm} longa 4–5^{cm} lata basi rotunda, nervis venisque utrinque praesertim subtus manifestis, venulis grosse reticulatis, petiolis 1–1.5^{cm} longis, stipulis lanceolatis 2–3^{mm} longis caducis. Pedunculi feminini 3–4^{mm} longi, fructibus 2–4 capitatis, additis floribus nascentibus nonnullis. Perianthium crasso-carnosum fusco-velutinum ovale 12^{mm} longum collo subintegro apiculatum, fructu subgloboso 6–7^{mm} diametiente, stylo 3^{mm} longo, semine infra apicem affixo rufescente scrobiculoso. Flores utriusque sexus deficiunt.—Haec species generis tertia adhuc edita ab *S. Mexicana* Liebm. glabritie et foliis pro rata latioribus caudatis paucinerviis, ab *S. strepitante* Fr. Allem. foliis integris pedunculis saepe binis fructibus minoribus inter alia differt.

In silvis prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 54).

Coussapoa oligocephala Donn. Sm.—Folia oblongo- vel subovato-elliptica apice obtusiuscula et apiculata basi rotundata et emarginata discoloria supra glabra subtus arachnoidea. Cyma brevissime bis terve dichotoma, capitulis paucis subglabris. Stamen perianthio lobulato bis longius, anthera quadriloculari.

Frutex epiphyticus (fide oculatissimi repertoris supra *Achras Sapota* L. re vera parasiticus), ramulis novellis stipulis petiolis pedunculis cum cyma pilosis. Folia 10–16^{cm} longa 4–7^{cm} lata, nervis lateralibus utrinsecus 9–11 rectis in margine ipso terminatis, imis e basi extrorsum ramosis, petiolis 1.5–2.5^{cm} longis. Pedunculi masculini solitarii vel gemini 2–2.5^{cm} longi, capitulis 3–5 circa 4^{mm} diametientibus, bracteolis tenuissime spatulatis. Perianthium turbinatum vix 1^{mm} longum, lobulis brevibus rotundis incrassatis uti bracteolarum apex ad lentem puberulo-punctulatis. Capitula feminina non vidi.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Apr. 1904, *von Tuerckheim*, n. 8659 ex Pl. Guat. etc., quas ed. Donn. Sm.

BALTIMORE.

THE DEVELOPMENT OF ROOT HAIRS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXIV.

Laetitia Morris Snow.

(WITH PLATE I AND SIX FIGURES)

INTRODUCTION.

Experimentation upon the effect of external agents on the development of root hairs is complicated by the fact that when external conditions are varied the internal factors are disturbed by an unknown amount. The varying of only one condition, which is the essential feature in accurate research, was thus extremely difficult, if not impossible. Therefore, the results to be set forth here are understood to be tentative. The last experimental work upon the immediate subject is that of Schwarz (**75**), to which the reader is referred for most of the earlier literature. Apart from three or four papers, the references to the causes for the development of root hairs are found incorporated, here and there, in reports on root studies, and as a rule are merely casual observations. The work here reported has been an endeavor to add some facts and suggestions as to the causes for the production of root hairs, variations in their structure not being considered.

LIGHT AND DARKNESS.

In view of the fact that in darkness there is generally an increase in the length of the axial organs and of their component cells (**47**, p. 64; **37**, p. 254), and because authors differ as to the effect of light and darkness upon the development of root hairs, it seemed best to reinvestigate the matter. Schwarz (**75**, p. 163) reports no effect; Went's (**85**, p. 8) experiments were not very convincing one way or another; Devaux (**10**, p. 306) finds that light retards growth and favors the development of root hairs; Pethybridge (**63a**, p. 235) reports that light retards the production of hairs upon the roots of oats and wheat growing in water cultures. The last experiment was repeated several times, but very little difference was noted between the jars, the roots showing individual peculiarities of growth under both conditions. In one experiment the general growth in length seemed to be a little less in light, accompanied by a slight increase in the length and thickness of the hairs. In others no difference was noticed. No zonal arrangement was observed, as was mentioned by DEVAUX (**11**). According to MACDOUGAL (**47**, p. 246) the development of hair upon aerial organs in response to light conditions varies greatly, some plants having a tendency to decreased hair production in darkness, and others showing no change.[1]

A. Seedlings.

Preliminary experiments showed that the primary roots of seedlings of *Triticum vulgare, Zea Mais, Pisum sativum, Cucurbita Pepo, Vicia sativa, Helianthus annuus, Brassica alba*, and *Raphanus sativus* produced hairs, for a longer or shorter zone, in air or water regardless of the light conditions. This is attributed by SCHWARZ (**75**, p. 162) to the abundant food supply, seedlings being in a measure independent of external conditions for their existence.

Seeds of wheat, corn, pea, and squash were sprouted upon moist filter paper under illuminated and darkened bell-jars. On plants of the same age the hair zones were measured. No decided difference was found, though the hair zones averaged somewhat longer in darkness. The influence of the light was not strong and was probably indirect, through its effect upon growth.

An attempt was next made to compare the increase of surface per square millimeter under the two conditions. Seedlings of sunflower, white mustard, and radish were attached to pine bars by means of filter paper and rubber bands, as described by NEWCOMBE (**55**, p. 150), and placed in glass jars, one set being illuminated and the other darkened. The measurements were taken in all cases, as nearly as possible in the zone of best average development, near the top of the root. The closeness of the hairs varied in different parts of the root, but the average of the numerous counts was probably not far from fair. The increase (in square millimeters) per square

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[1] In connection with the experiments here reported, the condition of the hairs on the epicotyl of etiolated and normal seedlings of Helianthus were compared. In the former case the cells were longer and the hairs were not only thus farther separated, but fewer cells produced hairs.

millimeter was calculated by multiplying the average length by the average width by the average number of hairs per square millimeter by π. Scrutiny of the results in the sunflower shows that for equally long roots the increase of surface varies, but that there is a slight predominance in the average increase of plants in dark (14.8) over those in light (14.02), and that this is entirely due to the greater average number of hairs per square millimeter (395 as against 373). The individual measurements for white mustard and radish show a like fluctuation of increase, but this time with a predominance in the average of light over darkness.[2] This is probably due to the fact that these are small seeds with little reserve food, and soon begin photosynthetic work in the light, while the plants in darkness have no such advantage. No evident difference in the length of hairs was observed in dark and light, as was noted by BENECKE (**5**, pp. 28, 29) for rhizoids of Lunularia.

B. *Older roots.*

Under ordinary conditions corn plants one or two weeks old, with roots growing through the bottom of the pots, did not produce hairs in water, whether illuminated or not. DEVAUX (**10**), on the other hand, found that light favored hair development on the roots of corn two months old growing in water. These plants, however, had been subjected to the rather severe operation of having all the roots cut off to one centimeter from the base, after which they were plunged into water. Upon repeating the experiment it was found that the plants in a day or so became yellow and unhealthy. In light five apparently healthy adventitious roots developed, and produced several isolated patches of hair, usually at the same time on all the roots, generally covered with a film of bacteria. In the darkened jar only three apparently healthy roots and two diseased ones were developed. No hairs or bacteria films appeared, although the odor of the culture betrayed greater decomposition than in the illuminated jar. Too many factors are involved to make the experiment, in its present form at least, of much value.

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[2] Thus, mustard showed average increase, dark 41.33, light 44.11; and the radish, dark 29.44, light 32.09. Here also number of hairs, 321 to 344 and 345 to 357, accounts for the increase.

WENT (**85,** p, 8) found in aerial roots that light was not favorable to hair production except in very damp air, which makes it appear that with aerial roots in general moisture is of much more importance for hair development than light (PFEFFER **64,** p. 130).[3]

When seedlings of corn were allowed to send their roots through the bottom of the pots into moist chambers, one darkened and one left in diffuse daylight, little difference was observed between them, some roots in light producing more hairs and some less than those in darkness. There seemed a slight tendency for the hair to be thicker in light. MER (**51,** p. 584) found variation in the appearance of hairs on the different roots in the same culture, and considers "cette inégalité d'apparition des poils dans un même milieu est bien propre à montrer que leur développement est étroitement lié à la constitution particulière de chaque radicelle." No zonation such as DEVAUX (**11**) reports was noted in these cultures. In some cases, wheat, corn, and sunflower produced hairs in irregular zones, which however could not be traced to the effect of light and darkness. Any one of the many causes which may result in irregular growth might have been responsible. Where there is any effect on the development of root hairs produced by light, it appears from the above consideration to be due to the indirect effect upon growth. It does not appear to have the direct retarding influence as found by VÖCHTING in the case of the growth of willows and the development of new organs (**83,** pp. 152–162).

TEMPERATURE.

The effect of high and low temperatures upon growth has been studied by many investigators (**64,** pt. 2), with the general result that increase of temperature favors growth on account of greater or more rapid absorption. KIRCHNER (**29,** pp. 353–355) reports growth increased by high temperatures; NĚMEC (**54a**) found longer, thinner cells in warm water than in cold; POPOVICI (**67,** pp. 37, 88) states that high temperatures (33° C.) diminish the zone of elongation, while low temperatures, just above the germination minimum, increase it, although the total growth is less. KOSAROFF (**32a**)

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[3] For numerous instances of hair production on aerial roots touching a support, see the bibliography in WENT's paper.

and KRABBE (**33**, p. 474) found roots to absorb less water at low temperatures. VAN RYSSELBERGHE (**70a**) considers that merely the rate of absorption is affected by the impermeability of the protoplasm. DEVAUX (**11**, p. 52) considers temperature to be of great importance in the production of root hairs, but has as yet merely made that preliminary statement. SCHWARZ (**75**, p. 158) reports that optimum temperatures (27–28° C.) do not overcome the inhibitory effect of water, as the roots grow smooth.

A comparison of the increase of surface in the cases of mustard and radish shows that temperature variations of small amount have no appreciable effect. The effect of greater changes was tested with seedlings of wheat and corn. These were placed in water at temperatures of 33–38° C. No hairs appeared on the parts in water, while the parts in air, as the height of the water varied a little, produced a few hairs.

Wheat seedlings in warm water, in water at room temperature, and in cold water, grew in all three conditions, and gave the following results:

Condition	Temperature	Duration	Result
Cold........	4.5–15.5° av. 11.6° (once 22.5)	Dec. 8–18	Haired to the tip, long and close set
Medium.....	16.0–29.5° av. 23.7°	Dec. 8–21	Hairs not so good, long bare spaces at tip
Warm.......	27.0–48.0° av. 34.5°	Dec. 8–14	Only two lived, smooth

Corn seedlings at temperatures of 29–37° (av. 33.4°) produced no hairs; while control plants at 16–27° (av. 22.9°) were haired at first, but later the root assumed its usual water type. This experiment was repeated many times with various modifications, and gave the same results.

That the smooth condition was due to the growth, rather than to the direct action of the heat upon the epidermal cells, was suggested by the following experiment. Corn seedlings were fastened in tap water of temperature 18–20° C., which was kept flowing in a very small stream from a rubber tube reaching the bottom of the jar. Under these conditions all the roots grew smooth and straight, omitting the seedling zone of hairs. Whether this was from the constant supply of oxygen or on account of rheotropic stimulation by the rising water currents was not evident (*fig. 10*). The experiment was continued by varying the temperatures in the cold jar from 4–26°, giving very short hairs on one healthy root and on portions infested with bacteria. Once or twice a tuft of hairs was produced when seedlings were changed from cold to warm water, due possibly to retardation (ASKENASY **2,** p. 70; TRUE **80,** p. 400), but more probably to the more rapid adjustment and stretching of the epidermal cells in the warm water than of the inner cells. KIRCHNER (**29,** p. 353) found that 4° C. allowed of little or no growth of corn roots, while wheat elongated at 0°C., which may partially account for the different hair conditions in the two plants in cold water.

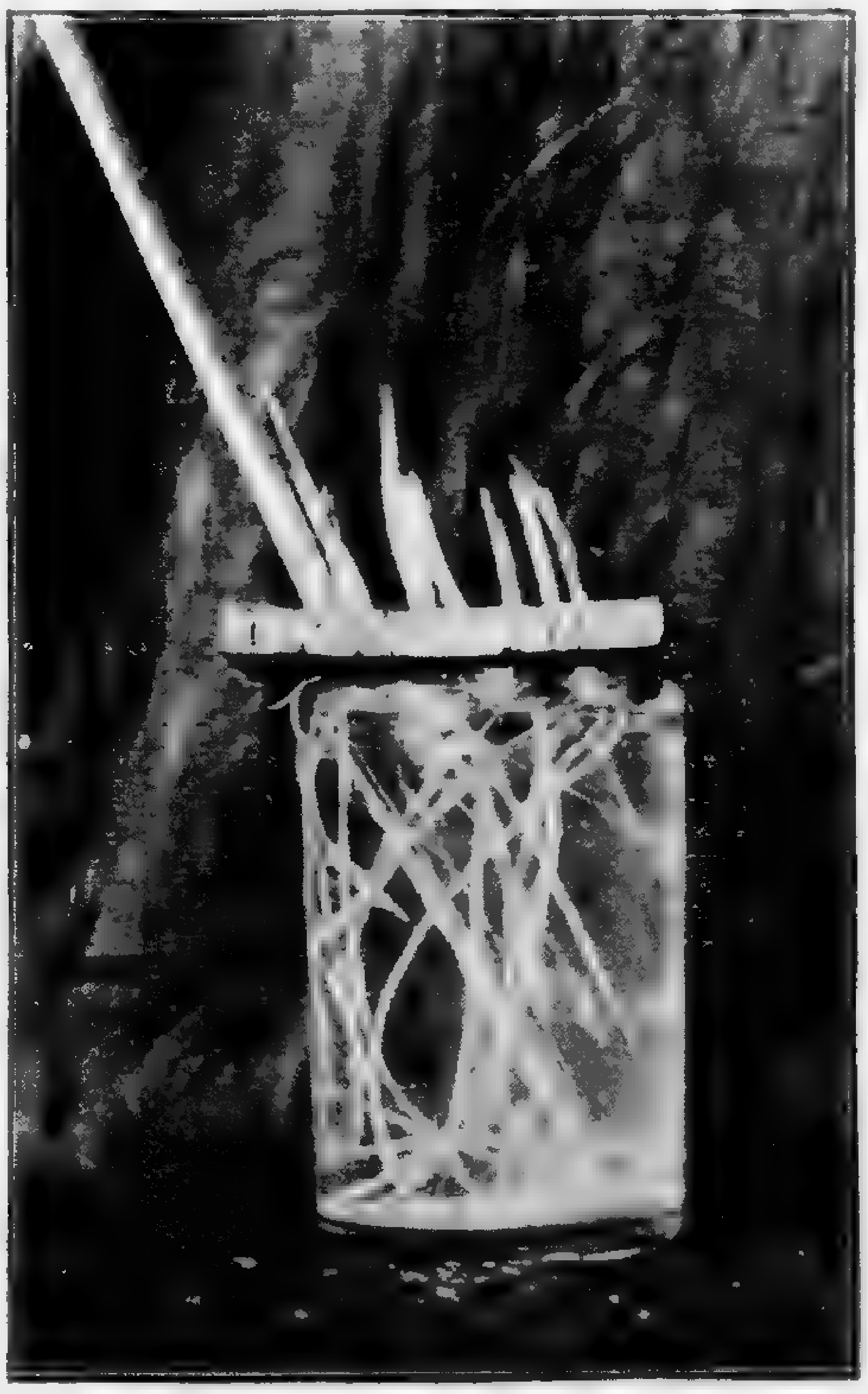

FIG. 10.—Corn roots growing in flowing tap water.

Wheat was planted in a pot of garden soil, and the roots allowed to come through the bottom and pass into warm water, of temperatures varying from 27–33° C. The roots were smooth at 33°, had scanty and irregular hairs at about 30°, and were more or less hairy at 27°. As this was tried repeatedly with the same result, it seems that for wheat, under these conditions, 30° C. is about the limit of hair production.

During a period of high temperature in the room, Elodea roots growing in soil were observed to be straight and smooth instead of kinky and hairy as is usual. When the temperature fell to the normal point, about 21° C., the roots assumed their usual aspect. In one case measured, the root growing in ground quartz at 27–34° C. elongated 4^{mm} in five days, and was curved and piliferous. The heat was not able under these conditions to suppress hair development. Another plant of Elodea growing in a glass cylinder had accumulated a little organic matter in the bottom of the vessel, not enough to make a layer, and consequently not enough to offer any appreciable resistance to root growth. The roots growing along the bottom in this debris curled and developed hair in some places, but were smooth where they curved up into the water.

CONTACT.

Concerning the effect of contact upon the production of root hairs authors differ. SCHWARZ (**75**, p. 160) offers no explanation for their production in the case of water roots of Nuphar or Elodea entering the substratum, but thinks they are not due to contact, chemical stimulation, or retardation of the growth of the root. On air roots of aroids and orchids dry contact produced no hairs, nor was he able to cause them on Elodea (presumably in water) by contact with glass beads or ground glass. In air roots he speaks (p. 120) of the suppression of hair by too close contact. EWART (**14**, p. 237) makes the statement that "for the formation of root hairs on the root tendrils (of Vanila) moisture is essential, darkness and contact accelerating, and light and dryness retarding it." PFEFFER (**64**, p. 156) denies the effect of contact, attributing the hair development to greater moisture near the support. WENT (**85**, p. 8) also thinks that not contact but moisture and absence of light are the factors.

In the experiments here reported there was a production of hairs on the roots of Elodea not only when the root grew into the mud at the bottom of the aquarium, but also when ground quartz was substituted for the mud, while in every case roots growing freely in the water produced no hairs. Several of these straight, smooth roots were allowed to grow into ground quartz, and the tips were found usually much bent and curved, and in all cases covered with hairs. Sections were made from roots in water, soil, and quartz, and the cells were measured. The averages were:

MEDIUM	AV. LENGTH IN MM. OF CELLS		CONDITION
	Of epidermis	Of cortex	
Water	0.104	0.160	Smooth
Quartz	0.091	0.110	Hairy
Soil	0.068	0.100	Longer hairs

There seems, therefore, to be a decided shortening of the cells in the substratum. As the mud at the bottom of the aquarium was of closer texture than the quartz, it probably offered greater resistance to the growth of the root. If the statement made by HABERLANDT (**22**, p. 188) concerning Elodea—"denen die Wurzelhaare in Wasser vollkommen fehlen, während sie beim Eindringen der Wurzeln in Erde sich reichlich einstellen"—means that the resistance of the substratum is instrumental in bringing about the production of root hairs, these results agree. The possibility of the chemical stimulus of the soil has been mentioned.

It does not seem probable that surface contact is a factor in the production of root hairs in soil, for when the earth is saturated the hairs on corn seedlings disappear, and those on wheat seedlings are decreased, although the soil particles are still there. This was stated by SCHWARZ (**75**, p. 160). In order to test the effect of contact with a smooth, solid body upon the epidermal cells of the root, corn seedlings were grown with their roots between glass plates, and in glass tubes open at the end. Where the roots filled the diameter of the tubes or the space between the plates, hairs were absent, both in air and water. On the sides not touching the plates hairs appeared nearly to the tip in air, and in the upper portions in water, as they do under ordinary conditions. Thus the contact on two sides of the root has no apparent effect on the hair production on the other two sides. Where the root did not fill the tube, hairs appeared in the usual zone in water and bent against the glass.

RETARDATION OF GROWTH.

It is of importance when speaking of the effect of growth upon the production of root hairs to indicate the effective stage. When the statement is made that slowing the growth of a root favors the production of root hairs (**51**, **52**, **11**), the retardation may be due either to fewer cell-divisions or to less elongation of the cells.

A. Rate of growth in air and water.

According to MER (**51**, **52**, **53**, p. 1279), retardation of the growth of a root produces or increases hair development. Thus lentil roots (**52**, pp. 665–6), growing straight and smooth in air, became piliferous when their growth was checked by the earth. Also, when these roots and those of corn were papillate in air, passage into water checked their growth, caused curves, and made the hair longer at first, after which the roots grew smooth. Swellings and curves are generally covered with long hair, for which he offers the following explanation:

> Lorsque les substances plastiques ne sont pas entièrement utilisées par l'extrémité végétative, ainsi que cela arrive quand l'accroissement de cette dernière est entravé par une cause quelconque, elles se portent sur les éléments voisins et principalement sur les cellules épidermiques dont les parois libres peuvent se développer plus facilement. De là des renflements, des radicelles et des poils.

SCHWARZ (**75**, p. 149) does not consider MER'S results trustworthy, and thinks that the checking of growth cannot cause development of hairs; but on the other hand that hair production goes with optimum growth energy (p. 155). MER repeated his experiments with the same results (**51**). SACHS (**71**, p. 410) found that the growth of roots in water is more rapid than in air. SCHWARZ (**75**, p. 154) reports slower growth in water than in air or earth, with a consequent decrease of hairs. Rapidity of growth caused by optimum temperature, however, was not able to overcome the inhibitory effect of water (p. 155). The following quotation is not quite in harmony with his criticism of the explanation offered by MER: "Am längsten werden die Wurzelhaare im feuchten Raume, und wenn das Wachsthum der Wurzel durch Nutation u. s. w. besondere Hemmung erleidet."

JAR 1.

24-HR. PERIODS	GROWTH IN 24 HRS. (mm.)		GROWTH PER HR. (mm.)		Temp.	CONDITION
	Water	Air	Water	Air		
I.	32.0	..	1.33	....	..	
II.	....	21	....	0.88	..	
III.	14.0	..	0.58	....	12°	Hairs half way down
IV.	....	5	....	0.20	11	One tuft
V.	4.5	..	0.19	....	14	No hairs
VI.	....	7	....	0.29	19	Hairs back to one tuft
VII.	6.0	..	0.25	....	18	Doubtful hairs at top
VIII.	15.0	..	0.65	....	18	Evident hairs at top
IX.	30.0	..	1.25	....	12	No hairs
Average	16.9	11	0.71	0.46	..	

JAR 2.

24-HR. PERIODS	GROWTH IN 24 HRS. (mm.)		GROWTH PER HR. (mm.)		Temp.	CONDITION
	Water	Air	Water	Air		
I..........	15	..	0.63	....	12°	Few towards top
II..........	....	6	....	0.25	11	No hairs
III..........	7	..	0.29	....	14	No hairs
IV..........	....	10	....	0.42	19	Hairs back to last air period
V..........	15	..	0.63	....	18	No hairs
VI[4]..........	5	10	0.84	0.42	18	Abundant in air, none in water
VII..........	15	..	0.54	....	12	Little evidence at top
VIII[5]........	....	10	....	0.42	18	Abundant
IX[5].........	....	6	....	0.25	12	Good hairs
Average.....	12.5	8.4	0.52	0.35	...	

An attempt was made to ascertain whether the difference in rate of growth of corn seedlings in air and water could be the cause for the lack of root hairs in the latter medium. The seeds were planted in small pots in a mixture of sand and humus, or in garden soil, and the roots allowed to pass through the bottom of the pots. By placing the pots in the tops of wide-mouthed bottles half full of water, the roots hung in moist air, and by changing the level of the water, alternating conditions of air and water were brought about. The roots were allowed to remain in each medium for twenty-four hours.

It will be seen upon examination of the above tables that there was a general tendency to produce hairs in air and to cease their development in water. The effect of the air was not lost immediately, but in some cases the hairs extended a short distance into the water. I see no satisfactory explanation for the non-appearance of hairs in the first air measurement in *jar 2*. Lack of energy from low temperature appears to be the most simple explanation. The short growth in the following water period was still in the elongation phase when placed in air, and hairs are developed by differential elongation. Other experiments not recorded here gave the same general results.

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[4] Grew into water and the different rates could not be calculated; so that as two air periods of 10^{mm} growth had a rate of 0.42^{mm} per hr., that was assumed for this calculation.

[5] Measurements of a root at the top of the jar.

Medium	Av. growth per day in mm.	Av. growth per hour in mm.	Av. length of cells in mm.	Approximate no. of cells per day
Air	8.6	0.36	0.067	128
Water	11.2	0.45	0.085	132

The lengths of the cells are averages from measurements of air and water roots twenty-four hours old, having the same length as the average growth per day in the respective medium. We find that the rough approximation of the number of cells formed per day gives about the same result for the two media; consequently the difference in length of the roots and in the rate of growth is due to the greater stretching of the cells in the case of the water roots.

B. Retardation by mechanical means.

Concerning the effect of retarding growth by mechanical means, SCHWARZ (**75**, p. 159) thinks it is impossible to produce hairs in this manner. He was not able to cause them to develop by stopping the growth of the root by wire gratings, nor in general by narrow tubes. The fact that the wire might have had a toxic effect would discredit the former method of experimentation. He does not consider the resistance of the earth to be a cause for hair production (p. 160), but states that it results in developing hairs nearer the tip. While this may not be due to a greater number of cells producing hairs, it at least indicates the favoring effect of resistance, in that hairs elongate in a region which otherwise only shows the papillae.

A pot of corn was placed in the top of a glass cylinder, with the roots passing through the bottom and entering the water. One root grew horizontally and struck the side of the vessel, becoming kinked and hairy. On May 9 it was drawn away from the glass, and on the next day showed a smooth space. On May 12 the root again reached the glass, and on May 15 showed hairs. The jar was darkened and a glass rod was placed under a smooth vertical root, as in diagram, *fig. 11*. On May 14 the root showed hairs, but had swung free and was growing smooth. A plaster cap was unsuccessful, as it killed the tip of the root. With the death of the tip many laterals grew out producing hairs, some touching the glass and bending, and some becoming kinky in free water.

A second cylinder was set up as in *fig. 11*. The glass rod was placed under a smooth straight root, but in twenty-four hours the root had curved and grown past the surface, a tuft of hairs on the curve indicating that some retardation of growth took place. For over a week the curling and hair production continued, then the root grew horizontally and struck the glass side. It became kinky and hairs continued to be formed for five days.

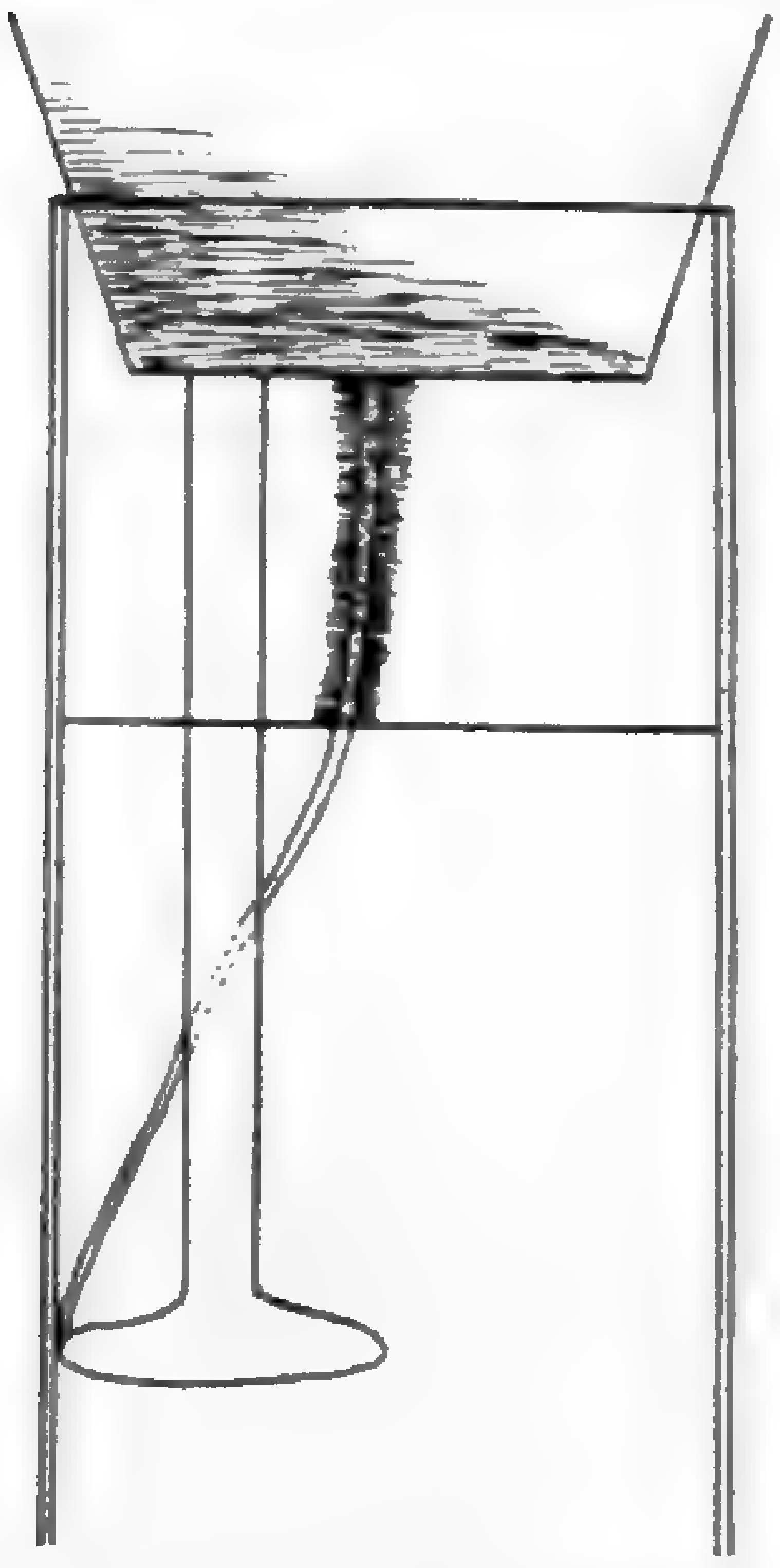

FIG. 11.—Diagram of apparatus to stop the growth of a root by a glass rod.

The fact that kinking takes place in free water shows that some other factor or factors besides resistance must be acting, but the facts brought out in the two experiments make it appear possible that resistance may be a partial cause for the kinking and hairiness of roots.

As the plaster cup in the preceding experiment was unsuccessful, glass tubes were tried. They were of sufficiently small bore to prevent a relief of pressure by too great bending. Smooth roots of corn were repeatedly allowed to grow into glass tubes (*fig. 12*). Usually the tip became more or less swollen, nearly or quite filling the tube. Primary roots showed kinking at the bottom, and hairs appeared in diminishing lengths from the bottom to the top. Only a few hairs appeared on the adventitious roots. When kept at high temperatures (24–34°C) the roots grew smooth, although bent and curved. If the resistance were relieved by allowing the roots to curve above the tube, hairs ceased to appear, conforming with the statement of MER (**51**, p. 584) that feeble retardation is not able to produce hairs. In one experiment the growth appeared to be so great that the roots were crushed and broken, producing no hairs on these portions.

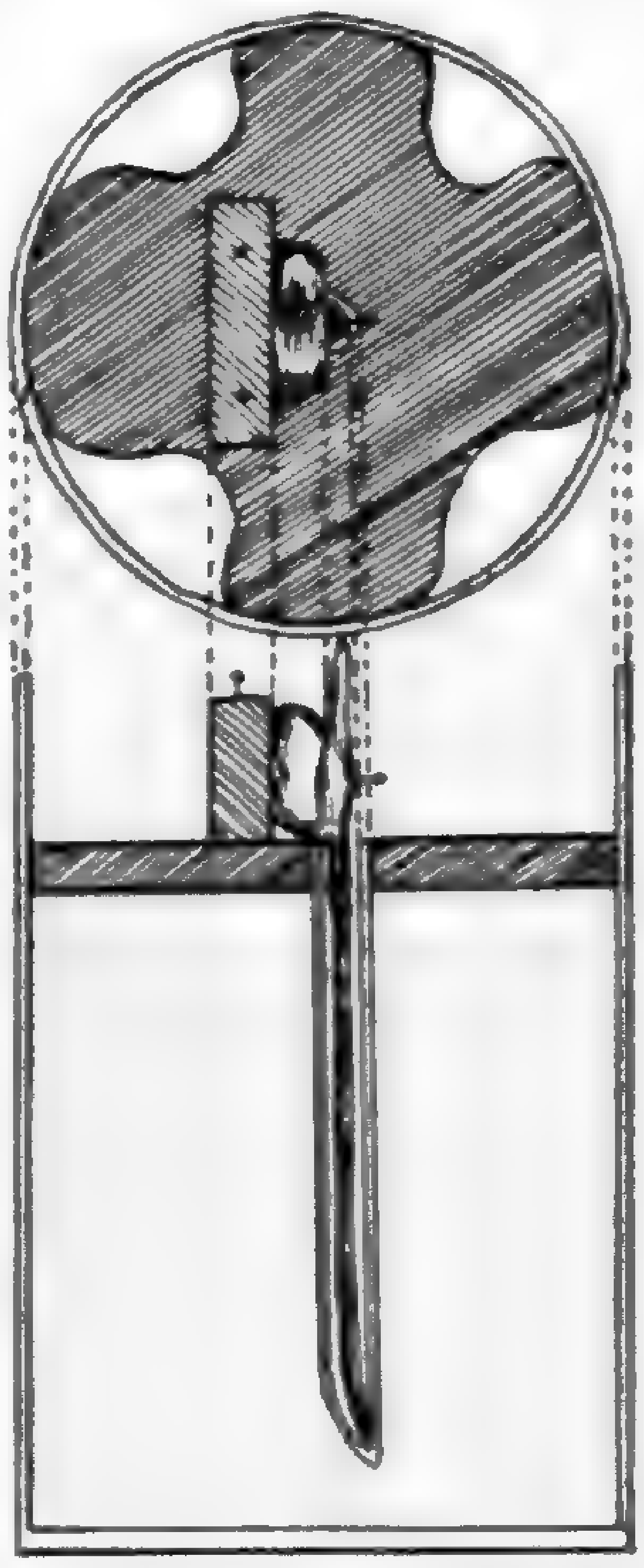

FIG. 12.—Diagram of apparatus to stop the growth of a root by a glass tube.

C. *Wounding.*

Schwarz (**75,** p. 158) was not able to cause hair formation by cutting off the roots 2–10^{mm} from the tip, nor by burning the tip with caustic. In my experiments the results were various according to the conditions. If the wound were not of sufficient depth to retard growth, if it were beyond the elongating zone, or if the plants were grown in warm water, no swelling or hairs appeared; otherwise hairs were produced. Thus in corn seedlings the tips of primary roots were pinched off about 1^{mm} from the tip. One showed hairs upon the swollen tips; another sent out a tuft of hairs and then grew smooth. In the latter case the wound was not of sufficient depth to more than slightly retard the growth. Of roots cut and burned, several showed hairs, the burned ones curving; several simply stopped growing and produced laterals; while others showed no effect. The cut tips of corn roots growing in air and producing short hairs became slightly swollen in twenty-four hours, and long hairs appeared above the cut. Both in light and darkness hairs were produced above the cut, whether the swelling appeared or not. This may have been due to the appearance of new hairs among the old ones, or to the stimulated growth of some of the old hairs, but more probably to the retardation of the zone in process of formation when the operation was performed. Devaux (**10,** p. 308) states that new hairs may appear among the old ones, but appearances which might be interpreted in that manner might be due to arrested development of some of the hairs. This would be difficult to decide, unless hairs were actually seen to originate between others (*fig. 2*). Schwarz (**75,** p. 165) and Haberlandt (**75,** p. 187) state that hairs are always produced in acropetal succession.

D. *Medium.*

Sachs (**71,** p. 410) found that roots of land plants grew more rapidly in soil than in air or water, and his results have been confirmed by Wacker (**84,** pp. 109–115). The latter, however, found that in slimy soil the growth was retarded more than in water, and the denser the material the slower the growth. Pfeffer (**66,** p. 320) says the rate of growth is not affected by the density of the medium, roots growing as rapidly in fluid clay as in water. These conflicting results are due probably to the different amounts of water in the soils used.

Roots of corn grown in ground quartz, garden soil, and air gave these results: in quartz, av. length 19.5^{mm}, hairs abundant; in soil, 22.3^{mm}, hairs good; in air, 50^{mm}, hairs poor. From these figures it seems that the resistance of the substratum bears direct relation to hair production; but the factor of water supply has undoubtedly an important influence, the quartz being less compact and therefore drier than the garden soil. Other experiments showed slower growth in air and quartz than in soil or water.

The behavior of roots of Elodea in the substratum has been mentioned, with the suggestion that retardation due to the soil particles was the principal factor. It will be shown later that a diminution of oxygen supply has a tendency to suppress hair production. There is less oxygen in the substratum than in the freely flowing water above it. It appears, therefore, that retardation, whether from soil resistance or chemical influence, must be the chief factor in producing the kinking and the hairs. Whether the hairs are due to the kinking, or both are due to the retardation of growth, cannot be stated. The production of hairs by retarding growth with glass tubes took place at times without kinking, though in the majority of cases the two results were associated. SCHWARZ (**75**, p. 159) considers "nutation" (kinking) the most potent factor in the production of root hairs, but it seems as if they might both be referred to unequal retardation of the growth of the root. Measurements of the epidermal cells of roots of Elodea give the following averages in millimeters:

Medium	Smooth	Haired
Water	0.104	.....
Quartz	0.110	0.077
Soil	0.128	0.065

Here the soil roots show better hairs than the quartz, and have the shortest cells when hairy. As will be seen later, however, the comparative lengths of cells of different roots can only be taken as supporting not as decisive evidence.

Corn seedlings were allowed to send their roots between glass plates, on one of which was a layer of paraffin with sections covered with dune sand and ground quartz. The growth over the paraffin was smooth; the roots running over the sand were wavy, in some places producing hairs; and the one on the quartz kinked with more hairs (*fig. 13*). One root from the plant growing over quartz wandered into the paraffin section, curled, and developed hairs. This appeared at the same time as the curling of the main root and may have been correlated with it. A second experiment with the sections horizontal also showed the laterals wavy at the same time that the main root kinked on the quartz.

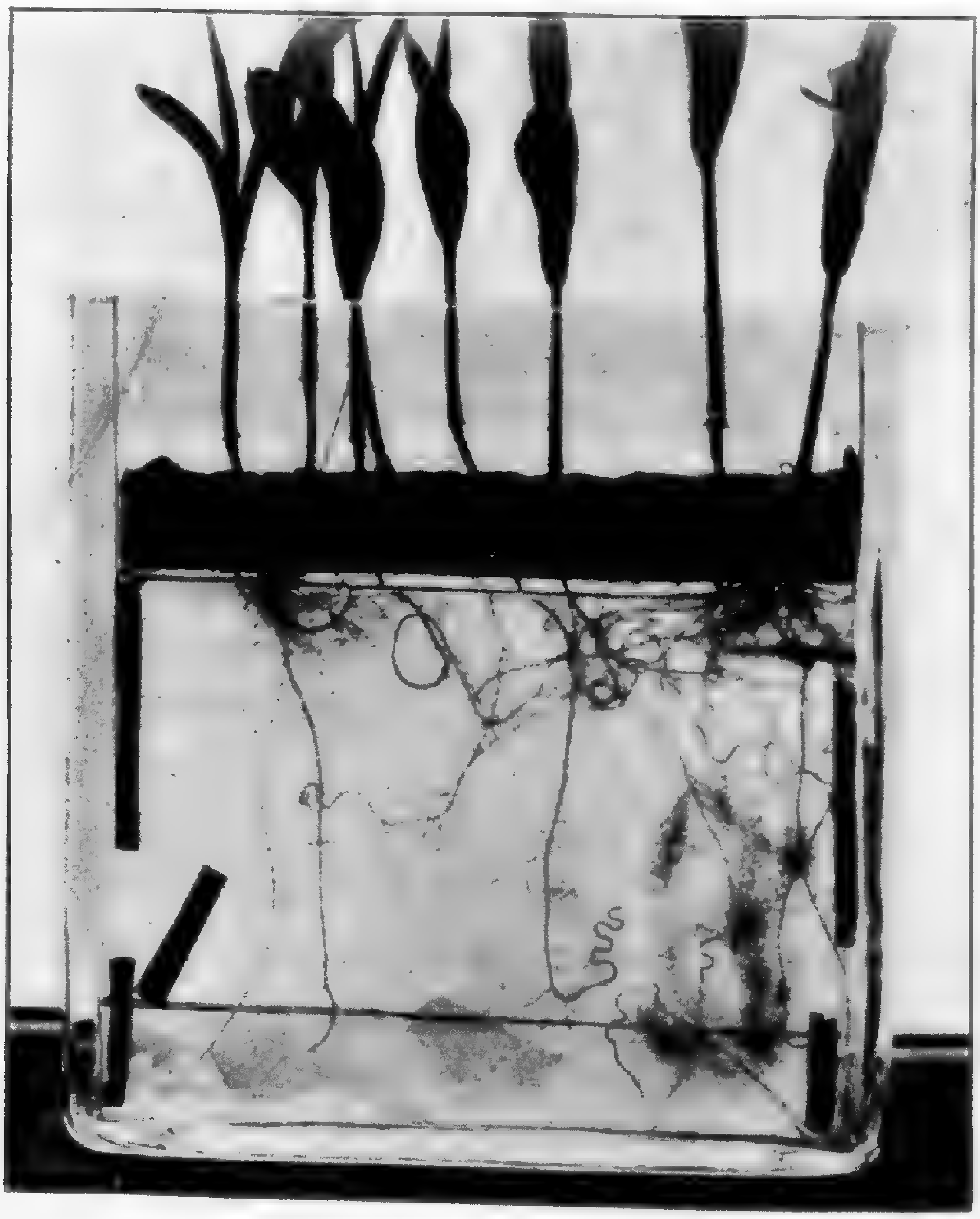

FIG. 13.—Corn seedlings growing in water in a glass jar between paraffined glass plates, on which was spread in the center a layer of coarse ground quartz; on the right is dune sand; on the left is clean paraffin.

WATER CONTENT.

According to several investigators (WIESNER **88,** p. 149; PFEFFER **64,** p. 100; PALLADIN **59,** p. 371; BRENNER **7,** p. 435; MACDOUGAL

47, p. 64; *et al.*) the attenuation of the axial members of etiolated plants, where it occurs, is due, in part at least, to a lack or diminution of transpiration. A greater proportion of water in etiolated plants is reported by MACDOUGAL (**47,** p. 64), PALLADIN (**60a**), JUMELLE (**28,** p. 386), *et al.*

Whether turgor is the cause or the result of growth, elongation of a cell is directly connected with its turgescence, greater water content producing greater elongation. Besides instances of etiolation, this is shown by the curling of roots which rest on the surface of water (SACHS **71,** pp. 398–9); by the rounding up of filamentous algae (LIVINGSTON **43,** p. 308; **44,** pp. 310–312) and of fungi (RACIBORSKI **68,** p. 111) upon withdrawal of water by osmotic solutions, and by the tendency of cells to stretch radially from loss of water by transpiration (KOHL **31a,** p. 297). The more turgid a cell becomes, therefore, the greater the tendency to stretch in a longitudinal direction. The water content of the root cells may be affected by changing the moisture content of the air, by altering the water content of the soil, or by surrounding them with solutions of higher osmotic pressure.

A. Transpiration.

It is well known that aerial transpiration favors the production of hairs upon aerial organs, WOLLNY (**89,** pp. 418–435) reporting an increased number of piliferous cells by count. On the other hand, some hairy-leaved plants grown in an aquatic habitat become smooth (COSTANTIN **8,** p. 40), and many have noted the absence of hairs on roots in water. Experiments to determine the effect of transpiration from leaves upon the development of root hairs gave negative results. Roots grown in saturated air at various temperatures showed few or no hairs, and any change that reduced the moisture content favored their development. Control plants showed that the temperatures used could not alone produce the results.

B. Saturated soil.

For these experiments corn and wheat were chosen because the former is very sensitive to the inhibitory effect of water, and wheat readily develops hair in that medium.

Corn roots grown in garden soil kept moist were found well covered with hair after seven days. Other pots were submerged in water for eight days. The uninjured primary roots showed long bare spaces and the laterals were nearly or entirely bare. One plant was allowed to dry out and the roots again became haired.

Wheat was grown in garden soil in pots, one of which was placed in water and the other watered a little every day. After a week's growth, the plants were found to have abundant hair on the roots passing through the pots into water, only zones of papillae on the roots in saturated soil, but good hairs on those in the dry pot. The zones may correspond to the drier conditions when the water fell below the bottom of the pot. In a control experiment precautions were taken to obviate the possible effects of a lack of mineral salts in the water on account of the absorptive action of the soil particles. It seems therefore that something besides lack of nutrient salts (probably lack of oxygen) must in this case be the important factor.

C. *Osmotic solutions.*

In connection with the experiments with osmotic solutions, cleaned sand was saturated with solutions of lactose, saccharose, and glucose of a concentration which allowed the zone of hairs to form. In lactose and glucose the hairs were much reduced and their presence in saccharose was extremely doubtful.

The effect of solutions upon the growth of plants and plant organs has been extensively investigated, but many of the results reported are of little use on account of a failure on the part of the investigators to distinguish the physical effect due to the osmotic action of the solution, and the chemical effect of the ions (LIVINGSTON **44**, pp. 124–7). Many authors (NOLL **57a**, GERNECK **18**, *et al.*) think the characteristics of water roots to be due to the lack of nitrates in the culture. The results of GERNECK and KRASSNOW (**36a**), showing that roots were richly haired in $CaNO_3$ solution, while the usual number of hairs or less were developed in KNO_3 solutions, make it appear that the kation has some special effect, and the mere absence of nitrates may not be the only factor to be considered in connection with the form and structure of water roots. Mere speculation on the subject, however, is of little value; careful physical and chemical experimentation is necessary. SCHWARZ (**75**, pp. 156–7) reports a cessation of hair production in "concentrated" solutions (15 per cent. $CaCl_2$ and KNO_3 and 10 per cent. nutrient salts), but no distinction is made between the physical and chemical effects of the solutions. PETHYBRIDGE (**63a**, p. 235) found root hairs more or less variable in his cultures of inorganic salts.

The results of my experiments are too incomplete and inconclusive to warrant detailed publication. Many of the plants died, and often an experiment when repeated did not give exactly the same result as before. Some factor or factors seem to have escaped observation. A possible variable factor is suggested by the variable results obtained by BENECKE (**5**, p. 24) with Lunularia buds, when he used different kinds of glass for the vessels. Considering such sources of error my results could only be considered as suggestions for further investigation.

Among non-electrolytes, lactose, saccharose, glucose, glycerin, and mannite were used, in normal solutions (1 gram-molecule to 1 liter of water). Dilutions were made from this, sometimes with tap water boiled and cooled in the air and shaken to renew the oxygen content, sometimes with unboiled tap water, sometimes with distilled water, and sometimes with distilled water redistilled from glass. The most convenient method of experimentation proved to be to nearly fill stender dishes with the solutions and to float upon the surface of the liquid round cakes of paraffin about one-quarter of an inch thick with funnel-shaped holes in which the seeds were firmly wedged. This method avoids pins and the cakes in a measure protect the solution from bacteria. They were easily kept clean and could be remelted for each experiment.

In ten experiments with lactose (nine with sunflower and one with corn) five showed variable limits (0.2–0.4 N) for hair growth. In 0.5 N solution very little growth of the roots took place, and only once were papillae found under the microscope. The seedling zone of hairs grew best in water and diminished with increasing concentration.

In five experiments with saccharose two sunflowers gave 0.5 N, one 0.4 N, and one 0.2 N (with boiled tap water) as the limit for hairs; but the growth was not good. Allowing sunflower roots to grow through pots into water and solutions made with tap water, the 0.5 N solution produced the best hairs. Corn roots growing through pots into water and solutions made with redistilled water showed hairs for the first three days; then they began to grow smooth, probably having become accustomed to the solution (WIELER **87** p. 376), as the strongest solution was the last one in which they became smooth. The pots were then transposed in various ways to test the effect of change. A transfer from a low concentration to a high one does not seem to be so favorable to hair production as the reverse. The roots seemed to be able to bear higher concentrations of saccharose than of lactose or glucose (cf. LIVINGSTON **44**, p. 295).

In three experiments with glucose in boiled tap water, sunflowers showed very poor growth, 0.5 N being about the growth limit and 0.1 N the limit for hairs.

In two experiments with glycerin in boiled tap water with sunflowers, one showed hair limit in 0.05 N and the second in 0.2 N solution. In the latter case one jar had roots haired nearly to the tip.

In two experiments with mannite, sunflowers showed very poor growth, with 0.1 N limit for growth and hairs.

The only electrolytes used were the salts of Knop's solution, and potassium nitrate alone. The modified Knop's solution "D," used by LIVINGSTON (**43**, p. 299), was used for two experiments with sunflower seeds. The best hairs appeared in 0.2 N, where they grew to the ends of the roots. The limit for growth appeared to be 0.4 N and the limit for hairs 0.3 N solution. Sunflower roots passing through the bottoms of pots gave very good hairs in 0.1 N solution, but were not healthy in 0.3 N solution. The unmodified Knop's solution made up with redistilled water was used in various dilutions, 0.1 N being made with distilled and also with tap water, 0.2 N and 0.3 N with tap water, while cultures in redistilled water were used for control. After ten days all but 0.3 N showed some hairs, the best appearing in 0.2 N. The redistilled water gave the zone of hairs which appear in tap water.

In two sets of experiments with potassium nitrate,0.016N solution gave the best hairs on corn roots. The roots were inclined to be knobby and swollen in the stronger solutions, and the 0.008 N acted much as water did. *Vicia sativa* seemed more sensitive than corn, for in one set of experiments, performed at the same time as the above, 0.016 N solution killed the root tips and 0.008 N gave the best hairs. Sunflower roots allowed to grow through the bottoms of pots into water and various KNO_3 solutions made with tap water grew best (in average length of roots) in 0.05 N and 0.1 N, 0.4 N entirely stopping the growth of roots. Hairs appeared on all parts of the roots in 0.2 N solution, and more or less on the roots in all the solutions in which the roots grew (*fig. 14*).

FIG. 14.—Seedlings of sunflower growing in a series of KNO_3 solutions.

The ill effects of distilled water on living protoplasm has been shown by LYON (**46**) and LOEB (**45**, p. 67). In my experiments with distilled water the behavior of roots was irregular; sometimes they would grow well, as in one case of Vicia and another of corn; in other cases the primary roots would not grow into it, for example wheat. As a rule, however, distilled water and water redistilled from glass gave less hair than tap water. In one or two experiments with wheat the tips of the roots stopped growing when they entered the water, and laterals were sent out (the longest nearest the tip) and produced some hairs. This peculiar branching was also observed in several cases of corn in distilled water and sunflower roots growing into KNO_3 solution, and even more markedly in the case of wheat seedlings from which the seeds had been removed, and which were growing in water culture (*fig. 3*). In this last case the laterals were very long. It seems probable that in each of these instances we have to deal with a problem of nutrition, but how cutting off the supply of stored food can cause the tip to branch, as it does when the growth is checked, is not evident.

FOOD.

The possible effect of the quantity of food in the seed upon the development of the zone of hairs in water has been mentioned. SCHWARZ (**75**, p. 162) found that if the food were taken away (how he does not state) or used by acceleration of growth by heat, the hair production ceases sooner than usual, the length of the zone depending on the size of the seed. Several experiments were performed to test the effect of removing the food supply from seedlings. Seedlings of sunflower were cut off at different distances from the tips of the cotyledons and then placed on floating cakes of paraffin so that the radicles passed through into the water. Many died, but of the number which survived the best hairs grew on those with the longest cotyledons. According to TOWNSEND (**79**, p. 518) injury to one part of a plant causes disturbances in others, and the fact that the seeds were mutilated may have had a harmful effect on the root; but from the whole set of experiments it seems fair to say that the greater the food supply the better the hair development.

Among the seeds which show the zone of hairs in water may be mentioned sunflower, corn, white lupine, pea, squash, etc. Others, as oats, wheat, mustard, etc., continue to produce hair in water until the food is exhausted and the plants die. In the case of the plants which form the zone, the cessation of hair production may be due to the hydrostatic pressure of the water; to lack of mineral salts, oxygen, or transpiration; or to the stimulating effect of the water upon growth of the root. Hydrostatic pressure can hardly be the cause when corn roots produced hair continuously in dilute solution of presumably the same pressure as tap water.

OXYGEN.

Although much has been written upon the relations of air and oxygen to growth, here as elsewhere little has been done upon root hairs. The statements of VÖCHTING, PERSECKE, and SCHWARZ seem to be the only available information on the subject. Persecke (**62a,** p. 548) considered the development of root hairs to depend upon the amounts of air and water in the interstices of the soil. Wieler (**86,** pp. 223–4), Schaible (**74a**), *et al.*, report an increase in the growth of roots as a response to a decreased oxygen pressure. Arker (**1a**) found that by passing air through water or soil, or by diminishing the air pressure above the soil or water, the roots grew faster. This he thinks was due not to the greater quantity of oxygen but to its greater mobility. The quantity of oxygen necessary for growth according to Wieler (**86,** pp. 213–4) is very small and varies with the plant. He found optimum pressure for *Vicia Faba* to be 5–6 per cent., for Helianthus 3 per cent., a retardation of growth taking place at 0.14–6 per cent. according to the to the plant. Vöchting (**82,** p. 94) found the roots of potato tubers to cease producing hair when the oxygen pressure fell to 3 per cent. The growth was slow, therefore the absence of hairs could not in this case be attributed to rapid growth of the roots. Vöchting also found (**83,** p. 132) in experimenting with willow twigs that there was sufficient oxygen in water to support life, but not enough for the production of new organs, a supply from above the surface being needed for the production of roots and shoots. Wacker (**84,** p. 110) considered that *Lupinus albus* and *Vicia Faba* died in saturated earth on account of the lack of oxgyen and the presence of harmful disintegration products, and believes land plants not to be able to supply oxygen to the roots by way of the aerial organs. Schwarz (**75,** p. 160) tried to overcome the inimical effects of water upon root hair production by passing oxygen through the culture fluid, but did not succeed in producing hairs, and came to the conclusion that other factors than lack of oxygen must be considered.

In the experiments here reported the oxygen content of the medium proves itself an important factor. Comparing corn and wheat in their ability to produce hair in water, we find that under apparently the same conditions the former grows smooth, while the latter produces long and abundant hairs. We may be dealing with the individual ability of the two plants to make use of the same amount of oxygen in a dissolved form, or with the individual needs of the plants for oxygen. Besides, one plant may be better able to supply its roots with oxygen from the aerial parts than the other. Several experiments to show the effect of diminished oxygen pressure upon the production of root hairs gave similar results and only one need be reported.

A pot of corn, the roots passing through the bottom, was sealed into the top of a jar half full of a solution of pyrogallic acid. The surface of the soil was also covered and sealed with paraffin, leaving a very small hole for watering. Any oxygen entering this hole had to pass through the moist soil before it entered the jar, where it would be absorbed by the acid. In some cultures this hole was plugged up with paraffin without altering the results of the experiment. The oxygen pressure started at normal at the sealing and was gradually lowered to a possible zero. By twenty-four hours the roots were growing smooth, while those in the control jar showed good hairs. The growth was slow, consequently the lack of hair was not due to the rapidity of growth. Suppression of hair was the result when the CO_2 was also absorbed (by KOH), showing that the relative increase of that gas was not the cause of the cessation of hair production. Wheat roots proved to be very sensitive to the lack of oxygen. Several experiments set up as above, but substituting wheat for corn, did not give any result because the roots quickly turned brown and died. In one jar, however, several of the roots lived for a day, elongating in that time from 0 to 4^{mm}. These living roots showed no hair for some distance above the tips.

The experiment with corn was varied in the following manner, to see if the vapor of the pyrogallic acid had the effect upon the hairs. The pot was sealed in as before, the jar, however, being half full of water, boiled and cooled, covered to prevent as much as possible the absorption of oxygen. Air was forced through two jars of pyrogallic acid, finally passing through the water to wash it of any vapor. The apparatus was arranged as shown in *fig. 15*. The jar was measured previously and equal contents marked. The water at first was at *a*, and then the air was passed over slowly, displacing the water to *b*. If the air coming over were entirely free from oxygen, the per cent. in the jar would be half the normal amount. As the rate of passage would determine in great measure the completeness of the extraction of oxygen, an analysis of the oxygen content was not attempted, the aim being more to do away with the acid in the jar, and to get a less complete extraction of oxygen than in former experiments, than to obtain quantitative results. The oxygen pressure was considered approximately one-half, and the roots indicated about the limit of hair production, showing irregular patches and scattered hairs with bare spaces. Repetition of the experiment showed the same condition of hair production. The temperature varied from 20–24°, which was probably not sufficiently high or low to effect hair production.

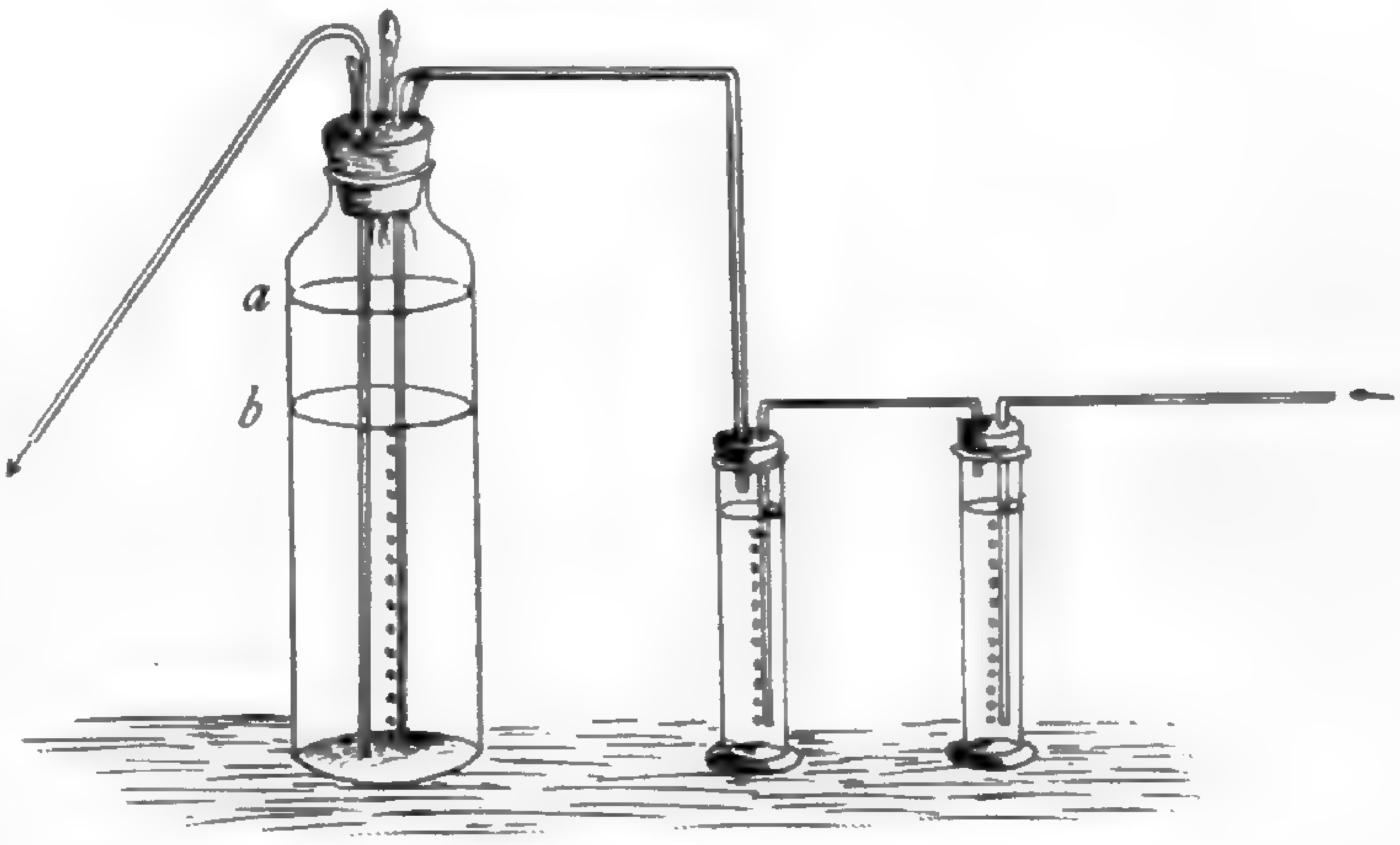

FIG. 15.—Diagram showing apparatus for diminished oxygen pressure; the air passes through two jars of pyrogallic acid solution before entering the experiment jar.

Willow twigs set up in Wolf's flasks in the same manner in about half oxygen content, with their lower ends in water, after three days showed hairs on the laterals in both jars. In seven days there was decidedly less air in the partial pressure jar. Left about two weeks longer, the hairs were better in both jars, appearing better in water than in air. This may be on account of accommodation to lack of oxygen (PFEFFER **64**, p. 2), or more probably to an increase in the supply by the green bark and the chlorophyll appearing in the roots.

GENERAL CONSIDERATIONS.

Many writers (KRAEMER **34**; LEAVITT **40, 41**; VAN TIEGHEM **78**; JUEL **27a**; SAUVAGEAU **72**, p. 5 for Naias and possibly for other forms, **73**, p. 169) associate short cells with root hairs, in most of the cases mentioned the cells being preformed. From many measurements of sections cut from roots grown in these experiments there appeared to be a relation between the length of the cells and the growth of hairs, but there was no evidence of the preformation of the piliferous cells. No definite length of cell can be given as the limit for hair development, either in general or in a single species; the piliferous cells of one root may be longer than the smooth cells of another root of the same species. But an average derived from many measurements of epidermal cells of roots grown under conditions producing hair is likely to be less than a similar average from the roots of the same species grown under conditions unfavorable for hair production. In the same root the average length of piliferous cells is less than that of smooth cells. SCHWARZ makes the significant statement (**75**, p. 177) that if in the roots of Elodea and Nuphar the short cells do not produce hairs, in time the difference in length is lost, thus indicating that the short cells stretch out if they do not grow into hairs. LEAVITT (**41**, p. 300) reports the same condition for *Nymphaea dentata*. In *Sagittaria Eatoni* (LEAVITT **41**, p. 292) and Phragmites (KRAEMER **34**, p. 22) the difference in size remains when no hairs are formed. The various statements concerning the condition of the root epidermis and the appearance of root hairs in the latter form are far from clear.

From *fig. 4* it will be seen that in corn root the origins of the hairs appear quite near the tip of the root, where the cells are isodiametric (OLIVIER **58**, p. 72). The statement that hairs appear in the zone where the cells have undergone considerable extension (LEAVITT **41**, p. 274) or are just ceasing to elongate (DEBARY **3**, p. 57) does not seem to be true generally. A probable explanation of the conditions observed by these authors is that the growth energy of the cell, after elongation has ceased, finds its expression in the rapid growth of the young papilla, which then takes on the typical appearance of a hair. By marking the roots of a series of corn seedlings growing in moist air, hairs visible to the eye were in several instances observed in the zone of elongation.

As mentioned above, in the plants studied there was no evidence of preformed piliferous cells; all the epidermal cells seemed capable of producing hair, and in corn at times did so. LEAVITT (**41**, p. 296) reports in some members of the Gramineae the whole epidermis to be piliferous. If each cell of the root epidermis is able to produce a hair, what prevents such an outgrowth from taking place? In water roots of corn we find the epidermal cells very much elongated and narrow. This characteristic extends inward through the cortex to the central cylinder, showing that the cells within as well as without are turgescent and stretching nearly equally. *Fig. 5* is a longitudinal section from a root of this water type. If, on the other hand, we examine a root grown in air, we find the cells shorter and thicker, but not equally so, the outer ones, in all but a few cases to be considered later, being longer and thinner than those near the central cylinder, showing that the former are stretching more strongly than the latter. *Fig. 6* represents a section of such a root, grown in the same experiment as that from which *fig. 5* was taken. Tested with KNO_3 solution, the outer cells of an air root were plasmolyzed in 0.2 N, while the inner cells showed no shrinking, thus indicating that the latter had more concentrated cell-sap and less water. In water roots the epidermal cells were plasmolyzed in 0.2 N and the cortical cells shrank, but the protoplasm did not leave the walls. PFEFFER (**66,** p. 301) reports the turgor of the cortex cells of corn roots in air to be greater than that of the epidermis. In the air roots the epidermal cells seem to have more water, and to be able to stretch more than the inner ones. This can take place to a certain extent, but the inner cells cannot keep pace with them, but hold back the epidermal cells from their full elongation, and the growth energy finds an outlet in the direction of least resistance, *i. e.* the free outer wall. A similar occurrence is noted when Spirogyra is held in a plaster cast (PFEFFER **66,** pp. 240, 385), or when Stichococcus is made fast at the ends (KLERCKER **30,** pp. 94–5).

This bulging takes place in corn near the tip of the root, while the cells are isodiametric, and nearly the whole wall curves at first (*fig. 7*), but with the continued stretching of the cell this primary bulge becomes a papilla. The lagging behind of the inner cells of the cortex during the elongation period allows this papilla to become a hair. It seems then that hairs represent the ratio between the capacity of the epidermal cells to elongate and their ability to do so. If the capacity be the greater, the hairs will be produced; if equal to or less than the ability to elongate, no hairs will be developed. This would limit the statement of SCHWARZ (**75,** p. 155)—"bei dem Maximum der Wachsthumsgeschwindigkeit und unter den günstigsten Bedingungen bildet die Wurzel die zahlreichsten Haar"—to the epidermal cells.

Testing this explanation in the different cases reported here, I suppose first, in the corn roots growing with diminished oxygen supply, that the growth of the epidermal cells is decreased. The inner cells on the other hand may obtain oxygen from the aerial parts, and thus with less moisture be able to keep pace with the epidermal cells growing with more moisture and less oxygen. In ordinary air the moisture and the oxygen reach the epidermal cells more abundantly than the inner ones, consequently the numerator of the fraction is increased as well as the denominator decreased, and hairs are developed. Upon the upper side of a corn root growing along the surface of water abundant hairs were developed, while the under side remained smooth. The difference in length between the epidermal cells and those of the cortex on the haired side was 20μ, and on the smooth side 6μ. KRAUS's tables (**37**, p. 254) dealing with the lengths of epidermal and cortical cells in relation to hair production are not very complete, and it seems useless to attempt to harmonize the results with those here reported.

KRABBE (**33**, p. 491) reports the inner cells of pith to be less turgescent than the outer ones when placed in water at 1–2°C, on account of the resistance to the passage of water offered by the protoplasts. According to VAN RYSSELBERGHE (**70**, p. 103) the influence of temperature is exhibited not in the total amount of water taken up, but in the rapidity of its passage. In warm water, therefore, the water reaches the inner cells and allows them to elongate sufficiently rapidly to keep pace with the epidermis, which is thus allowed to elongate to its full capacity and shows no hairs.

In the zone of hairs on seedlings in water cultures the available energy and the temporary retardation of growth (evidenced by the short outer and still shorter inner cells, and by the curling of many roots) combine to produce hairs. Also the presence of food may act as a stimulus to cause the cells to divide rapidly and form a thick root, whose inner cells do not get sufficient water, or oxygen, or both, to allow them to elongate as rapidly as the outer ones. Later, in the case of corn, the plumule elongates and probably supplies the inner cells with more oxygen. These are therefore better able to elongate, they are carried further from the food supply, division is less active, the roots grow more slender, the water supply of the inner cells increases, still greater elongation takes place, and the epidermal cells are allowed to stretch to their full capacity. Accommodation to a decrease of oxygen is mentioned by PFEFFER (**65**,

p. 70), and MER (**53**, p. 1279) speaks of the roots becoming accustomed to the medium.

The curving of corn roots in water is, according to Miss BENNETT (**6**) not aerotropic. BEAUVÉRIE (**4**) considers the turning up of water roots to be due to negative hydrotropism, for by using physiologically dry solutions he was able to get them to grow downward. In an experiment in which a slow stream of tap water was passed into the bottom of a vessel in which the roots of corn seedlings were growing, every one turned down, and grew straight and entirely smooth. The stimulus may have been a rheotropic one, or it may have been the presence of fresh aerated water which caused the omission of the hair zone.

An apparent exception to the explanation offered appeared in one root of sunflower grown in 0.5 N saccharose solution, in which the epidermal cells were shorter than the inner ones and still produced hair. Close to the tip, however, the papillae were found on cells shorter than the cortical cells, which makes it seem probable that the epidermal cells on the upper part of this root were shorter than the cortical cells from the start, as is the case with Elodea. In this plant the epidermal cells at the tip are very much shorter than those of the inner cortex, and the difference does not entirely disappear as the root grows older. Consequently there is not the same relation between the epidermal and cortical cells when hair is produced, as there is in corn. Measurements of the cells of roots of Elodea growing in soil, quartz, and water give the following averages in millimeters:

Medium	Cortex	Epidermis	Difference
Soil...........	0.100	0.068	0.032
Quartz........	0.110	0.077	0.033
Water.........	0.160	0.104	0.056

Upon examination of the table the greatest relative length of the inner cortical cells is seen to be in water, and the least in soil, with the hairs in inverse relation, as was the case with corn.

On the concave side of curved roots of corn the epidermal cells are shorter than the inner ones and at times show more hairs (*fig.*

8). Here the retarding action of the inner cells upon the epidermis is aided by the compression brought about by the curve. SACHS (**71**, p. 466) has shown that the average length of cells in a curve is less than in a straight portion of the root. MACDOUGAL (**49**, pp. 352–3) criticises SACHS' methods and reports the cells on both convex and concave sides longer than those on the same region of a normal straight root. His statement that the hairs are "abundant on the regions apical and basal to the region of greatest curvature, but are also wholly absent from the region exhibiting the shortest radius of curvature," seems to mean that the roots geotropically stimulated elongated at the curve and ceased to produce hair. In curving roots of corn growing in water, the epidermal cells appear to be restricted in their elongation, for curving almost invariably causes hair to develop. SCHWARZ noted this and called it "nutation" (**75**, p. 159). This term did not seem appropriate, and for want of a better word "kinking" has been used in this paper.

Transference from a solution of low osmotic pressure to one of high osmotic pressure appears to withdraw so much water from the epidermal cells that they do not grow into hairs. When the reverse order is followed there is a better chance for the epidermal cells to absorb water and to grow before the inner ones, and in this case some hairs appeared. The problem of the effect of osmotic solutions upon roots is quite different from that relating to filamentous algae and fungi. In the last two cases each cell is bathed in the solution to be tested, while with roots the action of the neighboring cells influences the epidermis, and on account of the thickness of the root the inner ones are not affected just as the outer ones. If a solution could be made which by its osmotic strength or chemical composition would retard the growth of the inner cells and allow the epidermal cells to grow, hairs might be expected. In one or two instances the epidermal cells of roots of sunflower and corn growing in 0.–0.2 N solutions seemed to become accustomed to the solution before the inner cells, and thus were able to grow out as hairs while the growth of the deeper cells was still retarded.

The retarding effect of diminished food supply on the production of hair on the internodes of the stem of potatoes is reported in a short note by KRAUS (**38**). In experiments with half seeds, one or two cases occurred in which the central cylinder was torn apart at regular intervals by the stretching cortex, the epidermis bearing no hairs. The food supply seemed not enough to give the cells of the central cylinder sufficient strength to retard the stretching of the outer cells.

No change in turgor is needed to explain the appearance of root hairs, for according to PFEFFER (**64^2**, p. 29) there is no change when growth is accelerated by a rise of temperature or by absence of light, or when growth is retarded by lack of oxygen or (**66**, p. 296) by pressure. In the first three cases hairs disappeared or were diminished, while in the last they appeared.

An interesting relation was noticed between the epidermal and the hypodermal cells of some corn roots. In roots growing in the air and producing hair, the nuclei of the hypodermal cells were usually larger than those of the epidermal or cortical cells (*fig. 9*). This may indicate that the hypodermal cells were passing food to the outer cells, the starting of the lateral growth thus initiating a movement of material in that direction. SAUVAGEAU (**73**, p. 171) reports small hypodermal cells under the piliferous cells in Zostera. This demand for food by the outer layer would decrease the supply in the central cylinder and may account for the inverse relation between root hairs and lateral roots, noted by LESAGE (**42**, p. 110), COSTANTIN (**9**, p. 149), MER (**52**, p. 666; **53**, p. 1278), SACHS (**71**, p. 589), *et al.* In Eichhornia the lateral roots extend nearly to the tip, but there are no root hairs. This activity of the central cylinder, contrasted with that of the epidermis, is in harmony with the results of the experiments here reported.

In spite of the structural and functional similarity which often exists between root hairs and rhizoids, it does not seem appropriate to consider them together. In the first place, they are not morphologically similar, rhizoids being of gametophytic origin and root hairs developing from the sporophyte. The fact that rhizoids arise usually from a rather small gametophyte, all the cells of which retain in large measure their primitive condition, may account for the irritability they display toward geotropic, phototropic, and thigmotropic stimuli. Root hairs, on the other hand, are developed on a highly differentiated organ of a highly differentiated sporophyte, and are not thus sensitive, a difference pointed out by HABERLANDT (**22**, pp. 194–5).

It would be well to limit the term "root hair" to hairs borne by morphological roots only.

SUMMARY.

1. Light and darkness appeared to have only an indirect effect, through their influence on growth.

2. High temperature with sufficient moisture tended to decrease hair production by increasing the elongation of the internal cells.

3. The slower the growth in air the better the hair development.

4. Retardation of growth by glass tubes, by wounding, or by resistance of the substratum favored hair production.

5. Roots of seedling corn in water first curled and produced hair, possibly because of the retardation of growth by the diminution of oxygen or its presence in the dissolved state. Later the roots grew straight and smooth, either on account of accommodation to the oxygen supply or because the gas was supplied by the aerial parts.

6. Saturated air with high temperature tended to suppress hair development (*cf.* 2).

7. Saturated soil tended to suppress hair in corn and wheat, but other factors must be considered when Elodea develops hair in the substratum.

8. Osmotic solutions gave very irregular results on account of some undiscovered disturbing factor.

9. Less hair was developed in distilled water than in tap water.

10. Air deprived of oxygen stopped hair production and retarded growth.

11. Curves and swellings had a favorable effect upon hair development, probably because they represent the retardation of the growth of the root.

12. In all these examples of retardation favoring hair development, not the mere rate of growth, but the differential elongation of the inner and outer cells was of prime importance. Hair production depends on the ratio between the capacity of the epidermal cells to elongate and their ability to do so.

13. The activity of the epidermis may be in inverse proportion to the activity of the central cylinder, lateral roots often appearing when hairs are suppressed, and *vice versa*.

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EXPLANATION OF PLATE I.

FIG. 1. Longitudinal section of a corn root, grown in a glass tube: *a*, ×45; *b*, two hair-producing cells lapping over the other epidermal cells, ×220.

FIG. 2. *a*, Longitudinal section of a corn root, grown in air; the section shows more than one line of epidermal cells with long and short hairs; ×75. *b*, rounded surface of a living root of corn, grown in redistilled water; the outlines of the epidermal cells were very indistinct; the only case observed where the difference in size was so great; ×45.

FIG. 3. Roots of wheat plants which had been cut from the seeds shortly after sprouting; water culture; ×½.

FIG. 4. Longitudinal section of a root of corn, grown in air, showing the origin of hairs from the region where the cells are still short; ×220.

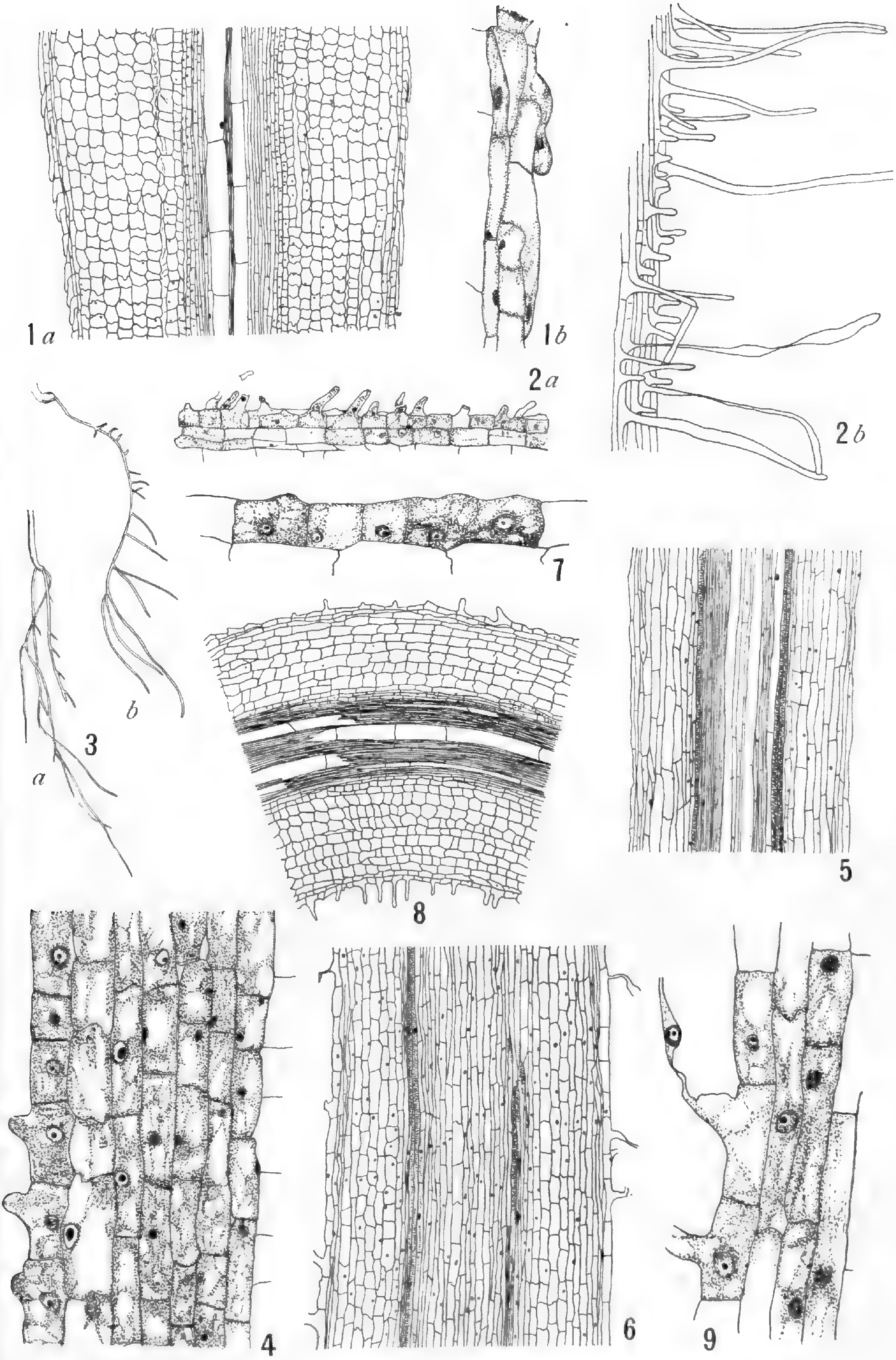
FIG. 5. Longitudinal section of a root of corn grown in water, in the same experiment with the root shown in *fig. 6;* ×45.

FIG. 6. Longitudinal section of a root of corn grown in air, in the same experiment with the root shown in *fig. 5;* ×45.

FIG. 7. Longitudinal section of a root of corn grown in air, showing the beginning of the hairs; ×220.

FIG. 8. Longitudinal section of a corn root curving on the surface of water; ×34.

FIG. 9. Longitudinal section of a corn root grown in air, showing one of the large nuclei of the hypodermal cells; ×220.



SNOW on ROOT HAIRS

A CONTRIBUTION TO THE LIFE HISTORY OF *APOCYNUM ANDROSAEMIFOLIUM.*

THEODORE C. FRYE and ELEANOR B. BLODGETT.

(WITH PLATE II)

IT appears that not one of the Apocynaceae, a family of about 1000 species, has ever been studied carefully in reference to the minute morphology of the flower. Considering this in connection with the fact that the family stands near the Asclepiadaceae, with their peculiar pollen and stigma, it was believed that it deserved investigation. Buds and flowers of *Apocynum androsaemifolium* L. were collected in various stages, and the results of their investigation are herewith described.

The order of appearance of the floral whorls is centripetal. The calyx shows no peculiarities other than a ruffling of the epidermis on the abaxial surface near the base, suggesting a mechanism for the folding of the sepals.

Each petal of the campanulate corolla has on its inner surface near the base a ridge (*fig. 1, r*) running from the midrib diagonally outward and toward its base. It is highest at the midrib, and undoubtedly functions as an aid in compelling cross-pollination. The ridge arises from the more superficial cells of the leaf, and does not affect the course of the veins. Its meristematic crest forms the cells for its enlargement.

The stamens are peculiar in form, adjusting themselves neatly in a ring rather closely applied to the stigmatic head (*fig. 1, s*). At the base of each are two long auriculate appendages (*figs. 1, 2, 3, ap*) extending downwards dorsal to the filament. The sporangia are above the insertion of the filament, and do not extend into the appendages. The loculi open on their inner surfaces, somewhat laterally, by longitudinal slits, and immediately beneath them is a beard of epidermal hairs extending transversely across the faces of the anthers, forming a ring around the stigmatic head (*figs. 1, 2, b*). These hairs meet similar ones from a ring around the head, thus preventing pollen from rolling into the base of the flower.

In the development of the stamen the enlargement of the tip, foreshadowing the formation of sporogenous tissue, occurs just about the time the carpels appear. The hypodermal layer gives rise to a primary parietal layer, and another homologizing with what is ordinarily the primary sporogenous layer (*fig. 4*). The former divides once; the latter also divides, forming the tapetum and primary sporogenous cells (*fig. 5*). This has been observed in a few plants only (**1**), the tapetum usually arising from the primary parietal layer. The primary sporogenous cells elongate as they do in Asclepias (*fig. 6*), but divide into a mass of mother cells, thus reinforcing the presumption that in Ascelpias this stage is simply omitted. The pollen is in the mother cell stage when the ovules appear. The rounded mother cells do not always divide simultaneously. Division of the two daughter cells is simultaneous or nearly so (*fig. 8*), and almost so in all the daughter cells of a sporangium; but not in different stamens of the same flower. Sometimes one daughter cell fails to divide, and three microspores instead of a tetrad is the result (*fig. 9*). Occasionally some of the pollen grains near the tip of the sporangium disintegrate after tetrad division, probably serving as nourishment for the others. The whole tapetum also disintegrates soon after tetrad division.

The microspores remain in tetrads in maturity, and their arrangement with relation to each other is various. In fact, one can find all stages grading from the bilateral to the tetrahedral arrangement. *Fig. 10* evidently resulted from the spindles in the second division being somewhat at right angles in the same plane, and is like a grouping found by WILLE (**2**) in *Orchis mascula*. Usually the four spores are in the same plane, but their arrangement with regard to each other varies; in *fig. 11* four pollen grains meet at a point on each side of the group; in other cases there are four on one side and three on the other; in still others only three meet at a point on either side. The pollen grains in a tetrad are often plainly unequal in size. In such a group as is represented in *fig. 11*, suppose the upper half (cells *a* and *b*) were revolved on the lower half 90°, with *xy* as an axis; if then they adjusted their form to fit each other the result would be the prevailing dicotyl grouping—tetrahedral. *Figs. 11, 12, 13* are three members of a series grading from the bilateral to the tetrahedral form, varying only in degree of rotation and in mutual adjustment. Both forms may thus occur in the same plant. However, the tetrahedral form is not common; most of the groups are like *figs. 11* and *12*, similar to those found in *Typha latifolia* (**3**). A case like Zostera (**4**), with its long pollen mother cells dividing lengthwise, makes it doubtful whether pressure is much of a factor in determining the direction of the spindles. The spindles in the microspore daughter cells of *A. androsaemifolium* seem to lack definiteness in direction.

The formation of the generative and tube nuclei occurs when the ovules are in the sporogenous cell stage. The division is not simultaneous in the same sporangium, nor even in the same tetrad; the division is complete by the time the embryo sac has reached its 8-celled stage. The generative cell is lenticular or fusiform, as in Asclepias. Two spherical male cells are formed about the time the embryo sac is ready for fertilization, and while the pollen is still in the anther. STRASBURGER (**5**) observed a small and a large nucleus in the pollen of *Vinca major*, and again found both nuclei in cultures of the pollen tubes. If these were tube and generative nuclei, Vinca differs from *A. androsaemifolium* in the time of the division of the generative cell. STRASBURGER also observed (**5**) a tube nucleus and two smaller ones, probably male cells, in *Amsonia salicifolia*, which seems to indicate that this one agrees with *A. androsaemifolium* in the time of male cell formation.

At the base of each petal and alternating with the stamens are five glands resembling those in Asclepias. They originate shortly after the floral parts appear and are said to be nectariferous (**6**).

The two carpels unite at their tips before ovules are formed, and just after sporogenous tissue appears in the stamens. The tips form a rounded lump or head with glandular epidermis over large portions of it, as in the Asclepiadaceae. The ovules are arranged in the same way as in the family just mentioned, and have the same form. The archesporial cell is of hypodermal origin and does not divide to form a primary parietal cell (*figs. 15* and *16*). A single integument deeply buries the nucellus and primary sporogenous cell. The latter divides into four megaspores, any one of which may become the embyro sac. In *fig. 19* the innermost spore becomes the sac;

in *figs. 17* and *18* it is hard to tell which spore will dominate; and in other cases the spore nearest the micropyle functions. The embryo sac passes through the regular stages to the eight-celled stage. BILLINGS (**7**) figures an embryo sac of *Amsonia salicifolia* with endosperm surrounded by an absorbing layer, and states that *Apocynum androsaemifolium* has no such layer, which we confirmed. A section through the ovules of *A. androsaemifolium* can hardly be distinguished under the microscope from a similar one of Asclepias, so great is the similarity in minute detail.

The pollen rolls out of the anthers upon the head, but is prevented by the pericephalous beard from reaching the stigma which is immediately beneath it. An insect having pollen on its proboscis, reaching after nectar, must insert it between the bases of the anthers, on account of the ridges on the corolla and the basal appendages of the stamens. The proboscis in withdrawal naturally slips into the crevices between the stamens and the head. The sticky, glandular stigma holds some of the pollen, while the pericephalous beard, acting as a brush, increases the probability of pollen remaining at the stigma (*fig. 1*). The head above the beard is glandular and the pollen sticky; therefore as the proboscis is withdrawn through the hairs it picks up a load of pollen for the next flower (*fig. 1*). KUNTH (**6**) gives a short account of the manner of pollination.

The chief facts are the origin of the tapetum from the homologue of the primary sporogenous layer instead of the primary parietal layer; the gradation between bilateral and tetrahedral microspore arrangement; the absence of a primary parietal cell in the ovule; the single layer of cells composing the nucellus; and the great similarity in the internal structure of the flowers of Apocynum and Asclepias.

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EXPLANATION OF PLATE II.

All figures were drawn with a camera lucida unless otherwise stated, and a Leitz 1–12 oil immersion objective was used for all figures requiring high magnification. The figures have been reduced to one-half the original drawings, to which the indicated magnifications apply.

Fig. 1. Longitudinal section of the flower, semi-diagramatic: *ca*, calyx; *co*, corolla; *r*, ridge; *g*, gland; *s*, stamen; *ap*, appendage; *sp*, sporangium; *b*, beard; *h*, head; *st*, stigma.

Fig. 2. Abaxial view of stamen: *ap*, appendages; without camera lucida.

Fig. 3. Lateral view of stamen: *ap*, appendages; *h*, head; without camera lucida.

Fig. 4. Longitudinal section of anther showing origin of primary parietal layer. ×1800.

Fig. 5. Longitudinal section of anther: *s*, primary sporogenous cells; *t*, tapetum. ×2650.

Fig. 6. Cross section of anther: *t*, tapetum; *s*, primary sporogenous cells. ×1110.

Fig. 7. Microspore mother cell before tetrad division. ×3300.

Fig. 8. Microspore daughter cells in simultaneous division. ×3300.

Fig. 9. Three pollen grains from a mother cell. ×2250.

Figs. 10–13. Various arrangement of pollen grains in tetrads. ×2250.

Fig. 14. Pollen grain: *t*, tube nucleus; *g*, generative cell. ×2650.

Fig. 15. Section of ovule showing archesporial cell enlarged and functioning as primary sporogenous cell; single integument; nucellus one layer of cells. ×2270.

Fig. 16. Same as *fig. 15;* integument closing. ×1400.

Fig. 17. Four megaspores; first and third disintegrating; *m*, micropylar end. ×3300.

Fig. 18. Four megaspores; first two disintegrating; *m*, micropylar end. ×3300.

Fig. 19. Four megaspores and nucellus; first three disintegrating. ×3300.

CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. VI.

AVEN NELSON.

SPHAEROSTIGMA F. & M., Ind. Sem. Hort. Petrop. **2**:49. 1835.

Since Dr. JOHN K. SMALL published "Oenothera and its segregates,"[1] much material has been accumulating illustrative of the various species and tending to confirm the wisdom of the earlier generic limitations which were again revived in that paper. In this group of genera, the species of which seem particularly susceptible to differences in environment, we may expect great variation, and therefore naturally differences of opinion as to specific limitations. This has resulted in a rather extended synonomy, which makes studies in the group more than ordinarily difficult. It is not the purpose of the writer to review these genera, but simply to put on record a study of the species of Sphaerostigma, made necessary by the attempt to name some material that came into his hands for examination. This study, in order that it might be the more complete, was extended to the collection of the Missouri Botanical Garden.[2] While listing all the species, there is no necessity for attempting a complete synonomy. SMALL's paper, cited above, will furnish references to all the important literature on this genus, except that of LÉVEILLÉ.[3] I give therefore only the first use of the present

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[1] Bull. Torr. Bot. Club **23**:167. 1896.

[2] Acknowledgment is here made of the uniform courtesy and kindness of the Director, Dr. WILLIAM TRELEASE, in permitting the examination of these valuable specimens—some 200 sheets.

[3] "Monographie du Genre Onothera." I will not attempt to review this very elaborate paper, but since LÉVEILLÉ's notions of generic limitations are so completely out of harmony with the now accepted ideas of American botanists, it may be permissible to relist the species of the American genus Sphaerostigma. The specimens of Sphaerostigma in the Mo. Bot. Garden Herb. were examined by him and bear his annotations. It is extremely difficult to believe that his grouping of the specimens can stand, especially when one finds that the annotations do not harmonize with the final published list, and that the nomenclature of the illustrations in some instances does not coincide with that of the text.

combination and a reference to what seems to be the first publication of the species or variety.

KEY TO THE SPECIES.[4]

Flowers yellow, sometimes turning red or green.		
Capsules straight.		
Fusiform	1.	*S. andinum.*
	1a.	*S. andinum Hilgardi.*
	1b.	*S. andinum minutum.*
Narrowly linear	2.	*S. filiforme.*
Capsule more or less curved or contorted.		
Narrowly linear, cylindrical or nearly so.		
Curved but not contorted.		
Ascending.		
Flowers minute.		
Capsule short (less than 2^{cm})	3.	*S. Nelsonii.*
Capsule long (more than 2^{cm})	4.	*S. chamaenerioides.*
Flowers 1^{cm} or more in diameter	5.	*S. campestre.*
	5a.	*S. campestre helianthemiflorum.*
	5b.	*S. campestre minus.*
	5c.	*S. campestre mixtum.*
Refracted	6.	*S. refractum.*
More or less contorted	7.	*S. contortum.*
	7a.	*S. contortum flexuosum.*
	7b.	*S. contortum pubens.*
	7c.	*S. contortum Greenei.*
Broadly linear, more or less 4-angled.		
Whole plant glabrous	8.	*S. nitidum.*
Plant not wholly glabrous.		
Flowers small (1^{cm} or less broad).		
Stems virgate, fructiferous to the base.		
Stem leaves ovate-triangular	9.	*S. arenicolum.*
Stem leaves oblong-lanceolate	10.	*S. hirtellum.*
Stems branched from the base	11.	*S. micranthum.*
	11a.	*S. micranthum Jonesi.*
	11b.	*S. micranthum exfoliatum.*
Flowers large (more than 1^{cm} broad).		
Leaves canescently pubescent.		
Narrowly oblong or oblanceolate	12.	*S. bistortum.*
	12a.	*S. bistortum Veitchianum.*

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[4] The following species are not included in this table: *S. angelorum* (Wats.), *S. pterospermum* (Wats.), *S. rutilum* (Davids.).

Ovate to orbicular..........13. *S. spirale.*
13a. *S. spirale viridescens.*
13b. *S. spirale clypeatum.*
Flowers white or rose color.
Leaves glabrous or nearly so.
Bark of stem shining and shreddy.....14. *S. decorticans.*
Bark of stem green.
Capsules evenly distributed.........15. *S. tortum.*
15a. *S. tortum Eastwoodae.*
Capsules interruptedly crowded......16. *S. tortuosum.*
Leaves not glabrous.
Villous or tomentose.................17. *S. utahense.*
More or less pubescent but not tomentose.
Capsules enlarged at base.
Bark glabrous and shreddy.......18. *S. Boothii.*
Bark hirsute, not shreddy.........19. *S. Lemmoni.*
Capsule not noticeably enlarged at base.
Branches paniculately branched above.........................20. *S. Hitchcockii.*
Branches simple above...........21. *S. alyssoides.*
21a. *S. alyssoides macrophyllum.*

1. S. ANDINUM (Nutt.) Walp. Repert. **2**:79; *Oenothera andina* Nutt., T. & G. Fl. N. A. **1**:512.—Not often collected but no doubt of frequent occurrence from western Wyoming westward and northward to Nevada and Washington, where it passes into

1a. S. ANDINUM **Hilgardi** (Greene), n. comb.; *Oenothera Hilgardi* Greene, Bull. Torr. Bot. Club **10**:42.—There is no possibility of maintaining this as a distinct species. No differences except a slightly greener hue and somewhat greater size in all of its parts is perceptible. These differences may well be due to the more vigorous growth induced by the greater moisture and higher temperature in the range of the variety.

1b. S. ANDINUM **minutum**, n. var.—A very diminutive form related to *S. andinum*, with minute flowers, obovate petals, very unequal stamens (the one set almost rudimentary), calyx tube nearly wanting, and the capsule somewhat clavate, tapering to a short pedicel.

The type of this variety is in herb. Mo. Bot. Gard., without data. With the specimens are pencil drawings, showing the above characters, made by DR. GEO. ENGELMANN, and bearing the herbarium name *Oenothera minuta*. Possibly future collections may show this worthy of specific rank.

2. **S. filiforme,** n. sp.—A diminutive annual 3–5^{cm} high, with filiform stem drooping at summit, and the filiform leaves and capsules more or less secund; ciliate-pubescent throughout; the diminutive flowers yellow; tube of calyx wanting; capsules erect, straight, pubescent, filiform, 1–2^{cm} long.

Type in herb. Mo. Bot. Gard. from New River (Reese's River), Utah, May 28, 1889. Collector not known.

3. S. NELSONII Heller, Muhl. **1**:1; *S. minor* A. Nels., Bull. Torr. Bot. Club **29**:130.—Though Léveillé has seen fit to reduce this, a re-examination of the material at hand simply increases my belief in its validity.

4. S. CHAMAENERIODES (Gray) Small, Bull. Torr. Bot. Club **23**: 189; *Oenothera chamaenerioides* Gray, Pl. Wright **2**:58.—This is a strongly marked species that seems never to be confused with any other.

5. S. CAMPESTRE (Greene) Small, Bull. Torr. Bot. Club **23**:189; *Oenothera dentata* Wats., Bot. Cal. **1**:216.—Variable as to the curvature of the capsule, which is often greatly flexed. The large-flowered form is most frequently collected and may be known as follows.

5a. S. CAMPESTRE **helianthemiflorum** (Lévl.), n. comb.—This is the form of the species which is often distributed as *Oenothera dentata grandiflora* Wats. See plate in Lévl. Monog. opposite 178.

5b. S. CAMPESTRE MINUS Small, Bull. Torr. Bot. Club **23**:189; *Oenothera dentata cruciata* Wats., Proc. Am. Acad. **8**:594.—Often distinguishable from the species with difficulty. Its stricter habit, smaller flowers, and more glabrate stems are characters usually mentioned.

5c. S. CAMPESTRE **mixtum** (Lévl.), n. comb.—Two specimens in herb. Mo. Bot. Gard. have been designated as forms *mixta* and *permixta* by Léveillé, Monog. 180. There seems to be no difference between them except the smaller flowers of the former. Since the former is a much older plant, it may happen that the later blossoms are small. Believing them to be the same, they are here given varietal rank. This variety may be known by the dark green, broadly linear leaves, which are dentate and very numerous, quite crowded and seemingly fascicled upon the short, spreading, or nearly prostrate branches.

6. S. REFRACTUM Wats., Proc. Am. Acad. **17**:373.—Quite distinct, and well-developed specimens are readily recognized.

7. S. CONTORTUM (Dougl.) Walp., Repert. **2**:78; *Oenothera contorta* Dougl., Lehm. in Hook. Fl. Bor. Am. **1**:214.—Why LÉVEILLÉ rejects this and a succession of available names, which he cites as synonyms, does not appear in his monograph. He figures a variety of *O. bistorta* (*O. cheiranthifolia*) as *contorta* Dougl., but even if he were right in thus referring the name given by DOUGLAS, there are yet several other available names. It still remains to be proven, however, that *S. contortum* is not a valid name for *Oenothera strigulosa* T. & G. Fl. **1**:512.

7a. S. CONTORTUM **flexuosum,** n. var.—Small, about 1^{dm} high; branches few, divaricate ascending, usually a pair near the base: leaves linear: flowers yellow; calyx tube obconic: capsule cylindrical, sessile, linear, 2–3^{cm} long, variously curved, usually deflexed and again upturned, producing S-shaped forms: seeds smooth.

This was distributed some years since under the herbarium name *S. flexuosum*. No. 4060, named as the type, was secured at Point of Rocks, June 16, 1898. Other specimens are: Nelson, 4698, Granger, Wyo.; Jones, Deep Creek, Utah, June 22, 1891; Genoa (?), Carson Valley, June 17, 1889; Merrill and Wilcox, 602, Pacific Creek, Wyo.

7b. S. CONTORTUM PUBENS (Wats.) Small, Bull. Torr. Bot. Club **23**:189; *Oenothera strigulosa pubens* Wats., Proc. Am. Acad. **8**:594.—Very diverse forms are distributed under this name. The variety probably shades into the species by imperceptible degrees.

7c. S. CONTORTUM GREENEI Small, Bull. Torr. Bot. Club **23**:189; *Oenothera strigulosa epilobioides* Greene, Fl. Francis. 216.—No specimens have been seen by me.

8. S. NITIDUM (Greene) Small, Bull. Torr. Bot. Club **23**:190; *Oenothera nitida* Greene, Pitt. **1**:70.—Perfectly distinct and not to be confused with any other unless it be with *S. spirale*, the canescence of which serves at once to separate them.

9. **S. arenicolum,** n. sp.—Annual, with one main virgate erect stem and 2–4 slender simple ascending-erect branches from near the base; the purplish stem and branches sparsely ciliate-pubescent: leaves crowded, triangular-ovate or narrower, sessile and somewhat clasping by a subcordate base, 1–2^{cm} long; root-leaves longer,

oblanceolate and tapering into a slender petiole; all of them hirsute with white spreading hairs: flowers axillary from the base up; calyx tube very short, the lobes lance-oblong, $3–4^{mm}$ long; petals broadly ovate-oblong, tridentate at the nearly truncate summit, about twice as long as the calyx-lobes, exceeding the longer stamens and about equalled by the pistil: capsules purplish, small and slender, less than 2^{cm} long, variously flexed and somewhat angled: seeds small, pale, smooth, usually oblique at base and obliquely pointed at apex.

I name as type A. D. E. Elmer's no. 3192, Monterey, Cal., distributed as *S. micranthum*. No. 5099, by C. A. Purpus, seems to be the same.

10. S. HIRTELLUM (Greene) Small, Bull. Torr. Bot. Club **23**:190; *Oenothera hirtella* Greene, Fl. Francis. 215.—LÉVEILLÉ in his monograph reduces this to a form of *S. micranthum*, but this does not seem to be justified by his specimens.

11. S. MICRANTHUM (Hornem.) Walp. Repert. **2**:77; *Oenothera micrantha* Hornem. Hort. Hafn.—That LÉVEILLÉ should take up the much later name *O. hirta*, and then reduce to this species such distinct forms as *S. hirtellum*, and *S. Nelsonii*, seems a little strange. However, he has described a very good variety which may be written

11a. S. MICRANTHUM **Jonesi** (Lévl.), n. comb.—Taking as the type the first number cited, viz. Hansen's 543, Amador Co., Cal. 1892, I would name as a close duplicate C. C. Parry's specimens (in the Missouri Botanical Garden) simply labelled "Oenothera. June 1889. Cal." Blanche Trask's Avalon specimen, cited by LÉVEILLÉ, seems rather to belong with the species itself. It is quite probable that the species as it now stands is an aggregate.

11b. S. MICRANTHUM **exfoliatum,** n. var.—Branched from the base, the stems stoutish, the bark white, shreddy, and exfoliating in thin sheets, giving the plant the appearance of *S. decorticans:* pubescence of the stems ciliate, that of the leaves and fruits closer and somewhat appressed: capsules sharply angled, contorted.

I cite here the following specimens: C. R. Orcutt, Colorado Desert, April, 1889; C. A. Purpus, no. 5083, Erskine Creek, Cal., 1897.

12. S. BISTORTUM (Nutt.) Walp., Repert. **2**:77. *Oenothera bistorta* Nutt., T. & G. Fl. N. A. **1**:508.

12a. S. BISTORTUM **Veitchianum** (Hook.), n. comb.; *Oenothera bistorta Veitchiana* Hook., Bot. Mag. *pl. 5078.*—The characters which were supposed to distinguish this variety sufficiently from *S. bistorta* and to constitute it a species become less well-defined the larger the series of specimens. Even the greater length of capsule and beak seems to be a variable quantity.

13. S. SPIRALE (Lehm.) Fish. & Mey., Ind. Sem. Hort. Petrop. **2**:50; *Oenothera spirale* Lehm. in Hook. Fl. Bor. Am. **1**:213.—Assuming it to be a fact that this Californian plant is distinct from *S. cheiranthifolium* of South America, the specific name as given by LEHMAN in Hooker's *Flora* is the next available one.

13a. S. SPIRALE **viridescens** (Lehm.), n. comb.; *Oenothera viridescens* Lehm. in Hook. Fl. Bor. Am. **1**:214.—If this be a good species, it certainly is very difficult to distinguish from the preceding. It was given only varietal rank by WATSON in his revision (Proc. Am. Acad. **8**:592), under the name *suffrutescens*—the woody base and possibly perennial duration, with the somewhat larger flowers, being the characters that he used. But even in these respects the species and the variety seem to grade into one another.

13b. S. SPIRALE **clypeatum** (Lévl.), n. comb.; *Oenothera clypeata* Léveillé, Monog. Oenothera, 222.—Distinguishable by the broad, shield-shaped leaves which are densely canescent, and by the large flowers (often 4^{cm} across).

14. S. DECORTICANS (H. & A.) Small, Bull. Torr. Bot. Club **23**:191; *Gaura decorticans* H. & A. Bot. Beech. Voy. 343.—SMALL seems to be well within bounds when he assigns priority to the name of HOOKER and ARNOT. The species, though apparently greatly variable, is so merely before it begins to blossom when quite small, at which time it is smooth and erect. With age it becomes large, more spreading, and roughened with the loosened shining shreddy bark. WATSON'S characterization of the seeds as "cellular-pubescent" is a good one.

15. S. **tortum** (Lévl.), n. sp.; *Oenothera chamaenerioides torta* Lévl., Monog. Oenothera, 230; *O. alyssoides minutiflora* Wats., Proc. Am. Acad. **8**:591.—Branched from the base and spreading, becoming at length nearly prostrate; leaves glabrous, mostly basal, oblanceolate and tapering into slender petioles: capsules about 2^{cm} long, cinereous, variously contorted.

LÉVEILLÉ is right in allying this with *S. chamaenerioides*, but on habit alone, to say nothing of the fruits, it is entitled to specific rank.

Following are specimens illustrating: Jones, 5548, Manti, Utah; Nelson, 4691, Granger, Wyo.; Cusick, 2515, Malheur River, Oregon; Trelease, 4435, Shoshone, Idaho; Nelson, 4707, Green River, Wyo.; Godding, Milford, Utah.

15a. S. TORTUM **Eastwoodae,** n. var.—Leafy throughout, the leaves oblong-linear: flowers very small: capsule tapering into a slender beak, spirally coiled at base.

This is probably a good species. Only one specimen is before me: Alice Eastwood, Grand Junction, Colo., May, 1892.

16. S. TORTUOSUM A. Nels., Proc. Biolog. Soc. **17**:95. 1904; *Oenothera gauraeflora caput-medusae* Lévl., Monog. Oenothera, 226. —LÉVEILLÉ'S plate shows only a single branch from Lemmon's specimens.

17. S. UTAHENSE Small, Bull. Torr. Bot. Club **23**:191.—Whitened with a tomentose pubescence, branching from the base upward, 15^{cm} or more high (the plants in hand are all young): leaves ovate, obovate, or oblanceolate, $2–4^{cm}$ long, generally tapering to a short petiole: flowers crowded in terminal somewhat corymbose racemes, white; calyx-tube longer than the lanceolate lobes; petals obovate, 5^{mm} long, longer than the stamens but surpassed by the pistil: capsule linear, less than 2^{cm} long, more or less contorted.

The specimens before me were collected by L. N. Goodding at Milford, Utah. As the original description calls for yellow flowers I thought at first Goodding's specimens were another species, but agreeing in most other respects I am going to assume that "flowers yellow" was a clerical error.

18. S. BOOTHII (Dougl.) Small, Bull. Torr. Bot. Club **23**:191; *Oenothera Boothii* Dougl., Lehm. in Hook. Fl. Bot. Am. **1**:213.—Seemingly seldom collected. Typical specimens by L. F. Henderson, Shoshone Falls, Idaho, July, 1897. Many of the specimens referred to this species belong to the next.

19. **S. Lemmoni,** n. sp.—Branched from the base up, $2–3^{dm}$ high, stem and branches rather stout, crinkled-hirsute; branches divaricate-ascending: leaves rather large, variable in size, $2–5^{cm}$ long, oblong or broader, mostly acute at apex, lower tapering into petioles, hirsute-ciliate especially beneath: flowers in a crowded terminal short-hirsute raceme, lengthening into a bracteate fruiting spike; calyx tube but slightly enlarged upward, scarcely as long as its narrowly lanceolate lobes; petals broadly obvate or suborbicular,

about 7^{mm} long, slightly longer than the calyx lobes and stamens, equalling the style; stamens similar and equal: capsule slender, tapering to summit, ascending, somewhat bent or contorted, about 2^{cm} long.

This has passed as *S. Boothii* Dougl. Similar as the descriptions seem, the two plants are quite distinct in appearance. *S. Boothii* is glabrous and with shreddy bark on the older stem; it branches mainly near the base, the branches also branching; its flowers are much smaller, and the capsules are shorter and more contorted.

The type is J. G. Lemmon, no. 103, eastern flank of Sierra Nevada, Cal. 1875. Two good specimens, both in herb. Mo. Bot. Garden.

20. **S. Hitchcockii** (Lévl.), n. sp.; *Oenothera gauraeflora Hitchcockii* Lévl., Monog. Oenothera, 226.—Softly hirsute or ciliate, branched from the base, $15–25^{cm}$ high; branches slender and more or less paniculately branched above: root leaves oblong, irregularly dentate, about 3^{cm} long, tapering into a petiole one-half as long; stem leaves smaller, bract-like, sessile, broadly linear or lanceolate: flowers crowded in bracteate secund racemes; calyx tube slender, scarcely enlarged at summit, as long as the linear-lanceolate lobes; petals white, obovate, $3–4^{mm}$ long, scarcely longer than the calyx lobes and the stamens; style slender, longer than the petals: capsules slender, $12–18^{mm}$ long.

This very excellent species rests upon two specimens in herb. Mo. Bot. Garden. One bears the data "Simpson Park, July 6th, 1859 (?)," and in pencil "nothing like it known to me;" the other is blank, but both look as if they were from the same collection.

21. S. ALYSSOIDES (H. & A.) Walp., Repert. **2**:78; *Oenothera alyssoides* H. & A., Bot. Beech. Voy. 340.

21a. S. ALYSSOIDES MACROPHYLLUM Small, Bull. Torr. Bot. Club **23**:192; *Oenothera alyssoides villosa* Wats., Proc. Am. Acad. **8**:591.

The following are, so far as the writer knows, still unknown except from the original specimens and descriptions. So far as one may judge from descriptions, they are valid and will no doubt again come to light.

S. ANGELORUM (Wats.), *Oenothera angelorum* Wats., Proc. Am. Acad. **24**:49.

S. PTEROSPERMUM (Wats.); *Oenothera pterosperma* Wats., King's Rep. 112.

S. RUTILUM (Davids.); *Oenothera rutila* Davids., Erythea **2**:61.

COOPER'S COLORADO COLLECTIONS.

In the summer of 1904, Mr. WILLIAM S. COOPER, a student in Alma College, Michigan, spent some weeks in Colorado collecting in the vicinity of Estes Park and upon Long's Peak. He secured over 300 numbers, many of them of great interest. The following I will characterize as new:

Oreocarya pulvinata, n. sp.—Cespitose-pulvinate, practically stemless, the small cushions a few centimeters across and about 1^{cm} high; flowers as well as the leaves involved in the soft villous pubescence: leaves crowded, broadly linear, less than 1^{cm} long: flowers few, glomerate at the summit of the reduced stems (the stems scarcely rise above the matted leaves): calyx-lobes linear, nearly equaling the corolla tube: corolla white; its tube dilated, subspherical, about 2^{mm} long, the broad throat only partly closed by the conspicuous crests; the lobes of the limb suborbicular, about as long as the tube: stamens small, included, inserted near the middle of the tube; filament almost wanting: style short, rather thick, equaling the stamens.

This species so closely simulates *Eritrichium aretioïdes* (before the flower stalks of that species have developed) that one would almost certainly pronounce it an Eritrichium at the first glance. The pubescence and pulvinate habit are similar, but a glance at the flowers does not leave one in doubt very long.

The type material, no. 278, is very scanty, but so characteristic a species cannot be ignored. Collected on Mummy Mts., Estes Park, Aug. 12, 1904, alt. $12–13,000^{ft}$.

Chrysopsis Cooperi, n. sp.—Whitened with soft loose long-villous pubescence throughout: stems low, spreading, more or less decumbent at base, $10–15^{cm}$ high, leafy throughout: leaves narrowly oblanceolate, tapering into a margined petiole-like base, from $2–5^{cm}$ long, middle and upper stem leaves usually longer than the basal: heads solitary, terminal and axillary; terminal head large, $12–14^{mm}$ high and considerably broader, subtended by some foliar bracts which are long-ciliate on the margins; axillary heads reduced downward, on successively shorter leafy peduncles, usually only the 2 or 3 uppermost developing, the others becoming sessile and aborted in the axils: involucral bracts narrowly linear, acute, midrib green and the margins scarious: rays 15–25, orange-yellow, ligule 12–15^{mm} long; disk corollas numerous, with very slender tube which is shorter than the narrowly tubular throat; teeth short, lanceolate, erect: pappus dingy, equaling the corolla: akene short-linear, minutely silky-pubescent.

This is probably to be compared with *C. alpicola* Rydb. and *C. Bakeri* Greene, but it is far more silky-hirsute than either. It seems to be unique in the axillary heads, which though usually aborted can be detected in the axils nearly down to the base of the stems.

Cooper's no. 50, Long's Peak, near timber line is the type; August 11, 1904.

CHRYSOPSIS ALPICOLA **glomerata,** n. var.—Closely resembling the species and like it nearly devoid of basal leaves at anthesis: heads several, closely glomerate at the summit of the simple stems.

Founded on Cooper's no. 174, Estes Park, August, 1904.

Aster Cordineri, n. sp.—Spreading by horizontal rootstocks, dark green and seemingly glabrous to the unaided eye, under a lens minutely but very sparsely scabrous (mostly on the margins of leaves and involucral bracts): stems 3–6^{dm} long, generally simple below, racemosely short-branched above, decumbent at base and either widely spreading or nearly erect, often puberulent especially upward, very leafy: leaves broadly linear, crowded, spinulose tipped; primary ones 4–7^{cm} long, 4–6^{mm} broad; secondary ones similar but smaller, more or less fascicled in the axils: heads solitary at the ends of the short leafy axillary racemosely disposed branchlets, rather large: involucre nearly 1^{cm} high, somewhat broader than high; bracts erect, glabrate, dark green on the spatulate-linear blade, lighter at base, spinulose tipped: rays 20–30, bluish shading to white: pappus rather coarse and dingy: akene short-pubescent.

A very characteristic species related to *A. commutatus*. Readily distinguished by its glabrate dark green appearance and the relatively few large solitary heads. The branchlets are strictly racemose, only 3–5^{cm} long, and those on the stems, which are widely spreading, are assurgent and therefore secund in appearance. Two collections are at hand. The first was secured at Myersville, Wyo., on the Sweetwater, Sept. 5, 1894, by Mr. George Cordiner, the writer's first enthusiastic field assistant;[5] the second is Cooper's no. 151 (type) from Estes Park, Aug. 11, 1904.

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[5] Mr. Cordiner was accidentally killed in 1895 by a falling wall at a fire where he was assisting. I name this plant in memory of a young life of great promise.

Crepis alpicola (Rydb.), n. sp.—Caudex short, vertical, semifleshy: leaves glabrous, rosulate on the crown, linear-oblong or oblanceolate, acute at apex, sessile or tapering into a short margined base, entire or saliently toothed or even subruncinate, 3–6^{cm} long: stems scapose, simple, glabrous, with one or two linear bracts, 10–20^{cm} high, usually monocephalous: involucre about 14^{mm} high, dark green, clammy or glandular pubescent; its bracts in 3 or 4 successively shorter rows: ligules 2^{cm} long: akenes short, fusiform, shorter than the fine white pappus.

This is probably *C. runcinata alpicola* Rydb., Bull. Torr. Bot. Club **24**: 299, although the above description does not quite tally with the brief diagnosis of the variety. A reasonable amount of variation will account for any differences. It is to be compared, however, with *C. riparia*, because of its large heads and the gland-tipped pubescence on the involucre. It is distinct from that species in its small glabrous leaves, its one-flowered stems, its involucre of 3 or 4 rows of bracts, and its short fusiform akenes. Cooper secured it in an alpine meadow (11,000^{ft}) on Long's Peak, Aug. 3, 1904, no. 218.

MISCELLANEOUS SPECIES.

Gilia exserta, n. sp.—Biennial, 2–3^{dm} high: stem single at base but branched from near the base upward; branches mostly simple and moderately divaricate, almost equaling the main stem, minutely pruinose-viscid: leaves 2–5^{cm} long, somewhat pungent, linear, entire or simply pinnatifid, with few to several linear lobes: flowers in small bracteate cymes forming narrow panicles: calyx membranous, narrowly campanulate, about 4^{mm} long, merely pruinose; its teeth very short, green, triangular-subulate, and minutely pungent: corolla white, purple dotted, 10–12^{mm} long, somewhat trumpet-shaped; tube surpassing the calyx; its lobes elliptic-oblong, acute, almost as long as the tube: stamens noticeably exserted; style scarcely so: ovules about 2 in each cell; seeds destitute of mucilage.

The type is no. 538, by C. F. Baker, Pagosa Springs, Colo., July 28, 1899. It was distributed on GREENE's determination as *G. multiflora* Nutt., which it certainly cannot be. It seems nearer *G. stenothyrsa* Gray of the section GILIANDRA (Syn. Fl.).

Amelanchier oreophila, n. sp.—A low scraggy-branched shrub, 1–2^{m} high, growing mostly in close clumps: young leaves, petioles, and twigs more or less lanate-pubescent, some of the pubescence persisting till maturity, especially on the lower face of the leaves:

leaves ovate, obovate, or broadly elliptic, rather small, not more than 3–4$^{\text{cm}}$ long even at maturity, incisely small-toothed from the middle to the obtuse or rounded apex, on petioles usually less than half as long as the blade: racemes short and dense: calyx-lobes subulate-triangular, lanate-pubescent on the margins and inner face, the pubescence persisting nearly or quite till maturity: petals spatulately oblanceolate, short (about 8$^{\text{mm}}$): pome globose, purplish black, developing but little pulp, and remaining rather dry and insipid, maturing late (September ?).

This is a segregate from *A. alnifolia* Nutt. I think most collectors must have felt that either *A. alnifolia* was unusually variable or that some segregation ought to be made. After many years' observation in the field and the study of a large series of specimens, I am satisfied that two valid species exist and can be readily distinguished. Nuttall's *A. alnifolia* is the widely distributed glabrous shrub of the creek banks, moist cañons, and snow slopes. At maturity it is perfectly glabrous and is quite glabrous from the beginning upon the calyx lobes. The leaves are larger, coarsely serrate, often suborbicular or with a tendency to truncateness at base and apex. The petals are much larger (12–15$^{\text{mm}}$ long). The fruits become much larger, are purple, with bloom, juicy and well flavored, are used extensively for sauce and pies, maturing during July or August according to the altitude.

A. oreophila is a smaller shrub, scraggy-branched, usually in dense clumps, and occurring in the driest situations (open stony slopes, ridges, and hilltops). It is never wholly glabrous, and the fruit is of little if any value. Many other differences are brought out in the characterization. Much of the material distributed from the Rocky Mountains belongs to this species. I may cite the following as at hand.

COLORADO: L. N. Goodding, 1456, Camp Creek, Routt Co., July 6, 1903; 1683, Willow Creek, Routt Co., July 25, 1903; Rydberg and Vreeland, 6030, La Veta, May 18, 1900; K. K. MacKenzie, 240, Breckenridge, Aug. 1901; C. F. Baker, 55, 139, and 380, Plants of West Central Colorado, 1901. WYOMING: By the writer, 2954, Evanston, May, 1897; 117, 6968, and 6985, Albany Co.; L. N. Goodding, 555, Elk Mt., Aug. 21, 1901; Merrell and Wilcox, 458, Point of Rocks, June 17, 1901. The following are allied, but when better known will probably be found to represent two other species: Baker's Plants of Nevada, nos. 946 and 1002; Mrs. R. W. Summers, specimens from Yamhill, Co., Oregon, March, 1903.

Amelanchier elliptica, n. sp.—A low shrub or more rarely a small tree, growing mostly as scattered individuals rather than in clumps: branches and twigs rather slender and willow-like, gray except at the tips which are purplish-black with an inconspicuous beady resin:

most of the leaves elliptic in outline, incisely serrate, with rather small teeth extending to the middle or sometimes nearly to the base, nearly glabrous above from the beginning, lightly floccose woolly beneath when young as are also the slender petioles: inflorescence few-flowered, quite open in blossom and more so in fruit: calyx somewhat woolly-pubescent, its lobes deltoid-triangular, shorter than the tube, lanate on the inner face: petals narrowly oblanceolate, 12–15^{mm} long: mature fruit not known, the half-grown fruit spherical.

This will also have to be considered as a segregate from *A. alnifolia*, from which it differs noticeably in its elliptic leaves, the teeth of which are smaller and sharper and point toward the apex. The woolly pubescence of leaf and flower at once calls attention to this as distinct from the thick-leaved glabrous *A. alnifolia*. *A. elliptica* seems to be a species of wet places in the mountain parks and open stream banks. The species is again noticeable because of its few large flowers which are well exserted from the leaves. It is as handsome a species when compared with *A. alnifolia* as is *A. florida* when compared with *A. Cusickii*.

I take as the type L. N. Goodding's no. 1447, Beaver Creek, Larimer Co., Colo., July 4, 1903. The following also seem to belong here: Goodding, no. 1036, Milford, Utah, June 5, 1902; Baker, Earle, and Tracy, no. 197, Bob Creek, Colo., June 28, 1898; possibly the following also: Jones, no. 1447, City Creek cañon, Utah, June 5, 1880; Baker's West Central Colorado Plants, 1901, nos. 47 and 260 (in my set distributed unnamed).

THE ROCKY MOUNTAIN HERBARIUM,
LARAMIE, WYOMING.

BRIEFER ARTICLES.

THE VIENNA CONGRESS.

THE SECOND International Botanical Congress was held at Vienna, June 11–18, 1905, and was highly successful in every way. There was a large and unusually representative attendance, the list of members containing about 600 names. Deducting ladies registered with husbands or relatives, and the considerable number of amateurs from Vienna and the neighborhood, it is certainly safe to say that there were present nearly 400 professional botanists. Of that number nearly one-half would be known by name to any one familiar with botanical literature, and among these were many whose reputation is world-wide. Naturally Austria was most numerously represented, but Germany sent a large contingent, and nearly all the European countries were represented, except perhaps those of the Iberian and the lower Balkan peninsulas. The English were few—a half dozen at most. Sixteen American botanists were present: ARTHUR, ATKINSON, BARNES, BARNHART, BLAKESLEE, BRITTON (Mr. and Mrs.), BROWN, CAMPBELL, COVILLE, DUGGAR, ROBINSON, SHEAR, TRELEASE, UNDERWOOD, and WOODS. But American societies were sadly negligent, and many were unrepresented which might have delegated authority to some of the sixteen.

The Congress was opened in the *Festsaal* of the University by WIESNER, with addresses of welcome by the minister of agriculture, speaking for the emperor; by the burgomeister, for the city; and by the rector for the university. BONNET, secretary of the Paris Congress, gave a historical statement of the organization of the present congress, and REINKE (Kiel) delivered an address on *Hypothese, Voraussetzungen, Probleme in der Biologie.*

In the afternoon the Nomenclature Conference organized in the hall of the Museum in the Botanical Garden by electing as president FLAHAULT; as vice-presidents RENDLE and MEZ; and three secretaries; received the report of the standing committees and of the *Rapporteur général* (BRIQUET); and adopted rules of procedure. The report of the Commission was presented as a quarto of 160 pages, having the text of the code of 1867 in the first column, the new formal proposals of various bodies in the second, notes by the *Rapporteur* in the third, and the text recommended by the Commission in the fourth. This *texte synoptique* was the work of BRIQUET, whose arduous labors for the past five years thus made possible the revision of the rules of nomenclature by this Congress. His untiring industry, unfailing patience, uniform courtesy and impartiality, as well as his linguistic facility won the admiration of all.

Afternoon sessions thereafter, from 3:00–7:00 or even later, were devoted to the discussions and actions of the *texte synoptique.*

Morning sessions and on some days also afternoon sessions, which were held in the lecture-room of the Engineer-Architects Club, were devoted to addresses upon special topics. Thus on Tuesday there were six papers on the development of the European flora since the Tertiary period; two introductory, on the geographical problems by PEACK (Vienna) and the botanical problems by ENGLER (Berlin), while ANDERSSON (Stockholm) spoke specially for the Scandinavian peninsula, WEBER (Bremen) for the north German lowlands, DRUDE (Dresden) for the mountainous region of central Germany, and BRIQUET (Geneva) for the alpine reigon.

On Thursday the topic was the present position of the doctrine of photosynthesis, MOLISCH (Prag) speaking of photosynthesis in chlorophyllous and HUEPPE (Prag) in chlorophyll-free organisms, KASSOWITZ (Vienna) giving a short talk on photosynthesis from the standpoint of metabolism. After a brief intermission the general problems of regeneration were discussed by GOEBEL (Munich), LOPRIORE (Catania) presenting a more special paper on the effects of wounding on regeneration of stems and roots. In the afternoon there were papers by ARTHUR (Lafayette) on the classification of the Uredinales; by ISTVÁNFFI (Budapest) on the life history of *Botrytis cinerea*, and by PETTKOFF (Sofia) on the algal flora of Bulgaria.

On Friday SCOTT (Kew) spoke on the fern-like seed plants of the carboniferous flora; LOTSY (Leiden) on the influence of cytology on taxonomy; and HOCHREUTINER (Geneva) on the Botanical Garden at Buitenzorg.

In the afternoon and on Saturday papers were mostly ecological: BECK (Prag), the significance of the *Karstflora* upon the development of the central European flora; DRUDE (Dresden), suggestions for an agreement upon the terminology of phytogeographical formations, and terminology used in the cartography of plant formations; WILLE (Christiania), Schübeler's theory as to the changes which plants undergo in acclimatization at higher latitudes; TANFILJEFF (St. Petersburg), the Russian steppes; TSCHERMAK (Vienna), the production of new forms by crossing; ADAMOVIĈ (Belgrade), phytogeography of the Balkan peninsula; PALACKY

(Prag), genesis of the African flora; KURTZ (Cordoba), the fossil flora of Argentina; BORBÁS (Klausenburg), the stipas of Hungary; HUA (Paris), report on the establishment of a new international organ for the publication of new names; SCHINDLER (Brünn), regulatory processes in the plant body in relation to cultivation.

On Wednesday a meeting of the *Association Internationale des Botanistes* was held, at which reports of the treasurer and secretary were presented. The most important action taken, by an overwhelming majority, was the direction of the Executive Committee, as soon as the present contracts permit, to print all *résumés* in type of the same size, abandoning the attempted discrimination. The next meeting will be held in Montpellier in 1908. The new officers are WETTSTEIN, president; FLAHAULT, vice-president; the present secretary and treasurer were re-elected.

The botanical exposition, under the auspices of this Association, occupied the Orangery at Schönbrunn, the emperor's summer palace on the outskirts of the city. The horticultural exhibit was open only during the week of the Congress, but the other exhibits remained for two weeks. There was an historical section, comprising books, atlases, original drawings, engravings, portraits, busts, herbarium specimens, instruments, and preparations of historical interest. This portion of the exhibits was limited to Austria, and naturally the most important contributors were the botanical section of the Imperial Museum of Natural History, and the two botanical institutes of the university.

The largest section of the exposition consisted of modern appliances for instruction and research. With many of the instruments demonstrations were given daily (10–12). In this section were shown living cultures of algae fungi, and bacteria; photographs of plants and plant-formations, and microphotographs of immense variety and all sizes, including many lantern slides; drawings and paintings; wall charts and maps; current books by the publishers; exsiccatae; and apparatus of many kinds (microscopes and their accessories, balances, ovens, and baths, glassware, physiological instruments, seed-control and wood-testing appliances, etc.

Particularly noteworthy in this section was a display of materials actually used in the *Realschule* and *Gymnasia* for botanical instruction, "whose purpose," the exhibitors say, "is to put before the eyes of visitors the advance which botanical instruction has made in the last decades. . . . Inasmuch as the phenomena of plant life must be brought close to the interest and understanding of pupils there stands in the foreground of the display the apparatus for conducting experiments in plant physiology, which break the path for the understanding of biological processes. Then come models and preparations for elucidating the anatomical and morphological features. . . . ." This exhibit shows clearly how thorough and wise the courses are. The equipment puts to shame all of our high schools and nine-tenths of our colleges.

The unique mechanical balances of NĚMETZ; the living algal cultures of the Biological Station in Vienna; the apparatus and methods of the imperial Seed-control Station in Vienna, and of the Imperial Forestry Station in Mariabrunn; and the display of pure cultures of fungi by the bureau established for this purpose by the *Association Internationale des Botanistes* (in Utrecht, in charge of Professor F. A. F. C. WENT) deserve special mention. The attempt of the Association to secure an exhibit of separates and works of many writers was practically a failure, only eleven sending papers. As a whole the exhibition was highly interesting and useful.

The third meeting of the *Freie Vereinigung der Systematischen Botaniker und Pflanzengeographen* also occurred on Wednesday, at which, in addition to a considerable list of papers, there was held a discussion on the introduction of a uniform nomenclature in phytogeography.

On Friday the agricultural botanists came together in the imperial Station for seed-control, in the Prater. No papers were read, but discussions were held on several topics, such as: methods of investigating sugar-beet seeds; weighing methods in determinations of germinative capacity; organization in seed-control stations; culture and study of barley; etc.

The actions on nomenclature are too extensive to summarize, and only a few of the more important decisions can be mentioned here. The word *laws* is to disappear, *rules* and *recommendations* taking its place. The rules for nomenclature of "cellular cryptogams," *i. e.*, the Bryophyta and Thallophyta, are remanded to a special commission of specialists, which is to present recommendations to the Congress of 1910, to be held at Brussels. In like manner a report on rules for the nomenclature of fossil plants is to be made by a Commission of paleobotanists. The word *ordo* (order) displaces *cohors*, recommended by the Commission for a group of families; but the American proposition to substitute *phylum* for *divisio* was lost. The date 1753 Linn. Sp. Plant. ed. 1. was adopted by a vote of 150 to 19. A vote on an article permitting laxity in the application of the rule of priority to generic names, and providing for a list of genera to be maintained *en tous cas*, was 133 yeas, 36 nays. Later, HARMS's list of such genera (400 and over) was adopted by a vote of 118 to 37. This list had been referred to a committee composed of BONNET, HARMS, BRITTON, PRAIN, and BRIQUET, and was recommended (by a majority) for adoption.

Some amusement was caused by the proposal of two corrections by the author while the motion to adopt was pending.

The proposition to except some old family names for the rule requiring such names to be derived from an important genus was carried by only 101 to 62.

The voting in regard to publication of a new species by plates and exsiccatae was confused, and the article was referred back to the Commission for editing. It is intended to exclude as valid publication *in future* plates without diagnoses, and past plates (without diagnoses) which contain no analytic drawings. Citation in synonymy and accidental mention are also declared invalid as publications. It was agreed (184 to 2) to adopt the compromise reported by a conference committee requiring the name of a section or species when transferred to another genus, or the name of a variety when transferred to another species, to be preserved or *re-established;* but when the rank is changed the preservation of the name is optional, and if not preserved its later re-establishment is not permissible. This is accompanied by a *recommendation* to preserve the primitive name whenever possible.

The vote on the use of double names (like *Linaria Linaria*) was unexpectedly close; 116 against them and 72 in favor. Generic names differing merely by their last syllable and even by one letter will be retained. Only typographic or orthographic corrections may be made in generic names.

After January, 1908, diagnoses must be written in Latin; so a close vote, 105 to 88, decided on Friday. A vote to reconsider was made on Saturday but was lost, 125 to 56. The metric system is recommended, and it is declared that "the foot, inch, line, pound, ounce, etc., should be rigorously excluded from scientific language." Fathoms, knots, and marine miles likewise fall under the ban. Authors are requested to indicate clearly the scale of magnification of figures.

On the whole the action of the Congress was conservative from the American point of view, yet marks great progress toward a stable nomenclature. Our European friends have not yet grasped the idea of generic types, and the rules relating to genera will doubtless be the next region of advance. When the final editing is accomplished and the new code is available, we may reasonably expect the rules to be generally followed until a further revision is possible.

The work on cryptogams and fossil plants will doubtless be prosecuted with vigor. The Commission of Cryptogams consists of MIGULA, LISTER, LAUTERBORN, GOMONT, WILLE, NORDSTEDT, WILDEMAN, SAUVAGEAU, DeToni, Chodat, Farlow, Arthur, Magnus, Saccardo, Patouillard, Jaczewski, Marshall-Ward, Vuillemin, Atkinson, Bresadola, Clements, Golenkin, Hua, Malmö, Zahlbruckner, Schiffner, Stephani, Levier, Evans, Cardot, Brotherus, Fleischer, Mrs. Britton, Salmon, and a few others whose names could not be secured. Some others could profitably be added to the list.

The entertainments, excursions, and visits to various institutions were numerous and attractive. A reception by the emperor was arranged, but the death of Grand Duke Josef on Tuesday estopped that, as well as a reception by the burgomeister at the Rathaus. Various long excursions after the Congress were provided, and all were sufficiently patronized to be undertaken.

The Committee of organization and the various local committees are to be congratulated on the success of their arrangements. These quinquennial international Congresses may now be considered a fixed feature of the botanical world.—C. R. B.

ANOTHER SEED-LIKE CHARACTERISTIC OF SELAGINELLA.

Two species of Selaginella (*S. rupestris* and *S. apus*) form embryos in the autumn which may resume growth after a period of rest. I left plants of these two species in a shallow box out of doors during the months of November and December, 1903. They were frozen and thawed several times during that time. In January the box was brought into the laboratory, the plants watered thoroughly, and allowed to thaw gradually. At the expiration of three or four days, the vegetative parts of the plants indicated a resumption of growth. Upon examining the strobili, young sporophytes were found thrusting roots and cotyledons from the female gametophytes. *Selaginella rupestris* is the species which displays a reduction in the number of megaspores, which are retained throughout germination, and even until the young sporophyte is well advanced.—Florence Lyon, *The University of Chicago.*

CURRENT LITERATURE.

BOOK REVIEWS.

North American Flora.

SUCH is the title of the most extensive systematic work hitherto undertaken in America. It is to contain all plants growing without cultivation in North America, which includes Greenland, Central America, Republic of Panama, and the West Indies, except Trinidad, Tobago, Curaçao, and other islands off the northern coast of Venezuela, whose flora is essentially South American. The work is published by the New York Botanical Garden, with Professors L. M. UNDERWOOD and N. L. BRITTON as the committee in charge. The names of the advisory committee are ATKINSON, BARNES, COULTER, COVILLE, GREENE, HALSTED, and TRELEASE.

The plans for such a publication have been under consideration for a number of years, and such large cooperation has been secured that there is every assurance of a completed work within a reasonable time. The plan includes the publication of thirty volumes, each to contain four or five parts; and in this way any part of any volume can be published as soon as it is ready. The volumes are assigned as follows: 1. Mycetozoa, Schizophyta, Diatomaceae; 2 to 10, Fungi; 11 to 16, Algae; 14 and 15, Bryophyta; 16, Pteridophyta and Gymnospermae; 17 to 19, Monocotyledones; 20 to 30, Dicotyledones.

The first fascicle has been issued recently,[1] dated May 22, 1905. Its typographical appearance gives abundant evidence of the great care that has been exercised in the selection of type and the arrangement of material. For example, the order with each species is the name and citation, description, type locality, distribution, and illustrations. The contents are as follows: J. K. SMALL gives a description of the order Rosales and a key to its twenty-four families; G. N. NASH presents Podostemonaceae, with five genera and ten species; N. L. BRITTON and J. N. ROSE contribute the Crassulaceae, occupying the bulk of the fascicle, twenty-five genera being recognized (*Oliveranthus*, *Corynephyllum*, *Cremnophila*, *Sedastrum*, and *Tetrorum* being new) and 284 species (twenty-nine being new); P. A. RYDBERG presents Penthoraceae, with its single genus and species, and Parnassiaceae, the single genus containing thirteen species, four of which are new.

The New York Botanical Garden and American botanists are to be congratulated upon the inception of this great work.—J. M. C.

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[1] North American Flora. Vol. 22. Part 1. Rosales, JOHN KUNKEL SMALL. Podostemonaceae, GEORGE VALENTINE NASH. Crassulaceae, NATHANIEL LORD BRITTON, JOSEPH NELSON ROSE. Penthoraceae, Parnassiaceae, PER AXEL RYDBERG. 8vo. pp. 80. New York: The New York Botanical Garden. 1905. Subscription price $1.50 for each part.

Studies in general physiology.

THE APPEARANCE OF LOEB'S *Studies in general physiology*[2] should give new impetus to the already active research in regard to the factors which control vital phenomena. No one has emphasized more clearly the essential similarity existing between the protoplasms of the two kingdoms than has this writer, and the present work promises to be of great use to plant as well as to animal physiologists.

These two volumes, of the Decennial Series of the University of Chicago, bring together in reprint the list of brilliant contributions which gave to the author his prestige in protoplasmic physiology. They consist of thirty-eight papers, published through various channels and in two languages, between the years 1889 and 1902. These are arranged in the chronological order of their previous publication, beginning with those on tropisms and ending with those on artificial parthenogenesis and on the irritability of muscles. Some of them have been somewhat shortened by the omission of repetitions which are unnecessary in the collected series; those originally published in German have been excellently translated into English by Dr. MARTIN FISCHER, and considerable additional light has been thrown upon certain points by appended footnotes bearing the date 1903.

The author and the physiological world as well are to be congratulated upon the attractive form of the publication. The volumes are printed upon a good quality of paper, and in type which is easily read. Illustration is by means of very clear figures in the text, and the citations of literature are where they should be, namely at the base of the page on which reference is made.

The only cause for regret to be felt by the reader of these volumes comes from the thought of how much more valuable the work might have been had it but taken the form of a treatise on the physiology of protoplasm; for in such a form the author might not only have connected his ideas into a more available whole, but also would have been offered a better opportunity to give to the reader the benefit of his broader view of the suggestions arising therefrom.—B. E. LIVINGSTON.

NOTES FOR STUDENTS.

ITEMS OF TAXONOMIC INTEREST are as follows: F. S. EARLE (Bull. N. Y. Bot. Gard. **3**:289–312. 1905) has published 33 new species of West-American fungi and 19 new species of tropical (mostly Porto Rican) fungi.—J. K. SMALL (*idem* 419–440), under the title "Additions to the flora of subtropical Florida," has published new species in Stenophyllus, Limodorum, Quercus (2), Phytolacca, Aeschynomene, Linum (2), Polygala (4), Phyllanthus, Croton, Stillingia, Chamaesyce, Gaura, Proserpinaca, Adelia (2), Rhabdadenia, Jacquemontia, Heliotropium, Lantana, Verbena, Scutellaria, Ruellia, Ernodea, Melanthera, and Carduus.—P. A. RYDBERG (Bull. Torr. Bot. Club **32**:123–140. 1905), in his

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[2] LOEB, JACQUES, Studies in general physiology. Part I, pp. xiii+423. Part II, pp. xi+425–782. Decennial Publications, The University of Chicago 1905.

14th paper entitled "Studies on the Rocky Mountain flora," has described new species in Machaeranthera (3), Xylorrhiza, Erigeron (7), Antennaria, Helianthus, Tetraneuris (2), Artemisia (3), Pyrrocoma, Tetradymia, Arnica, Carduus (5), Gaertneria, Crepis (5), Agoseris (5), and Taraxacum.—H. D. HOUSE (*idem* 139-140) has described two new species of Convolvulus from the western United States.—M. L. FERNALD and C. H. KNOWLTON (Rhodora **7**:61–67. *pl. 60.* 1905), in presenting *Draba incana* and its allies in northeastern America, have described two new species.—C. K. SCHNEIDER (Bull. Herb. Boiss. II. **5**:335–350. 1905) has published a synopsis of the species of Spiraea (Euspiraea), recognizing 57 and describing 8 as new.—G. LINDAU (*idem* 367–374), in his fourth paper on American Acanthaceae, has described a new genus (*Diateinacanthus*) from Honduras, and also 9 new species.—C. K. SCHNEIDER (*idem* 391–403, 449–464), in continuing his synopsis of Berberis, includes 53 species, 12 of which are new.—C. DECANDOLLE (*idem* 417–427) has published an account of the Meliaceae of Costa Rica, recognizing 23 species, 15 of which are described as new.—R. CHODAT (*idem* 481–506), in continuing his publication of Hassler's Paraguay collection, has described a new genus (*Aporosella*) and 16 new species of Euphorbiaceae.—A. W. EVANS (Bull. Torr. Bot. Club **32**:179–192. *pl.* 5. 1905) has described 3 new liverworts from Florida.—ALICE EASTWOOD (*idem* 193–218) has described new western species of Clematis, Aquilegia, Myosurus, Horkelia, Astragalus, Vicia (2), Lathyrus, Thermopsis, Rosa, Heuchera, Lithophragma, Jepsonia, Arctostaphylos (2), Cynoglossum, Cryptanthe, Phacelia, Polemonium, Pentstemon (6), Orthocarpus (4), Castilleia, Antirrhinum (2), Collinsia, Chrysoma (2), Raillardella, Hieracium, and Lessingia.—J. M. C.

PROTEID SYNTHESIS in developing peas forms the subject of a paper by ZALESKI.[3] In one series of expermients the ripening seeds were cut in halves and kept several days in either a dry atmosphere or one saturated with water. In either case the analyses of the seeds at the beginning and end of the experiments showed that there was an increase in the proteid content and a corresponding decrease in the content of asparagin, amido-acids, and hexon bases. When whole peas were used for the experiments, the analyses show that in place of the proteid increase there is a decrease, with the formation of crystalline nitrogenous derivatives. Experiments were carried out to determine whether or not the proteid synthesis was due to enzyme action. Finely ground developing peas were treated with solutions of ammonium sulphate or asparagin and allowed to stand with antiseptics for varying lengths of time. In all cases there was a decrease in proteid content followed by a slight increase. In none of the tests did the final quantity of proteid nitrogen equal that at the beginning of the experiment.

ZALESKI's study of the proteid changes in ripening seeds showed that these

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[3] ZALESKI, W., Beiträge zur Kenntniss der Eiweissbildung in reifenden Samen. Ber. Deutsch. Bot. Gesells. **23**:126–132. 1905.

organs contained proteolytic enzymes, and in a second paper[4] he gives the results of his study of the protease in ripening peas. Autodigestion experiments were carried out with freshly ground developing peas, with a powder prepared by drying the tissues at 35–37° C., and with a powder made from ground peas in a manner analogous to ALBERT'S acetone method for making zymase preparations from yeast. Evidence of proteolytic activity was furnished by analyses showing a diminution of the proteid as the digestions progressed. The enzymes of peas in the earlier stages of development caused a much more active proteolysis than those from the seeds in more advanced stages. This greater vigor of the enzyme of younger tissues is brought out in experiments showing the influence of strong sugar solution and of potassium nitrate. These agents had little effect on the progress of autodigestion with young peas, but caused a noticeable inhibition in the tests with older ones. The proteolysis is hurried by the presence of a trace of alkali, but retarded by stronger alkalis and by acids. The optimum temperature lay between 40 and 50° C. The enzyme acted vigorously on Witte peptone.—ARTHUR L. DEAN.

MISS TAMMES[5] has tested the sensibility to differences of environment of several fluctuating characters in each of several species grown under more and less favorable soil conditions. Of the fifteen characters studied, fourteen agree with the experience of others who have studied the influence of nutrition on fluctuation, in showing a shifting of the curves to the left when the plants are grown on poor soil; but, as would have been expected, the corresponding characters in the different species and the different characters in the same species show considerable differences of sensibility, some being relatively stable, others showing a very marked response to changed conditions. As a measure of variability, the author follows VERSCHAFFELT in using the quartile (Q) divided by the mean instead of the standard deviation (σ) divided by the mean, which is used by English and American biometers. In comparing the sensibility she employs a new measure, the "sensibility-coefficient," which is the difference between the well-fed and poorly-fed plants with reference to the character in question, divided by the condition in the well-fed. It is obvious that this measure can be of use only in allowing the comparison of different characters in a single series of observations such as those presented, and not as an absolute measure of sensibility which would permit comparison with the sensibility-coefficients for the same characters under other conditions. In the well-fed plants the coefficients of variability for all the characters of a given species were found to be nearly alike, though the several species differed markedly from each other in this regard; but in the poorly-fed plants the variability of the several characters was very differently affected, being sometimes increased sometimes decreased.

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[4] ZALESKI, W., Zur Kenntniss der proteolytischen enzyme der reifenden Samen. Ber. Deutsch. Bot. Gesells. **23**:133–141. 1905.

[5] TAMMES, TINE, On the influence of nutrition on the fluctuating variability of some plants. Koninklijke Akad. Wetens. Amsterdam **7**:398–411. *pl. 1.* 1905.

Miss TAMMES[6] has also studied the periodicity in the occurrence of supernumerary leaflets in *Trifolium pratense quinquefolium* DeVries. She finds that there are two concurrent anomalies, namely, a division of the lateral leaflets and a division of the terminal leaflet. The former is much the more frequent and reaches its maximum development below the middle of the primary branches, while the latter reaches its maximum also on the primary stems but on the upper half near the inflorescence. Few supernumerary leaflets occur on branches of second, third, and fourth orders.—G. H. SHULL.

LUXBURG[7] has presented some experimental data and a very able discussion to show that our views of the distribution of growth in geotropically stimulated organs, based largely on the experiments of SACHS, are no longer tenable. After applying more approved methods in a reinvestigation of the results obtained by SACHS and NOLL especially, he finds it no longer permissible to regard any position as leaving the organ insensible to the geotropic stimulation. The thesis maintained by NOLL that the normal vertical position of an organ furnishes it a condition of indifference to geotropic stimulation is regarded by the author as a striking example of the overestimation of the value of curvature reactions as indicators of the perception of stimulation by gravitation. The absence of a curvature response by no means implies that the stimulus is not perceived. HERING'S results with inverted organs are regarded as rendering a perception in the erect position very probable; the absence of a curve means merely that an asymmetrical growth was not induced. The author advances the theory that geotropic curvatures are accomplished by two different but as yet not separately observed processes, whose concurrent operation involves an alteration in the rate of growth and an asymmetrical distribution of growth. That favorable objects may be found in which these two processes ordinarily combined may be separately observed is regarded as not impossible. The theory advanced is supported chiefly by the study of organs for which a resumption growth is a prerequisite to curvature. The reaction of organs in the position of normal equilibrium, in which case a curvature does not appear, is to be distinguished from that in which curvature does occur merely by this, that an asymmetrical distribution of growth necessary to produce the curve is not induced.—RAYMOND H. POND.

CORRENS[8] has published ten letters written by GREGOR MENDEL to CARL NÄGELI during the period of MENDEL'S greatest activity in the study of hybrids (1866–1873). NÄGELI was the recognized authority on Hieracium hybrids in nature, and MENDEL wrote him careful accounts of the progress of his experi-

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[6] TAMMES, TINE, Ein Beitrag zur Kenntniss von *Trifolium pratense quinquefolium* DeVries. Bot. Zeit. **62**:211–225. 1904.

[7] LUXBURG, GRAF. H., Untersuchungen über den Wachstumsverlauf bei der geotropistischen Bewegung. Jahrb. Wiss. Bot. **41**:399–457. 1905.

[8] CORRENS, C., Gregor Mendel's Briefe an Carl Nägeli 1866–1873. Ein Nachtrag zu den veröffentlichten Bastardierungsversuchen Mendels. Abhandl. Math.-Phys. Dasse Sächischen Gesells. Wiss. **29**:189–265. 1905.

ments, and also sent him much of his artificially produced hybrid material, particularly of Hieracium. The letters were written with great care, and as they report many hybrids that were not mentioned in MENDEL'S published works, they are an important addition to the literature of hybridization. CORRENS has carefully annotated the letters and added two appendices, in the first of which he discusses the bearing of parthenogenesis upon MENDEL'S results in Hieracium, pointing out that these letters can leave not the slightest doubt that true hybrids were secured, but inferring from the constancy of the hybrid forms in successive generations that there is no reduction division, and that consequently, following STRASBURGER, we should speak of apogamy rather than parthenogenesis in Hieracium. In the second appendix CORRENS considers the question whether sexual characters are inherited according to MENDEL'S principles, such a possibility having been suggested in one of these letters. After examining the various possible assumptions as to dominance and the purity or the hybrid character of the gametes with respect to sex, he concludes that sex-determinants are fundamentally unlike the ordinary character-units and incapable of being satisfactorily explained by the laws of dominance and the segregation of parental gametes.—G. H. SHULL.

LEWIS[9] has investigated the development of *Phytolacca decandra*, his main purpose being to follow the origin and fate of the endosperm, with special reference to its behavior during germination. The development of the microsporangium follows the usual course, the tapetal cells perhaps deserving mention in that they sometimes contain six nuclei, the average number being four. In the megasporangium one and sometimes two archesporial cells appear, and a tapetal cell is cut off. The endosperm grows rapidly, "forming a sac with a great central vacuole." The nuclei lie free in the cytoplasm of the endosperm and always divide amitotically. The embryo sac finally becomes the extensive cavity characteristic of campylotropous ovules. Walls later begin to appear in the micropylar endosperm, the cells encroach on the central cavity, and finally the endosperm is completely cellular except for a mass of cytoplasm at the chalazal end of the sac. The embryo in its early stages consists of a well-developed suspensor and a many-celled, undifferentiated, spherical embryo. Starch is observed to accumulate in the perisperm, notably next to the concavity of the curved embryo, which disorganizes the endosperm almost completely. In germination the embryo elongates, and the radicle is pushed through the endosperm cap and the seed coat. The cotyledons continue to elongate until the stem tip is free, and the cells of the thick endosperm cap remain turgid, persisting "as a thick ring of tissue clasping the bases of the cotyledons and stopping the opening made in the seed coat at germination."—J. M. C.

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[9] LEWIS, I. F., Notes on the development of *Phytolacca decandra* L. Johns Hopkins Univ. Circ. No. 178. pp. 35–43. *pls. 3.* 1905.

NEWS.

J. Franklin Collins has been appointed assistant professor of botany at Brown University.

Dr. Karl Fritsch has been appointed professor of systematic botany at the University of Graz.

During the last year 59,349 specimens were added to the Herbarium of the New York Botanical Garden.

Professor Adolf Engler will attend the meeting of the British Association in South Africa, whence he goes to East Africa for further study of the flora.

Dr. Richard Sadebeck, professor of botany and director of botanical museums at Hamburg, and well known for his work on pteridophytes and plant diseases, died recently at the age of 64 years.

J. N. Rose left Washington June 21 for the "cactus fields" of southern Mexico, expecting to be gone about four months. His purpose is to collect not only herbarium specimens, but also material preserved in formalin and living plants.

At the June Convocation, the University of Chicago conferred the degree of Ph.D. upon H. Hasselbring, the title of the thesis being "Carbon assimilation;" and upon Etoile B. Simons, the title of the thesis being "A morphological study of *Sargassum filipendula*."

The botanical subjects for the two annual Walker prizes in 1906 are as follows: An experimental field study in ecology, A contribution to a knowledge of the nature of competition in plants, A physiological life history of a single species of plants, and Phylogeny of a group of fossil organisms.

P. Porsild, the Danish botanist, has secured the establishment of a biological station on the island of Disco, western Greenland, latitude 70°. The necessary 35,000 kroner (about $9500) was given by Justitsraad Holck, of Copenhagen, and the Danish government has promised maintenance.

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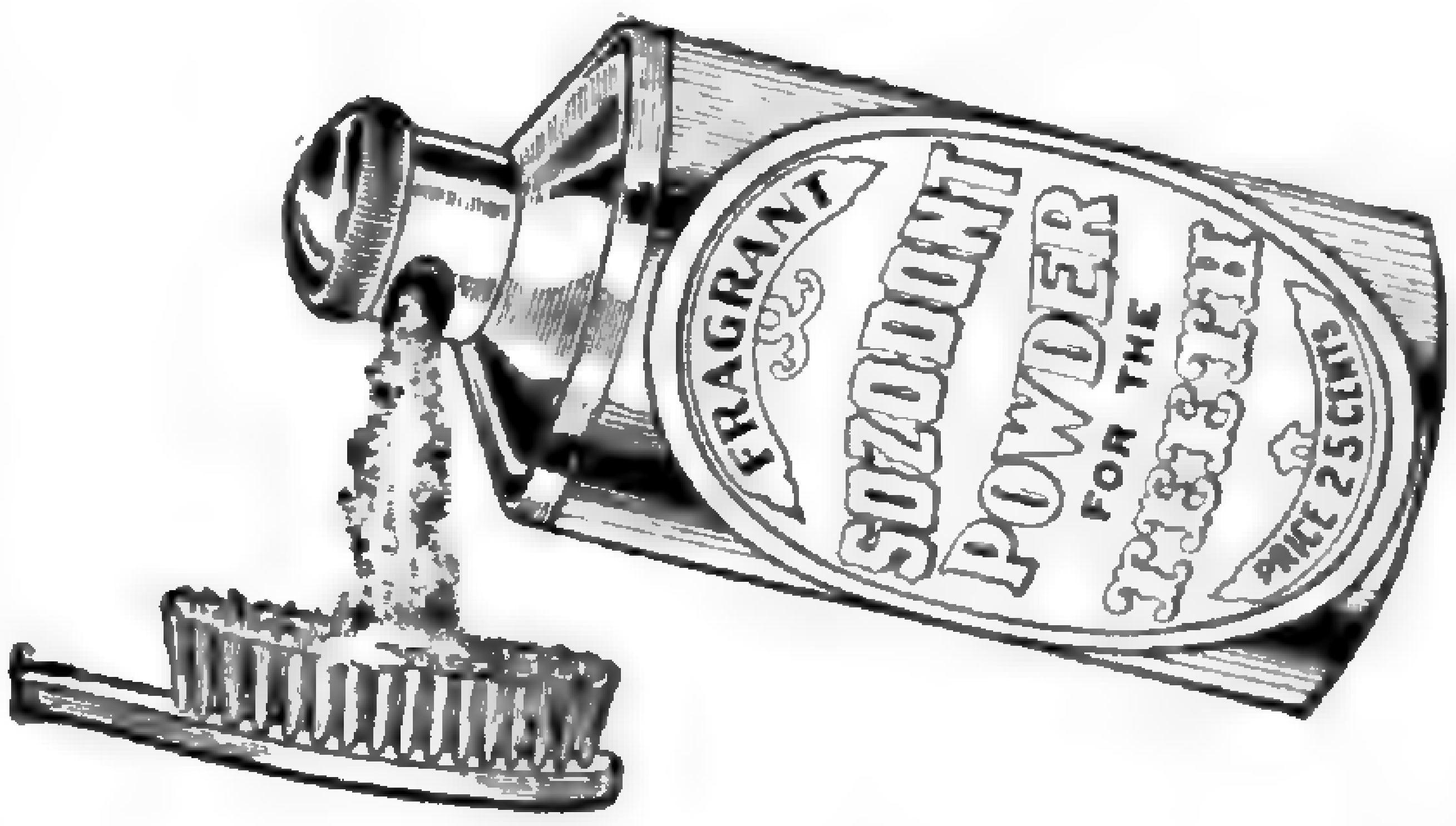

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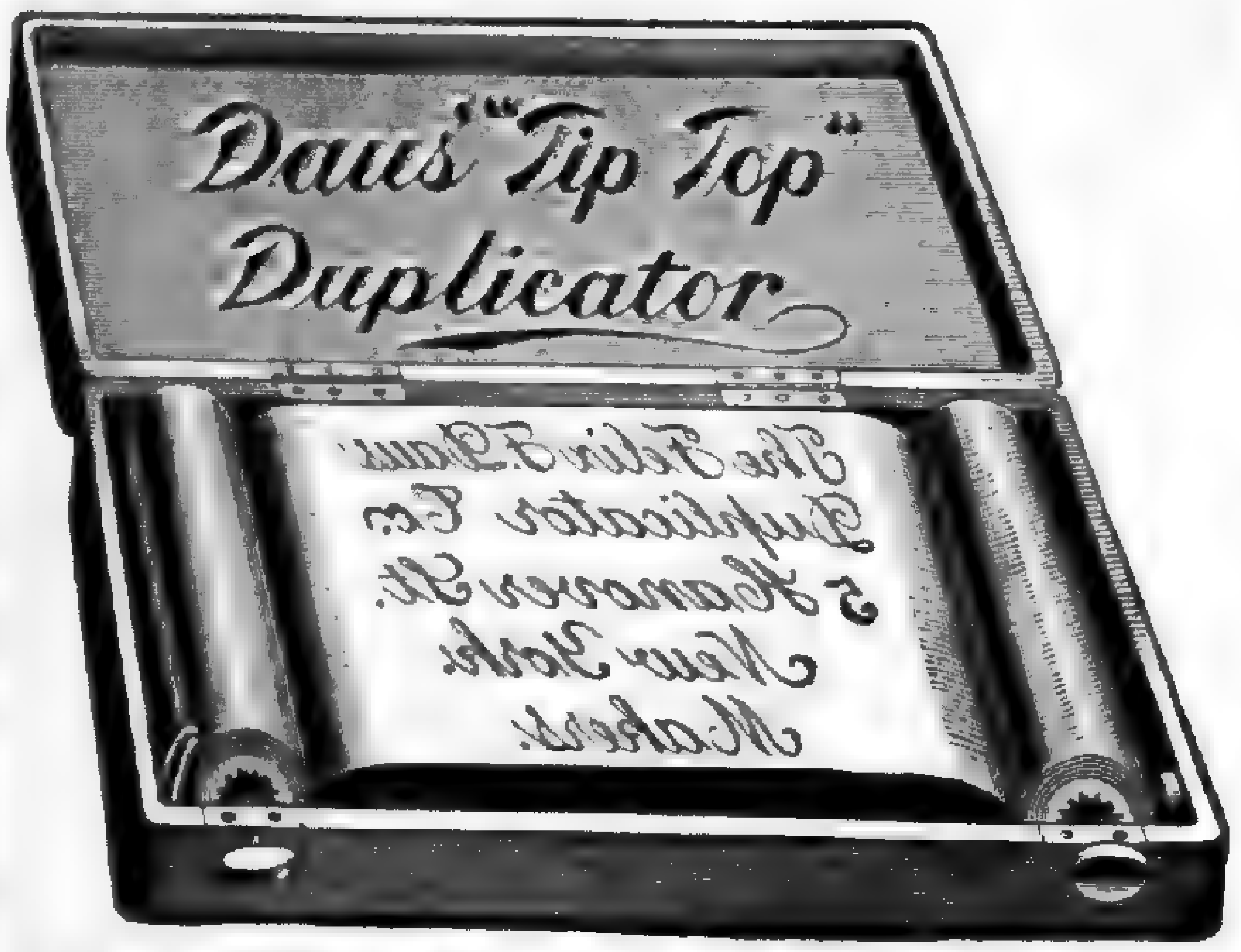

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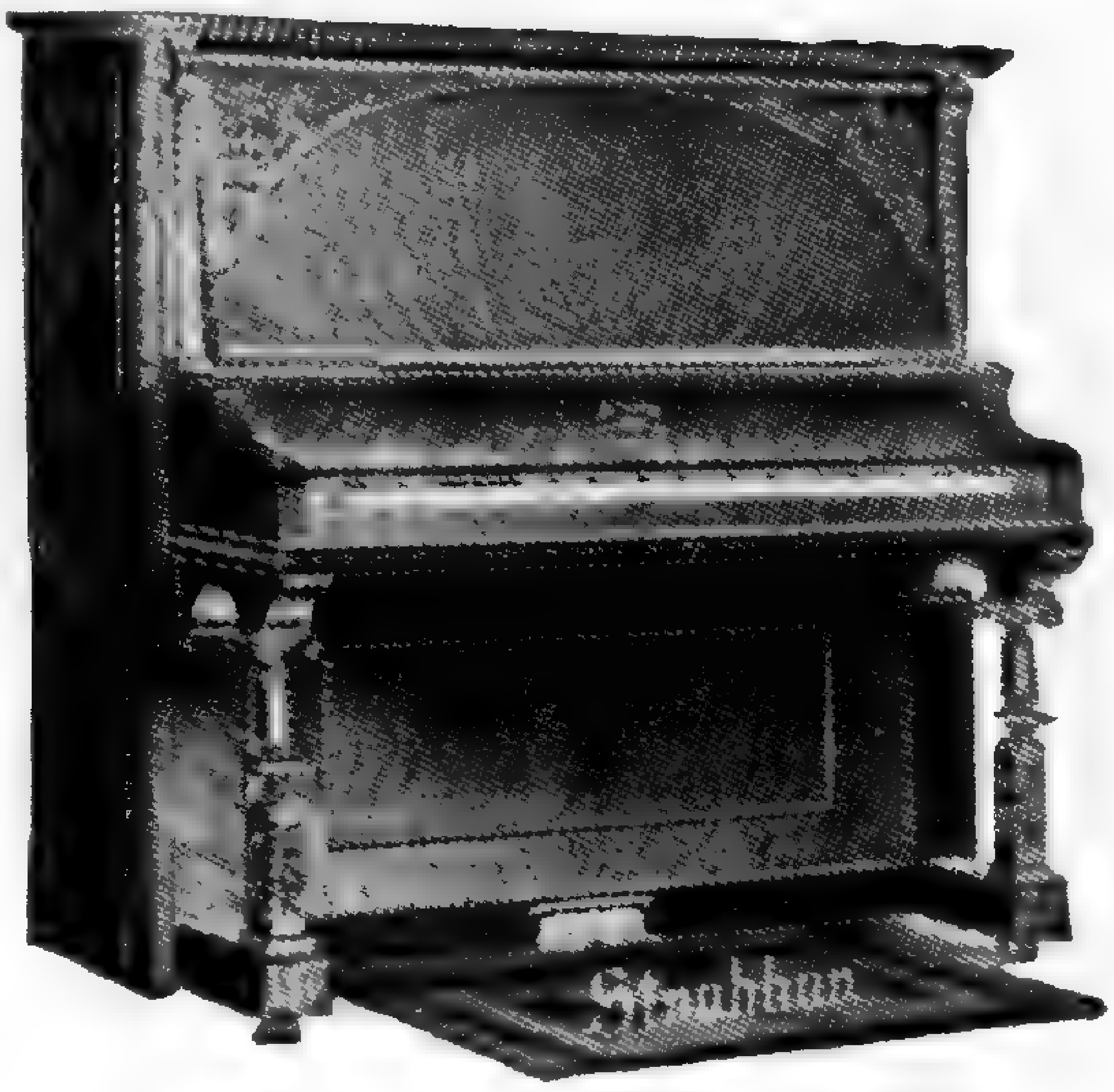

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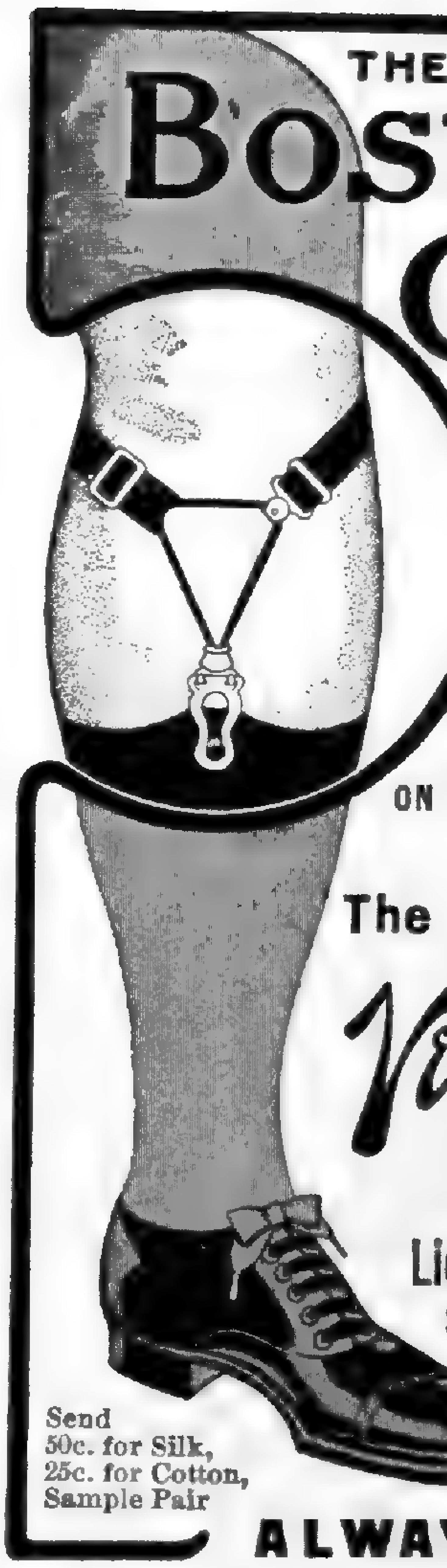


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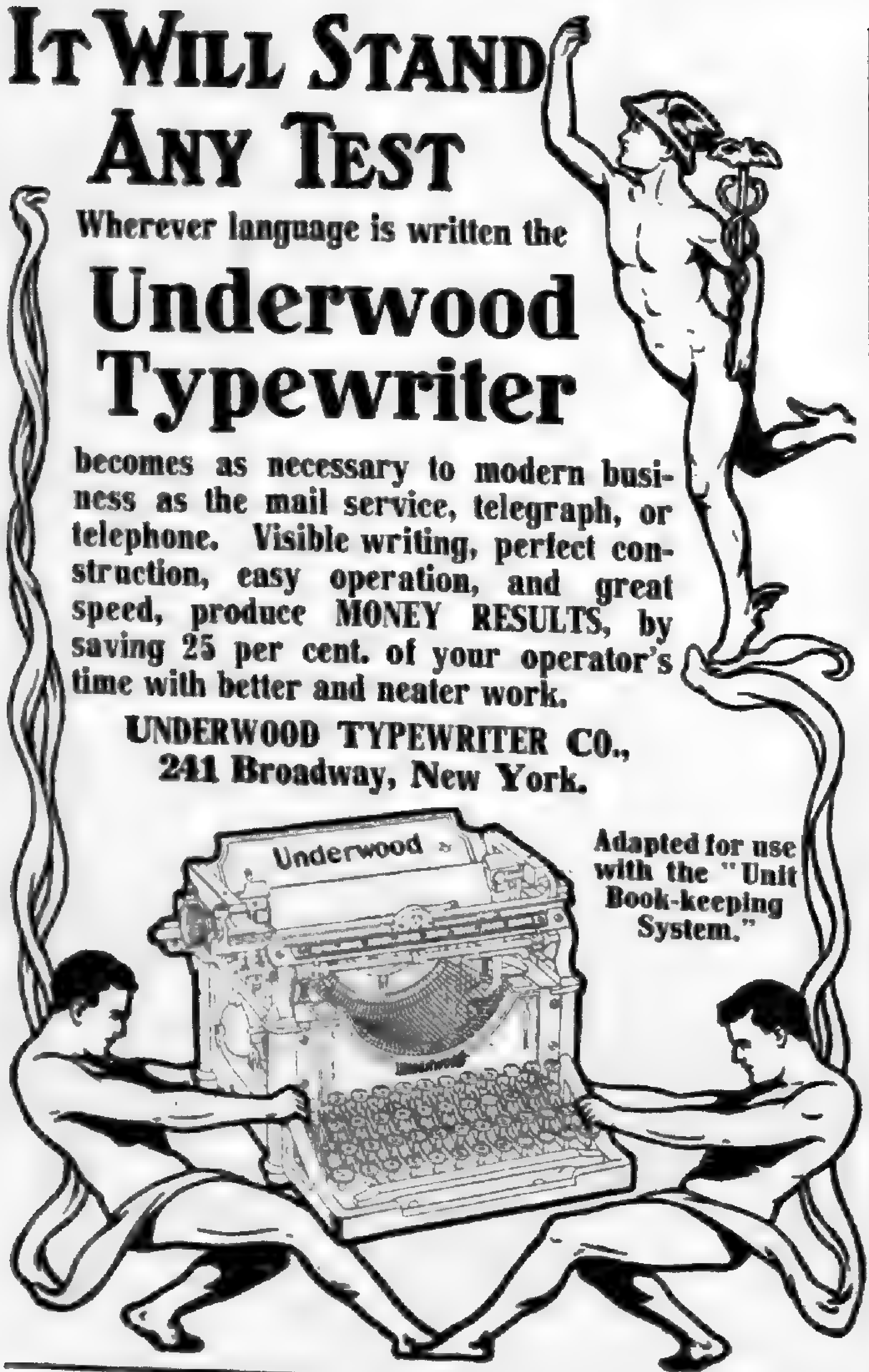

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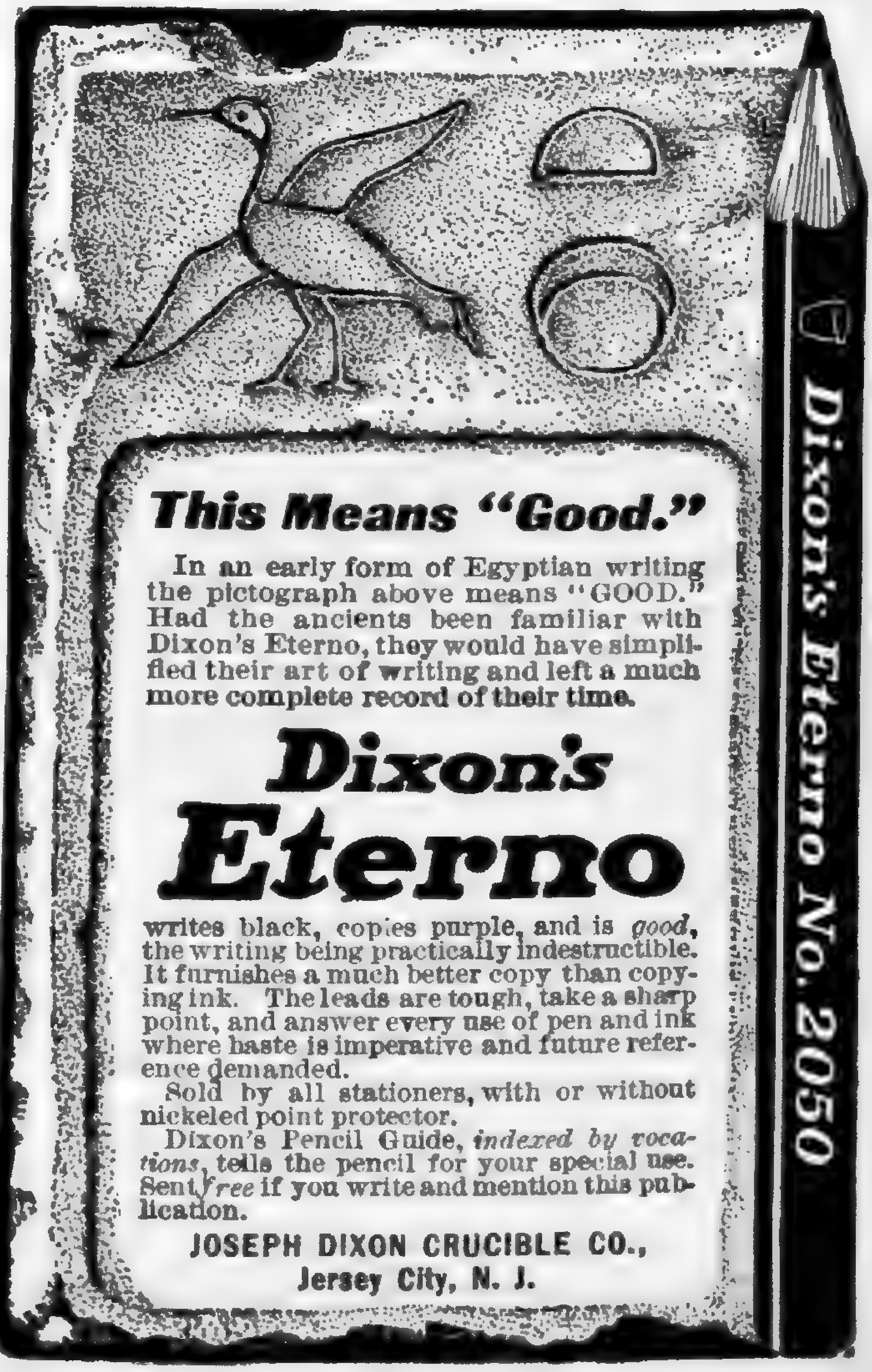
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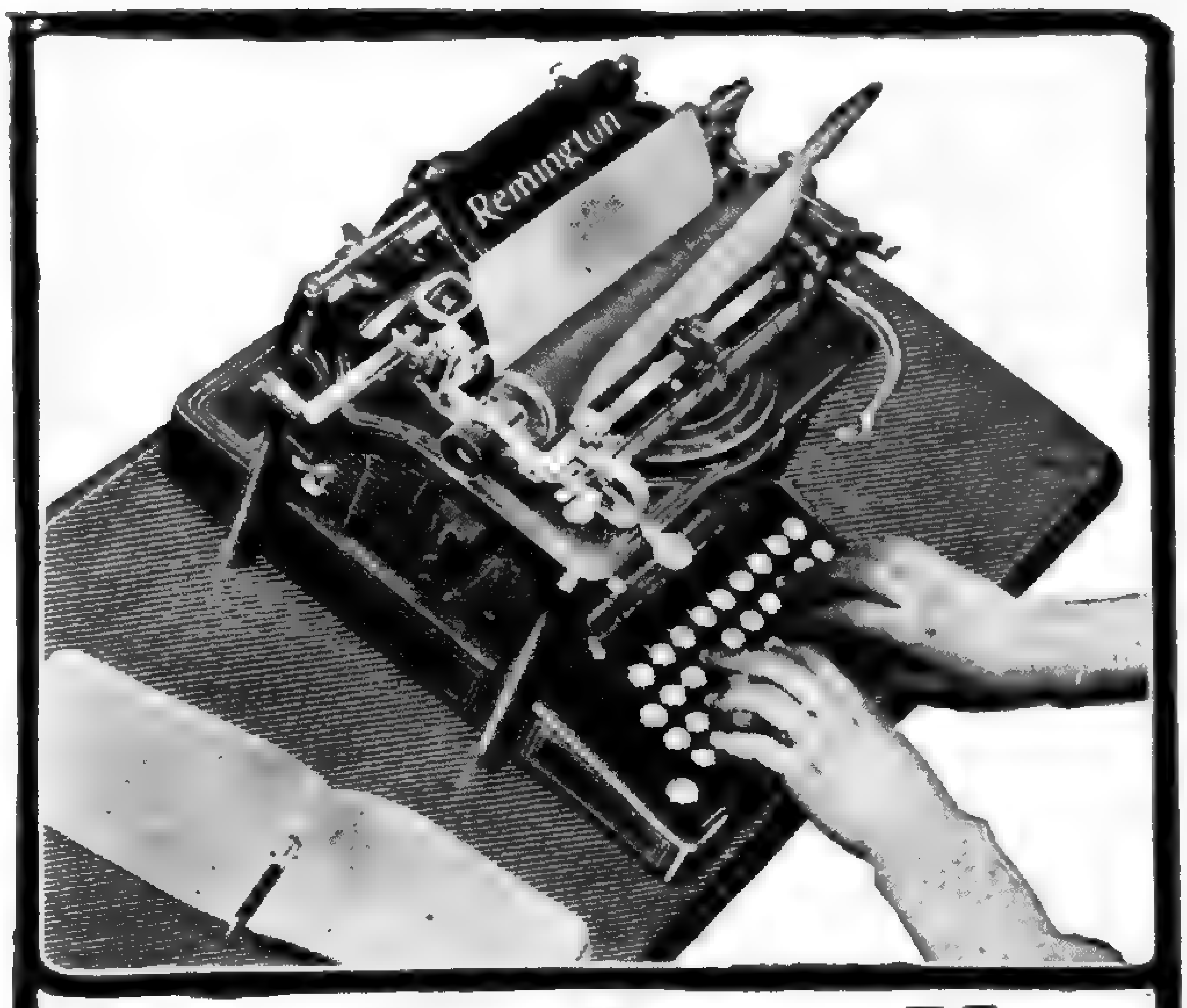


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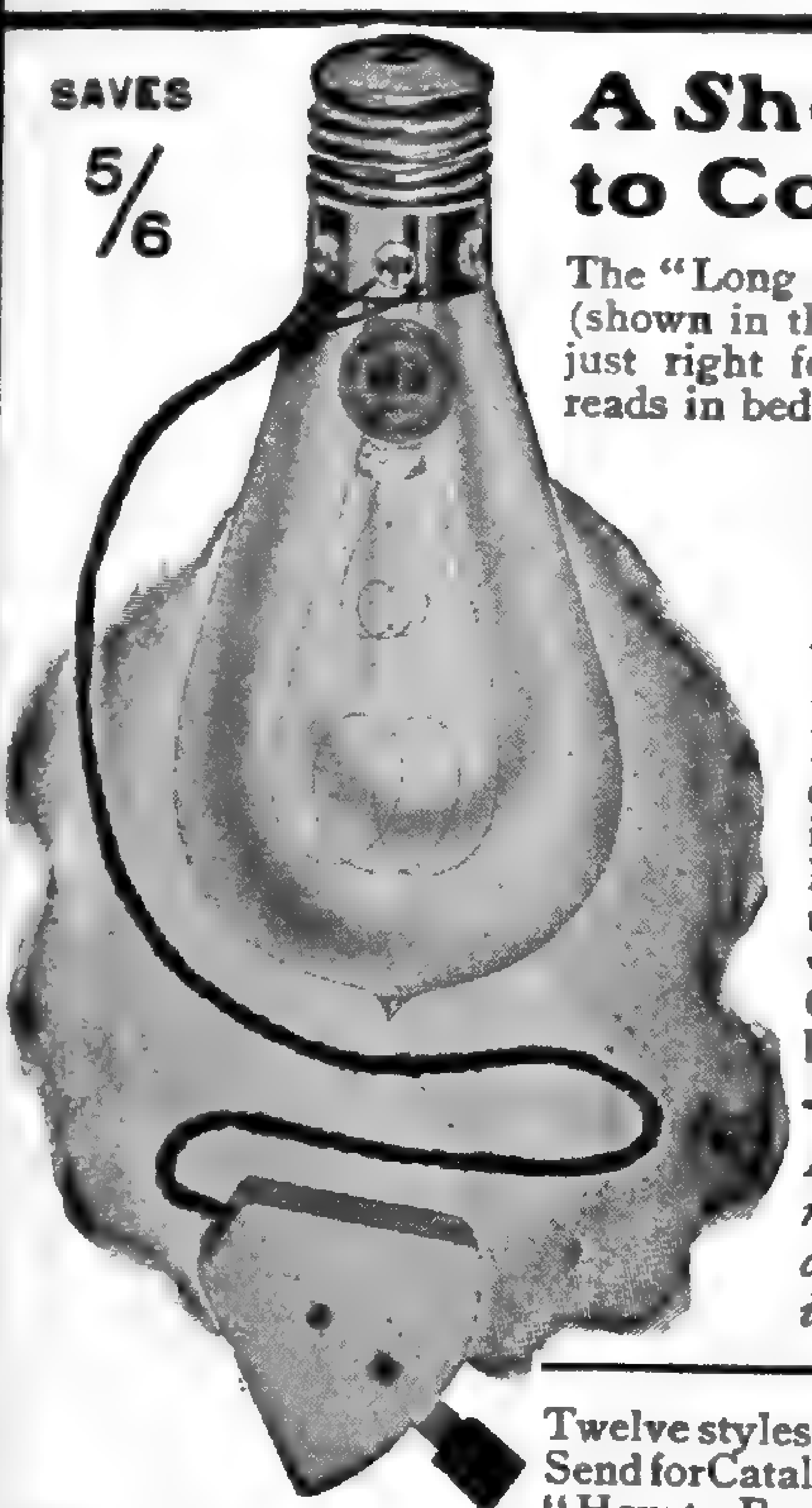


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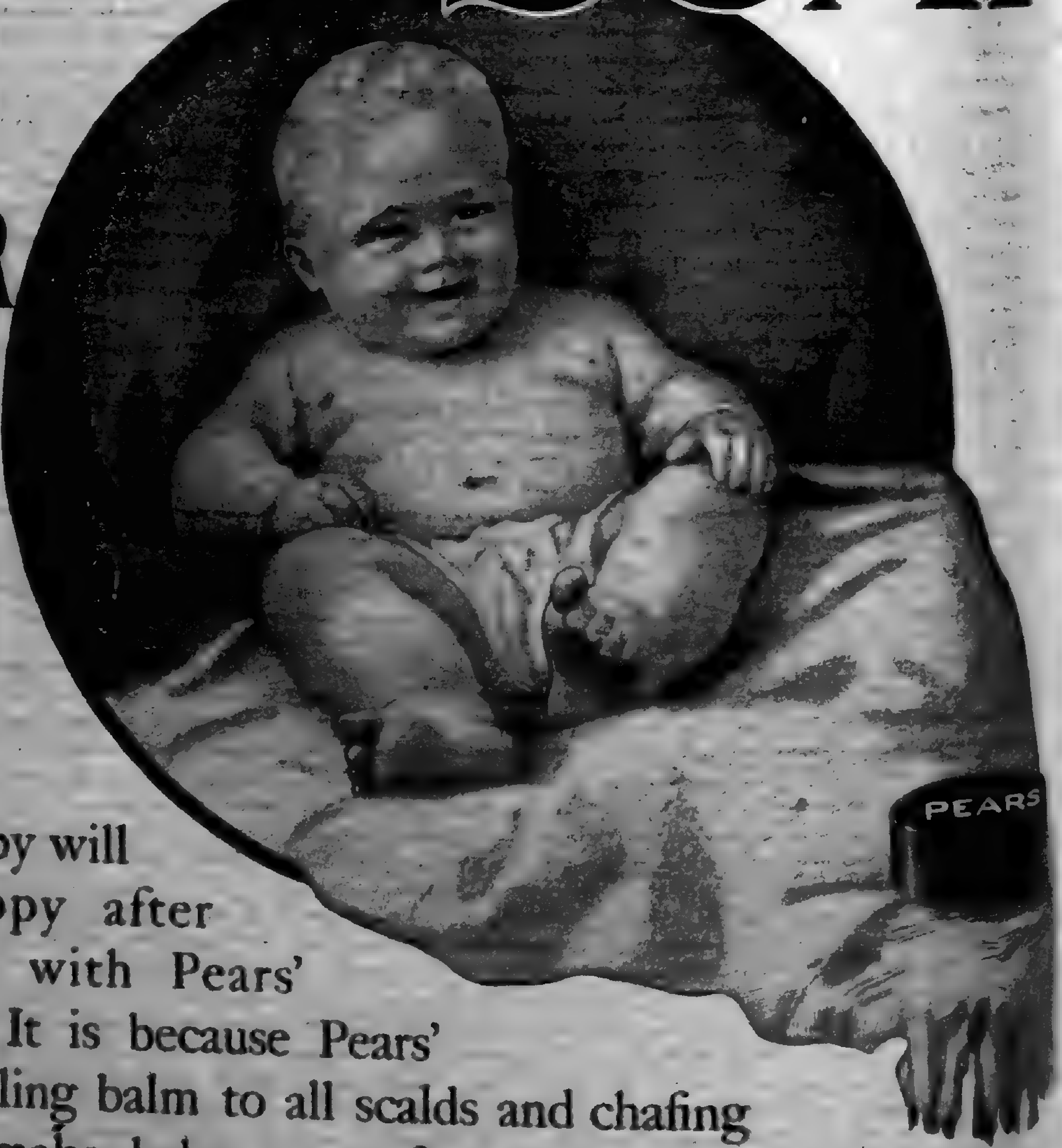

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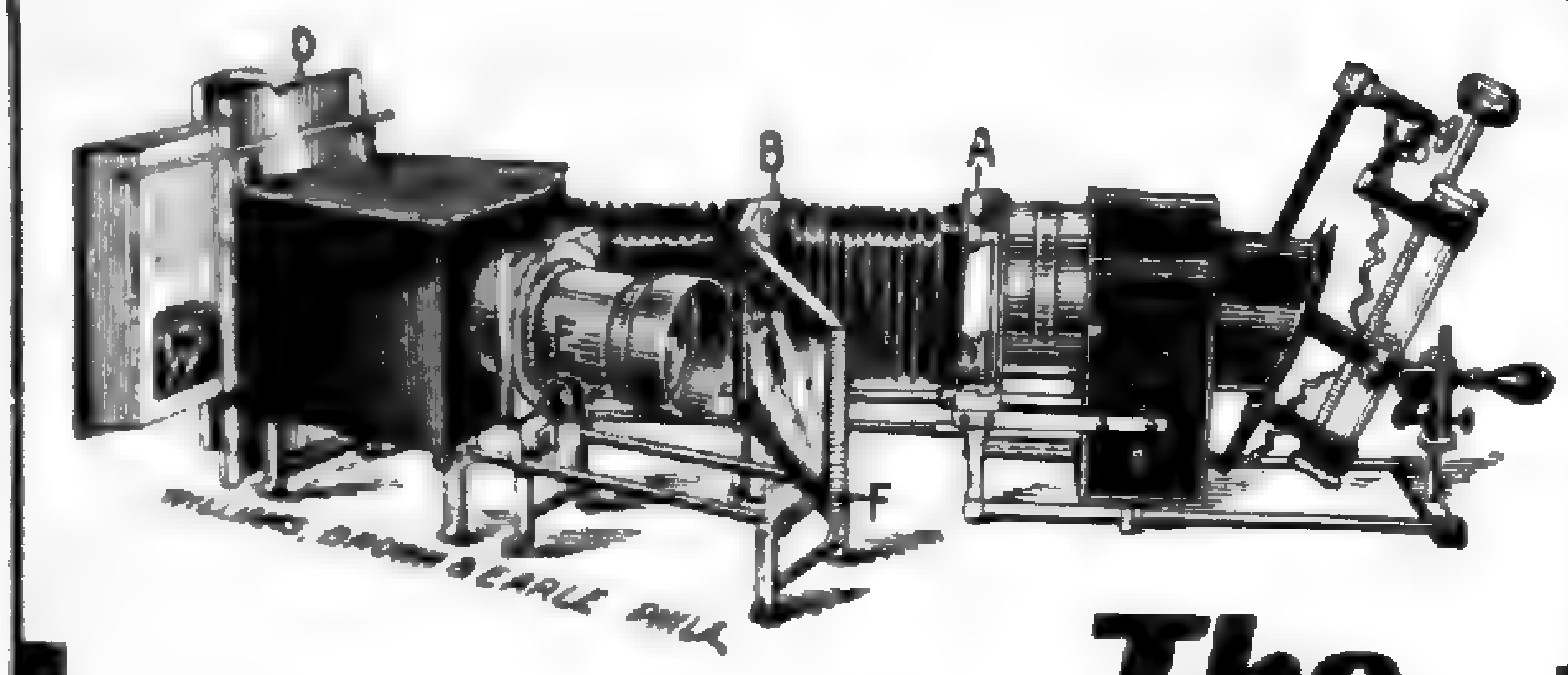

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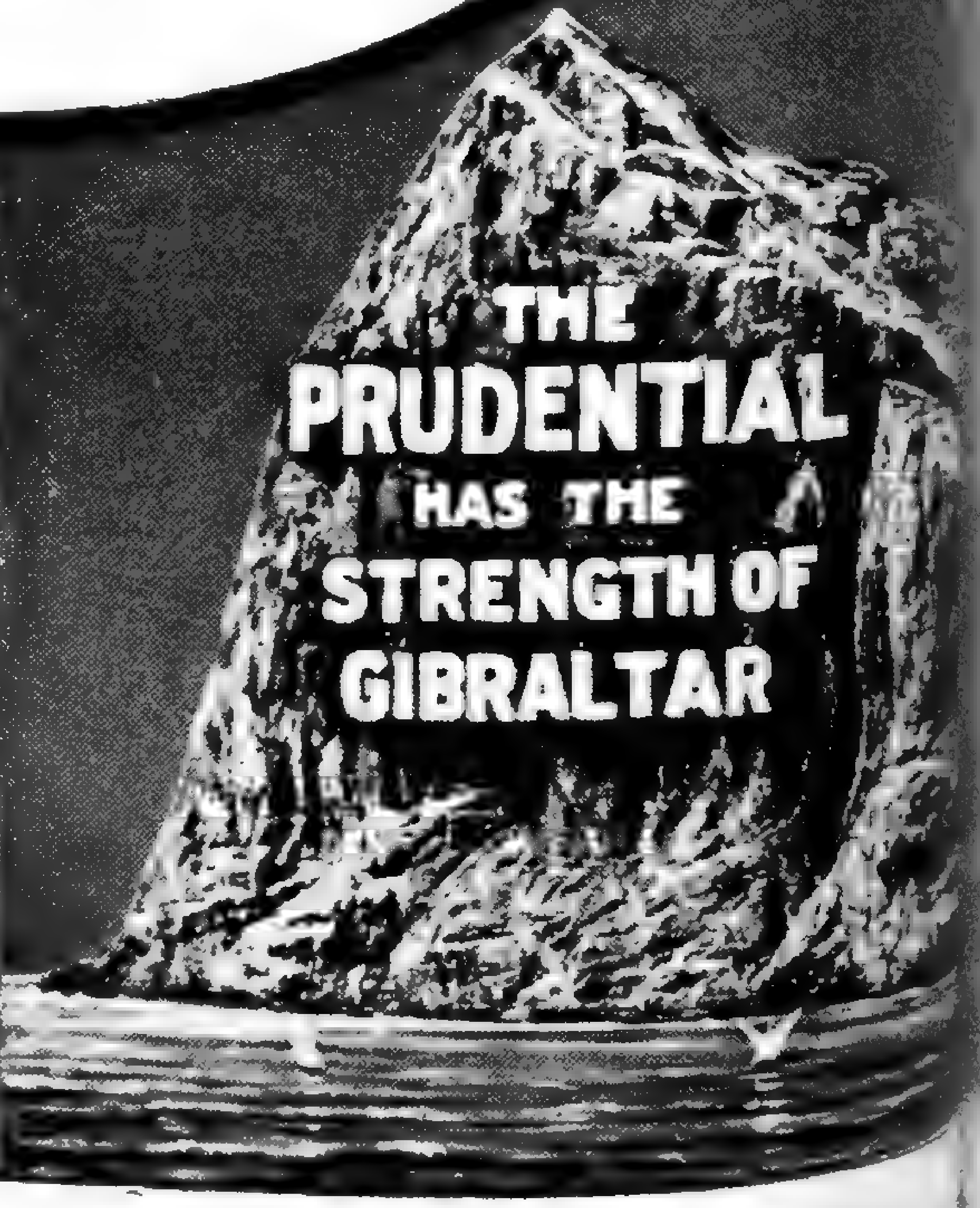
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BOTANICAL GAZETTE

AUGUST, 1905

SPOROGENESIS IN PALLAVICINIA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXV.

ANDREW C. MOORE.

(WITH PLATES III AND IV)

THE presence of a quadripolar spindle in the division of the spore mother cell of *Pallavicinia decipiens* was announced by **FARMER** in 1893, and in 1894 he published his detailed studies upon the same plant. The most remarkable feature of these papers is the significance which the author attributes to a quadripolar spindle as a means for the simultaneous distribution of the chromatin to the four daughter cells which become the spores.

According to **FARMER'S** account (**5, 6**), the structure in question is developed quite early, before any evidence of approaching division is visible in the nucleus. Later the nucleus becomes lobed, and finally four chromosomes make their appearance. The number is increased by division to eight, which point off in pairs to the four lobes of the spore mother cell. "A further doubling of the chromosomes occurs, so that four of these bodies . . . . go to form the nucleus in each spore. The whole process is very much crowded up, the four-rayed spindle persisting to the end; and even after the exodus of the chromosomes, traces of it can still be seen converging to the original center."

The presence of a quadripolar spindle is of itself not surprising, since tripolar, quadripolar, and multipolar spindles have been frequently described by various authors; but in every case these structures represent early stages in the development of the achromatic figure and later become normal bipolar spindles. The peculiar interest attaching to the structure described by FARMER is the reported distribution of the chromatin simultaneously to the four daughter nuclei. If his observations and his interpretation of the spindle are correct, Pallavicinia occupies a unique position among plants and animals.

FARMER (7) sought through a study of other liverworts to throw further light on this subject. He found the quadripolar spindle present in *Aneura pinguis, A. multifida, Scapania undulata,* Fossombronia, and in other types of the Jungermanniales, but in no case did he find it persisting and functioning, as in Pallavicinia, in the simultaneous distribution of the chromatin. In these forms, according to his interpretation, the ends of the quadripolar spindle fuse in pairs and the distribution of chromatin takes place in the usual manner through two successive mitoses. While not directly confirming his results on Pallavicinia, FARMER thinks the conditions found in these plants strengthen his position. He regards them as representing transitional stages between the normal type of division and the very unusual type which he reports in Pallavicinia. CAMPBELL (1) and other authors generally have accepted FARMER'S account.

DAVIS (4) from an investigation of Pellia was led to question FARMER'S conclusions. He regards the quadripolar spindle as a condition of prophase, and believes that it is always followed by two successive mitoses after the usual manner in the spore mother cell, each with a normal bipolar spindle. FARMER (8) is not willing to exclude the four-rayed figure from the spindle apparatus or to employ the term spindle in the restricted sense of DAVIS; but the main features of the discussion are not the questions as to when the achromatic structure becomes a spindle and as to the limitation of this term as a matter of usage—points upon which authors may readily disagree. The fundamental differences between the views of DAVIS and FARMER lie in the history of the quadripolar spindle, and the method by which the chromatin in the spore mother cell is distributed to the four spores. FARMER positively asserts that the quadripolar spindle retains its form and that the chromatin is distributed simultaneously to the four daughter nuclei. DAVIS believes that the quadripolar spindle is a condition of prophase which is followed by two successive mitoses, each with bipolar spindles, by which the chromatin is distributed in the usual way within the spore mother cell. Apart from the rapidity of the two mitoses and the prominence of a four-rayed achromatic figure in the prophase of the first, the latter author holds that there is no essential difference between the processes of sporogenesis in Pallavicinia and in other liverworts and higher plants. DAVIS (**4a**) further maintains these opinions in his recent review of the events of nuclear division within the spore mother cell.

In view of the unusual character of FARMER'S results and of the fact that doubt has been expressed as to the accuracy of his observations and their interpretation, I have undertaken an investigation of *Pallavicinia Lyellii*, believing that evidence obtained from the study of another species of the same genus would help in clearing up the disputed points. Some of my results (**15**) have already been published, and they do not confirm FARMER in his main contention, namely, the simultaneous distribution of the chromatin.

Pallavicinia Lyellii is a cosmopolitan species which I have found growing abundantly near Columbia, S. C., and in the vicinity of Woods Holl, Mass. The young sporophytes make their appearance in the early fall and mature about the first of April. The material was fixed in chromo-acetic acid and stained with saffranin and gentian violet alone, or in the triple combination of saffranin, gentian violet, and orange G. Iron-alum haematoxylin was also used after the method of Haidenhain. Upon the whole the last-named stain has given the best results. The fibrillar structures are not so well brought out by it as by the gentian violet, but the chromosomes are much more clearly differentiated.

The spherical resting nucleus occupies a central position in the distinctly four lobed spore mother cell. It enlarges considerably preparatory to division and becomes somewhat angular, extending into the lobes of the spore mother cell. At the period of synapsis the nucleolus is conspicuous for its size and prominence (*fig. 1*), as is also the confused tangle of chromatic threads. The spore mother cell is not so deeply lobed as FARMER (**8**) figures for *Pallavicinia decipiens*, and DAVIS (**4**) and CHAMBERLAIN (**2**) for Pellia.

FARMER did not observe the spirem of *Pallavicinia decipiens*. In *P. Lyellii* it is exceedingly well-developed, and immediately after synapsis is observed as a very definite linin thread in which deeply staining chromatic droplets (*fig. 2*) occur at intervals. This spirem is loosely wound in many convolutions through the nuclear area and shows no signs of fine anastomosing filaments uniting its parts. The nucleolus is not so conspicuous as in the preceding stages of synapsis.

The spirem thread shortens and thickens and the chromatin granules become larger and less numerous (*fig. 3*). This process continues until the length of the whole thread is not more than that of the circumference of the nucleus, though it does not always occupy a peripheral position. During the latter part of this shortening process, there is a crumpling of the thread and a crowding together of its chromatin granules. This condition is of comparatively short duration and it is at this point that I observed the first evidence of a double thread (*figs. 4* and *5*).

The thread presently segments into eight chromosomes which lie scattered about in the nucleus in the form of a ring. These eight chromosomes are irregular in shape and frequently show with great clearness that they are not homogeneous masses, but made up of individual parts. I was at first in much doubt as to the number of parts, but subsequent study has convinced me that there are four, and that we are dealing here with tetrads. FARMER (**7**) shows very clearly by his figures of Fossombronia that he saw a similar arrangement. He says "sometimes four such aggregations could be seen in each chromosome, but the number was not sufficiently constant to afford very secure ground for theorizing." However, he expresses the opinion that we have here a double longitudinal split, in which the chromosomes are already prepared for the two succeeding divisions.

The tetrads are clearly shown in *fig. 8*. The appearance of several of the eight chromatic masses suggests very strongly that they are made up of four parts, while the evidence presented by the one in the center is conclusive. Here there is present the ring form, and the four elements of the tetrad are quite distinct. Several of the forms assumed by the tetrads are illustrated in *fig. 10*, viz., crosses, Ys, Ts, and rings. The fourfold nature of the group is most clear in the ring form. In *fig. 10 a* the four daughter chromosomes of the tetrad are shown entirely separated from one another. *Fig. 11* illustrates another case where the daughter chromosomes of the tetrad are separated. In this figure the two groups are drawn in correct relative positions, the one showing an almost homogenous mass, the other four daughter chromosomes. The fourfold character of the chromatic masses is most evident immediately after the segmentation of the chromosomes. Very soon they become more compact, and while they continue to show irregularities in outline, up to the metaphase of mitosis, they are not so evidently composed of four elements. *Fig. 9* presents a stage somewhat later than *fig. 8*.

I have not been able to determine the origin of the tetrads with any certainty. *Fig. 6* would seem to indicate that the elements of the tetrads are formed previous to the segmentation of the spirem and that these in some way become properly grouped. The large number of chromatic elements, together with the differences in their size and shape in this figure, are no doubt to be correlated with the different degrees to which the aggregations have progressed in the formation of the tetrads. In *fig. 7* the number of masses has been reduced, their size is approximately uniform, and the time has almost arrived for the segmentation of the chromosomes. Until the origin of these tetrads can be made out definitely, it would be useless to theorize concerning them.

While the foregoing changes take place within the nucleus, the outer form of that body is altered. It becomes strongly lobed, often assuming a tetrahedral form, one angle projecting into each lobe of the spore mother cell. **Farmer** (**7**) describes a similar form in several of the Jungermanniales studied by him, and attributes it to a pull by the four centrosomes which he finds in the four lobes of the mother cell. In describing the process for Fossombronia he says "the nuclear wall is not broken, although it becomes greatly pulled out beneath each centrosphere, and thus the quadripolar spindle is so far a nuclear distortion."

While the tetrahedral form is perhaps the most usual at this stage, it is by no means the only one. Frequently there are more than four projections. Such a condition as is illustrated in *fig. 12* would require the assumption of more than four centrosomes. In many cases the lobes of the nucleus are rounded and do not indicate that they are caused by a pull upon the nuclear membrane (*fig. 3*). Besides, the membrane in sections can be seen to be wavy, showing that it is not under tension from a dynamic center. The lobing occurs long before fibrillar elements are visible, and if the assumption that fibers are the expression of lines of force be true, then such lines of force do not exist at this time, and hence the irregularities in the shape of the nucleus cannot be attributed to a pull by them. It would seem much more probable that they are due to an amoeboid movement of the nucleus. It is well known that the nucleus of certain cells possesses this power, and observers have noted the phenomenon in living cells. It has also been noted that there is in a measure a correspondence between the shape of the nucleus and that of the cell to which it belongs. When the cell is much attenuated the nucleus is greatly elongated. In *fig. 28* is shown a resting nucleus from an elater of Pallavicinia. Miss MERRIMAN (**14**) discusses this question in relation to the differentiation of tissues from the meristem in the root tips of Allium and attributes to the nucleus the power of amoeboid motion. KORSCHELT (**12**) describes in the egg of the water beetle Dytiscus a nucleus with pseudopodia-like processes extending out into a mass of granular food particles.

As previously stated, the resting nucleus of the already deeply lobed spore mother cell is spherical. In preparation for division the great changes which take place in its size and in the character of its contents must be connected with great metabolic changes going on within it. The materials necessary for the supply of this demand must come from the cytoplasm, which in this case consists of four masses occupying the four lobes of the spore mother cell, and the reaching out of the nucleus for food might tend to produce a tetrahedral form.

According to FARMER the quadripolar spindle was the first evidence of approaching division. He says the first evidence noted in the nucleus itself was the collection of four chromatic droplets in the center at a time subsequent to the appearance of the four-rayed structure. In *Pallavicinia Lyellii*, as has already been pointed out, the changes which take place in the nucleus itself indicate approaching division before any structure makes its appearance which could be interpreted as a quadripolar spindle.

Farmer does not discuss the origin of the achromatic spindle, evidently regarding that as a matter of minor importance as compared with its later behavior in his account of the simultaneous distribution of the chromatin. The study of the origin and development of the achromatic structure of *Pallavicinia Lyellii* is attended with considerable difficulties, owing to the large number of chloroplasts in the cell. However, it seems to conform in general to the type described by Davis (**4**) for the corresponding phase of Pellia. He finds that kinoplasmic caps form over the lobes of the nucleus and extend down over it, finally forming fibrillae which enter the nuclear area. In my preliminary note (**15**) I described a similar process for Pallavicinia. I found aggregations of kinoplasm at the angles of the nucleus, and out of this material fibers are formed, which extend down over the protruding portion of the nucleus. Farmer (**8**) has recognized in one of my figures representing this stage the same structure as his quadripolar spindle.

In *P. Lyellii* this structure is never so prominent as that described by Farmer, but his figures do not distinguish clearly the spindle fibers from the nucleus. My preparations show a decided lobing of the nucleus, but with very slight indications of differentiated fibrillar protoplasm over the lobes. I find no astral rays and no evidence whatever of the existence of centrospheres or centrosomes. Davis (**4**), Chamberlain (**2**), and Grégoire and Wygaerts (**9**) find asters and kinoplasmic caps well developed in other periods of ontogeny, but do not find them so prominent, if at all, in the spore mother cell. Farmer indeed does not mention the presence of asters in Pallavicinia, nor does he figure them. Davis (**3**) in his investigation of Anthoceros was the first to question the presence of centrosomes in the spore mother cell of liverworts. My studies lead me to hold similar doubts and to believe with him that the spindle fibers in the spore mother cells of liverworts develop independently of centrosomes, so that multipolar stages in spindle formation may be expected, as Osterhout, Mottier, and Juel established in 1897 in the pteridophytes and spermatophytes.

Chamberlain (**2**), who studied the germinating spore of Pellia with special reference to the centrosome problem, describes a peculiar structure in the form of a vesicle fitting over the end of the nucleus, and in this he is confirmed by GRÉGOIRE and WYGAERTS (**9**). This vesicle, which he interprets as a *Hautschicht*, resolves itself into fibers and furnishes at least a part of the material for the spindle. I do not find such a vesicle separate and distinct from the nuclear membrane, but I find strong evidence that the nuclear membrane itself becomes resolved into fibers. This view is quite compatible with the generally accepted theory of the nature of a plasma membrane, and the evidence is presented by such appearances as are shown in *figs. 12–14*. In *fig. 12* we have a nucleus which in one plane shows a number of prominent lobes. A few fibers are visible over one lobe, and at several other places the nuclear cavity is apparently bounded by a weft of fibers. These are either derived from a layer of kinoplasm which closely invests the nucleus or from the nuclear membrane itself. The fact that the nuclear membrane disappears as these fibers come into view would lend force to the latter supposition. In *fig. 13* fibers are shown over one lobe of a nucleus which is very much elongated, and in *fig. 14* they may be seen at both ends of a similarly elongated nucleus. In the latter case the nuclear membrane persists in several places, seeming to merge gradually into the fibrillar condition. The fibers appear to conform to the irregularities of the surface, giving strong indications that they are derived from the nuclear membrane.

HARPER (**10**) has shown a close relation between membranes and fibers in Erysiphe, where, in free spore formation in the ascus, the fibers which mark out the boundary of the future spore fuse side by side to form a plasma membrane. The nuclear membrane is generally believed to be of kinoplasmic origin, and so are the fibers of the achromatic spindle. Evidently then, the transition from the one to the other may be easily accomplished.

Soon after the appearance of the first fibers, the number is greatly increased, but I have not been able to determine the origin of the remainder. The completed spindle is bipolar, and may be pointed (*fig. 15*) or blunt (*fig. 16*). The ends may terminate near or at a distance from the cell wall. It happens frequently that one end extends into a lobe of the spore mother cell, and the other abuts on the infolded wall between the two adjacent lobes which stand opposed to it, thus producing a very much flattened pole or even a forked one (*fig. 16*).

At the completion of the achromatic spindle, the chromosomes are found grouped in a ring at the equatorial region of the structure. *Figs. 8* and *9* show the arrangement of the chromosomes at this stage. *Fig. 15* gives a side view, slightly oblique, of the chromosomes at metaphase of mitosis. Five chromosomes are in view and the other three are hidden or have been removed by the razor in making the section.

I have not been able to make out satisfactorily the details of the separation of the daughter chromosomes. The distribution is effected very quickly, for great numbers of nuclei in metaphase have been observed and a great many in telophase, but very few in anaphase. Little indication is given as to the exact manner in which the separation takes place. A few instances of chromosomes as they are pulled apart are shown in *fig. 17*. The appearance of the chromosomes indicates beyond doubt that they are plastic bodies subjected to a pull, and that they are being halved; but what real relation this distribution bears to the original tetrads is left in doubt. In *fig. 18* we have shown anaphase in which the chromosomes are somewhat scattered upon a very broad spindle. There are five near each pole and one almost half way between. It is evident that the remaining chromosomes are upon another section.

During telophase the chromosomes are found arranged in compact rings at the two poles. When one end of a spindle abuts on a dividing wall between two lobes, the ring at that end sometimes lies very close to this wall, partially surrounding it (*fig. 19*).

There is no resting stage between the first and second mitoses. The chromatic elements of the nucleus do not resolve themselves into a reticulum and the chromosomes do not lose their individuality. The rings of chromosomes which have been formed at the telophase of the first division merely alter their positions, so that their planes lie at right angles to one another. It is evident from *fig. 20* that the chromosomes come in contact and form a thick spirem, but do not lose their identity. This is the nearest approach to a resting stage I have been able to find, and I believe it is unusual for the reconstruction of the nucleus to proceed even this far. No nuclear membrane is formed at the end of the first mitosis and no cell plate is laid down. In a few instances granules were seen across the equatorial portion and in this he is confirmed by GRÉGOIRE and WYGAERTS (**9**). This vesicle, which he interprets as a *Hautschicht*, resolves itself into fibers and furnishes at least a part of the material for the spindle. I do not find such a vesicle separate and distinct from the nuclear membrane, but I find strong evidence that the nuclear membrane itself becomes resolved into fibers. This view is quite compatible with the generally accepted theory of the nature of a plasma membrane, and the evidence is presented by such appearances as are shown in *figs. 12–14*. In *fig. 12* we have a nucleus which in one plane shows a number of prominent lobes. A few fibers are visible over one lobe, and at several other places the nuclear cavity is apparently bounded by a weft of fibers. These are either derived from a layer of kinoplasm which closely invests the nucleus or from the nuclear membrane itself. The fact that the nuclear membrane disappears as these fibers come into view would lend force to the latter supposition. In *fig. 13* fibers are shown over one lobe of a nucleus which is very much elongated, and in *fig. 14* they may be seen at both ends of a similarly elongated nucleus. In the latter case the nuclear membrane persists in several places, seeming to merge gradually into the fibrillar condition. The fibers appear to conform to the irregularities of the surface, giving strong indications that they are derived from the nuclear membrane.

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That the second mitosis succeeds the first very closely is attested by the fact that examples of both divisions are frequently found in the same capsule. The spore mother cells of a given capsule are in division at the same time, though not exactly in the same phase of mitosis. Occasionally cells are found which lag considerably behind or precede the majority in division. Such cases are of great value in determining stages with certainty.

The spindles for the second mitosis make their appearance very suddenly, and I have not been able to determine their origin. They are quite strongly developed, and as a rule are longer and narrower than the spindles of the first mitosis. The passage from the metaphase to the telophase is almost as rapid as in the first division, and no additional evidence is afforded as to the manner in which the chromosomes separate. *Fig. 21* illustrates metaphase of the two spindles, showing a polar and a side view. In this example the poles of the spindles are sharply pointed. In *fig. 22*, which represents an anaphase, the poles are blunt. The chromosomes pass rapidly to the poles and are grouped at the two ends in rings (*figs. 23* and *24*). At this stage the fibers are very prominent in transverse sections of the spindle (*fig. 24*).

Soon after the chromosomes have passed to the poles, granules make their appearance upon the equatorial region of the spindle (*fig. 24*). These become divided and a cell plate is laid down between them (*fig. 25*). Meanwhile the nuclear membrane is formed and the chromatic elements pass over into the reticulum characteristic of the resting state.

Finally, the new cell plates unite with the folded walls between the lobes and the separation of the spores is complete (*fig. 26*). The contiguous walls split apart and the spores become free. They next increase in size, becoming almost spherical, and the wall thickens and is finally marked with delicate points (*fig. 27*).

The spores do not germinate in the capsule as do the spores of Pellia. Soon after being shed, they increase greatly in size, stretching the wall, as is clearly shown by the separation of the points upon its surface. After the cell has attained a size several times that of the original spore, the first mitosis of the gametophyte generation takes place.

I have not been able to contribute much to a knowledge of the behavior of the nucleolus. It stains like the chromosomes most of the time, and when the latter are differentiated it becomes difficult to identify the nucleolus with certainty. During synapsis the nucleolus is a very large and conspicuous body (*fig. 1*). It is not so large during the later spirem stages, but still quite prominent (*figs. 2* and *3*). At the time the spirem is ready to segment, the nucleolus shows a slight difference in staining reaction from the chromosomes. With the saffranin and gentian violet combination it takes slightly more gentian violet, and with the iron-alum haematoxylin it stains less intensely than the chromosomes. At this time it shows signs of fragmentation (*figs. 6* and *9*).

Various theories regarding the constitution of the nucleolus have been advanced: one that it is achromatic and contributes to the formation of the spindle; another that it is chromatic and contributes to the formation of the chromosomes. **WAGER** (**18**) in a recent paper attributes to it important functions in the organization of the chromosomes and in the transmission of the hereditary substance. Its staining reactions would seem to ally it more closely with the chromatic elements of the cell. If the nucleolus plays a part in the formation of the achromatic spindle in the first division of Pallavicinia, it certainly does not in the second, since there is no reconstruction of the nucleus and the nucleolus is not reformed. Upon the whole the evidence, though by no means conclusive, indicates that the nucleolus in Pallavicinia may be regarded as contributing to the chromatin.

FARMER (**6**) states that there are four chromosomes in *Pallavicinia decipiens*. In *P. Lyellii* I find eight as the reduced number in the spore. The count is very easily made when a polar view is obtained, and the compact form of the chromosomes makes the task an easy one. The chromosomes are in most favorable position for counting when viewed from the poles during metaphase and early telophase, as the figures clearly show (*figs. 8, 9, 21, 23*).

In *fig. 23* it will be observed that there are nine chromosomes in one group. It is possible that the sister group would show only seven. In the same figure, upon the conspicuous spindle which is cut longitudinally it is uncertain to which group the chromosome lying near the middle belongs. *Fig. 18* shows that the chromosomes do not always pass simultaneously to the poles, and it is possible that the distribution is not always equal. I have frequently been able to count only seven chromosomes in a group, but such evidence is uncertain, since there is always the possibility that one has been removed by the razor in making the section. In case the number exceeds eight the difficulties are fully as great, since there is always the possibility of a tetrad being broken apart. It is true that in such an example the size of the bodies is some check, but still there is great uncertainty. Also the nucleolus, which as has been stated stains as the chromosomes, is to be reckoned with, if the count is made at a stage when that body is present. However, I believe that while the number of the chromosomes is normally eight, occasionally a variation from this number will be met, due no doubt to an unequal distribution during division.

The number of chromosomes in the sporophyte is undoubtedly sixteen, though I have not made an actual count. *Figs. 29* and *30* represent the two parts into which a single cell of the seta has been cut. It will be observed that the spirem is just segmenting into the elongated chromosomes; two nucleoli are still visible (*fig. 29*). The count cannot be made with absolute certainty, but the number is approximately sixteen. *Fig. 31* shows one section of an early telophase from a cell of the seta. There are seven and eight chromosomes at the respective poles. The other section of the same cell shows about the same number of chromosomes in each group, but the masses are too confused to admit of an accurate count. I have observed figures in dividing spermatogenous cells, and here also the number of chromosomes is without doubt sixteen.

It seems desirable to point out that my final conclusions agree in all essentials with my preliminary paper of 1903, and are in conflict with **FARMER'S** views in the fundamental feature of his account of Pallavicinia—the simultaneous distribution of the chromatin to the four daughter nuclei through a quadripolar spindle. It is perfectly clear from my studies that the chromosomes in *Pallavicinia Lyellii* are distributed by two successive mitoses, each with well-defined bipolar spindles, and that the chromosomes are organized as tetrads just before the first mitosis. The achromatic structure which corresponds to FARMER'S quadripolar spindle appears during the prophase of the first nuclear division, and is followed by clearly defined bipolar spindles of the two successive mitoses with no evidence of accompanying centrosomes. The events of sporogenesis in *Pallavicinia Lyellii* present then no fundamental differences from those of other liverworts and higher plants, the chief peculiarity being the rapidity with which the second mitosis follows the first.

SUMMARY.

1. The resting nucleus is spherical in shape and centrally situated in the spore mother cell. The spore mother cell is deeply four-lobed at an early period in its history.

2. During synapsis the nucleus, containing a large and conspicuous nucleolus and a contracted chromatic thread, enlarges and becomes irregularly lobed.

3. There is a distinct spirem stage in which a clear cut linin thread bears deeply staining chromatin granules. The thread shortens and thickens and at the same time the granules become larger and less numerous.

4. The first evidence of a double spirem is observed just previous to the segmentation of the thread.

5. The spirem segments into eight tetrads, which may be in the form of rings, Xs, Ys, Ts, or irregular masses.

6. While these changes are taking place within the nucleus, the membrane becomes strongly lobed. Frequently, though not always, the form of the nucleus is tetrahedral, the angles projecting into the respective lobes of the spore mother cell.

7. There is no direct evidence of centrosomes or centrospheres and the indirect evidence is against their presence.

8. The lobing of the nucleus is due to amoeboid motion in response to nutritive stimuli.

9. The achromatic spindle originates in kinoplasmic caps to which the nuclear membrane contributes material.

10. The distribution of the chromatin is effected through bipolar spindles in two successive mitoses.

11. There is no resting stage between the first and second mitoses.

12. The two bipolar spindles of the second mitosis are strongly developed and stand at right angles to each other.

13. After the second mitosis, cell plates are formed and the nuclei pass into a condition of rest in the usual manner.

14. The spores do not germinate in the capsule before its rupture, as do those of Pellia.

15. The nucleolus is more closely allied to the chromatic than to the achromatic material of the nucleus.

16. The number of chromosomes for the gametophyte is eight and for the sporophyte sixteen.

This investigation was conducted under the direction of Professor **Bradley M. Davis**, to whom I desire to acknowledge my indebtedness for valuable criticism and suggestion; as well as to Professor **John M. Coulter** and Dr. **Charles J. Chamberlain**.

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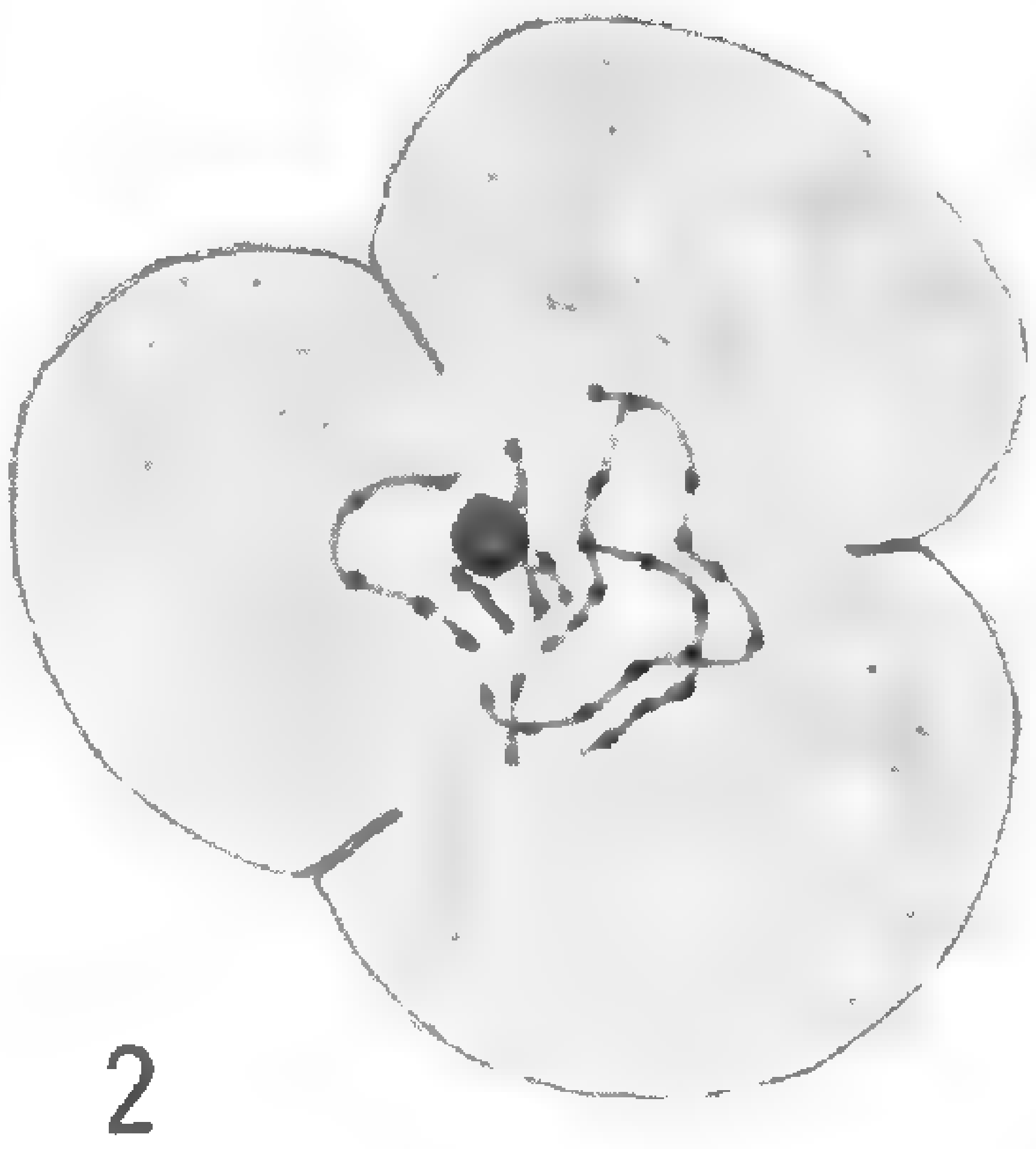
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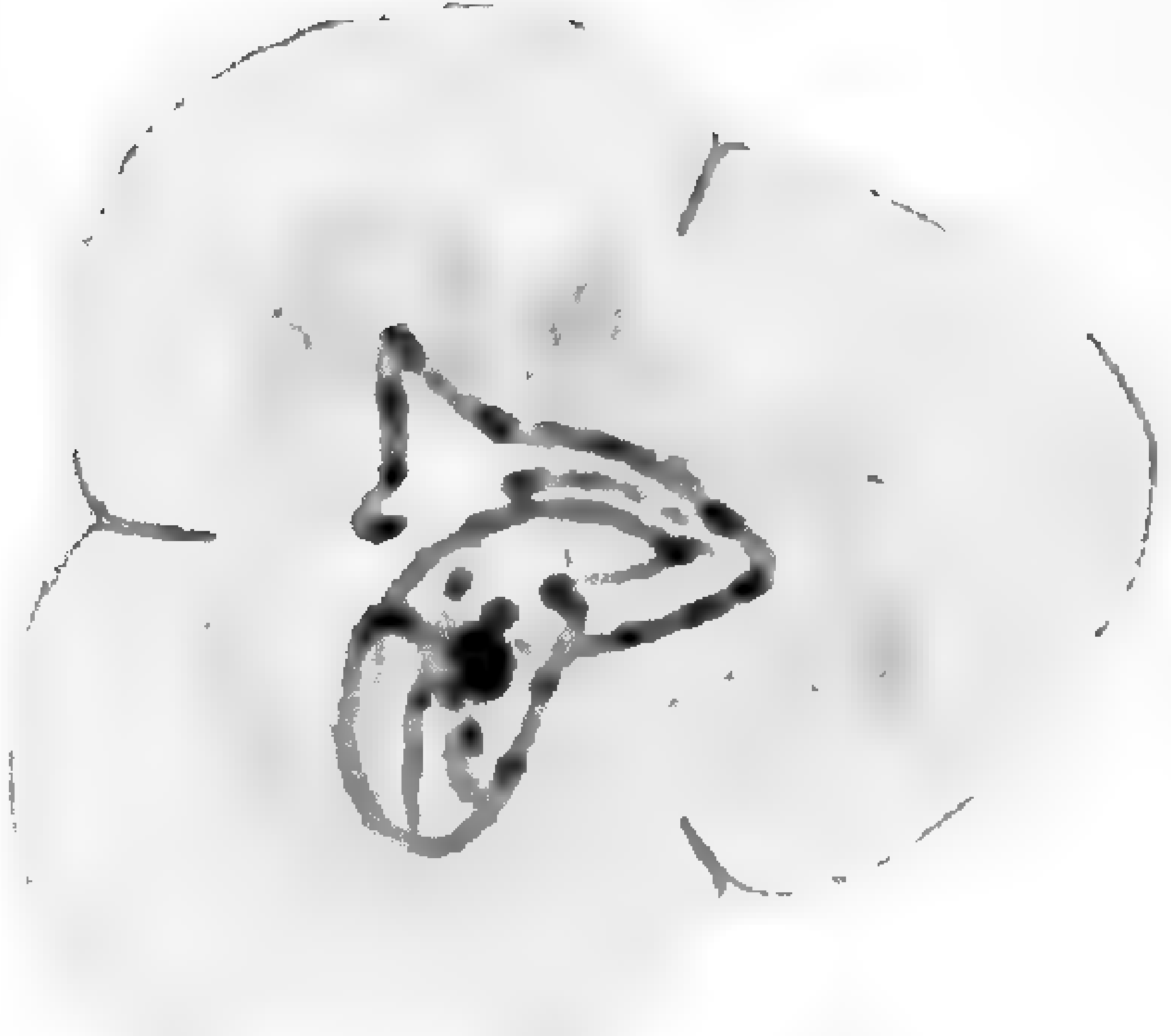
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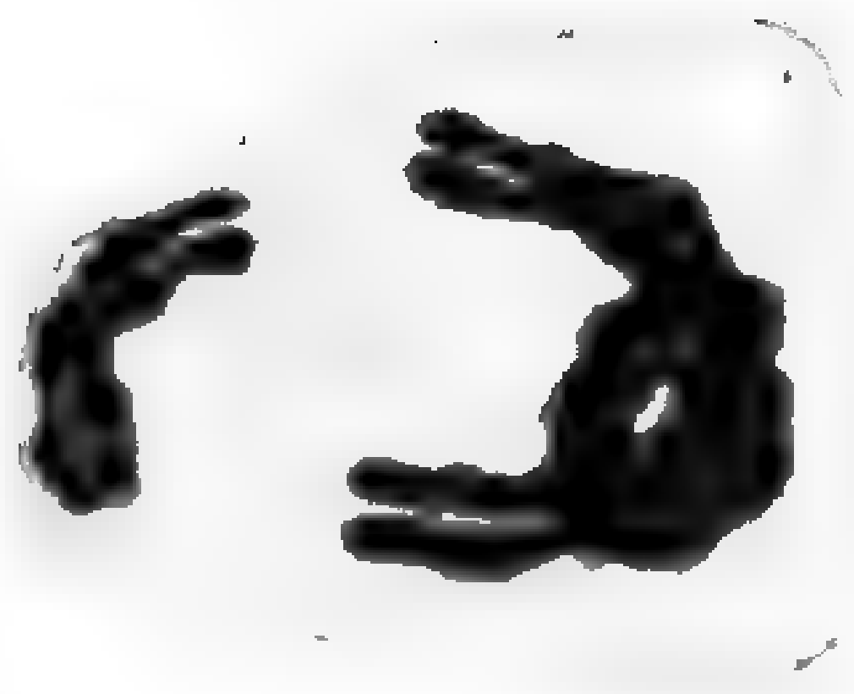
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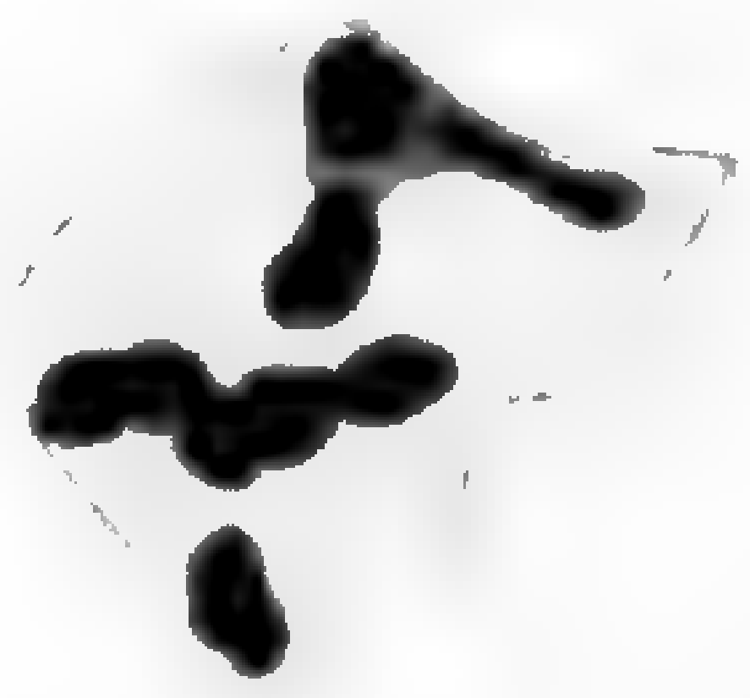
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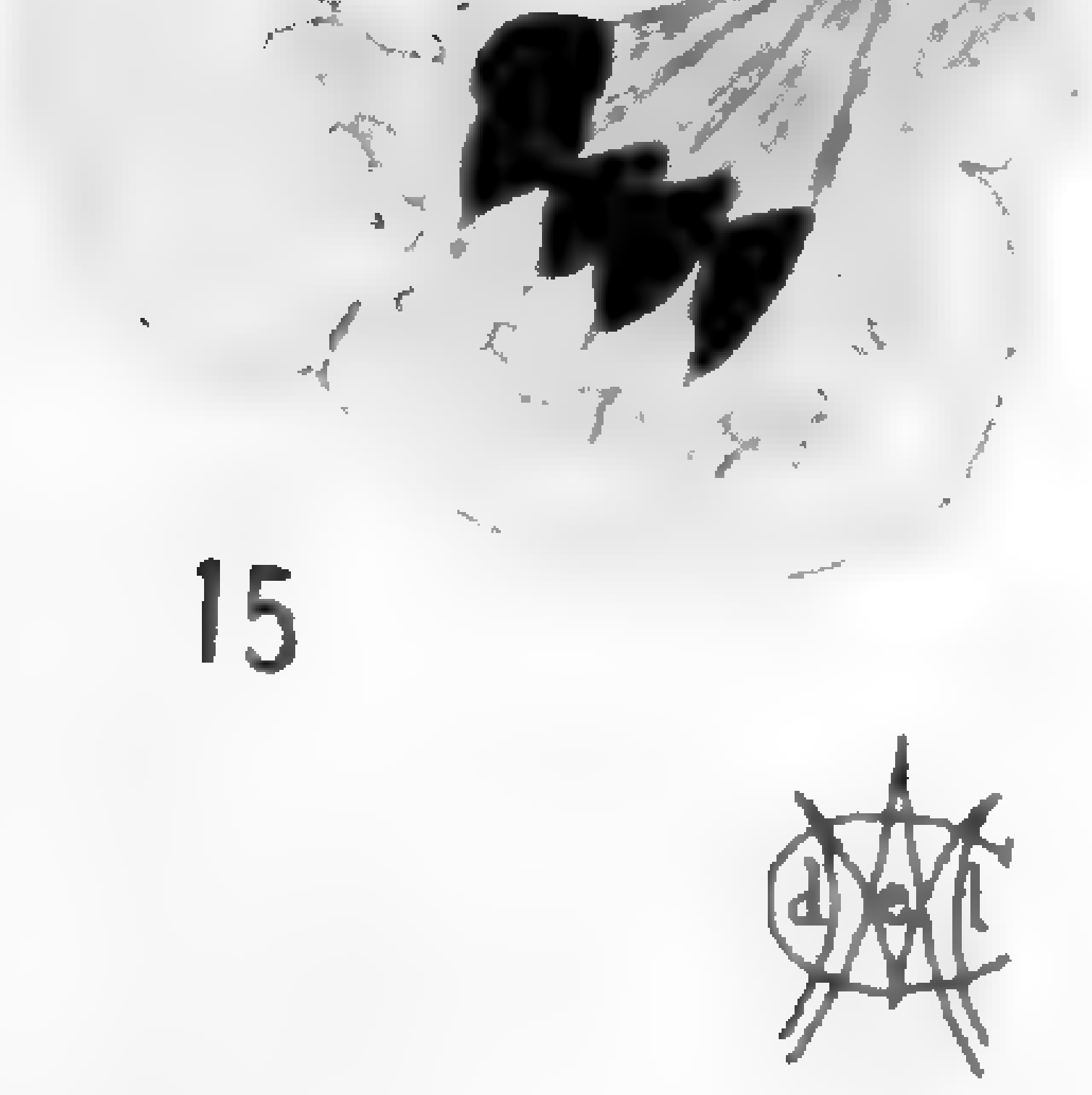
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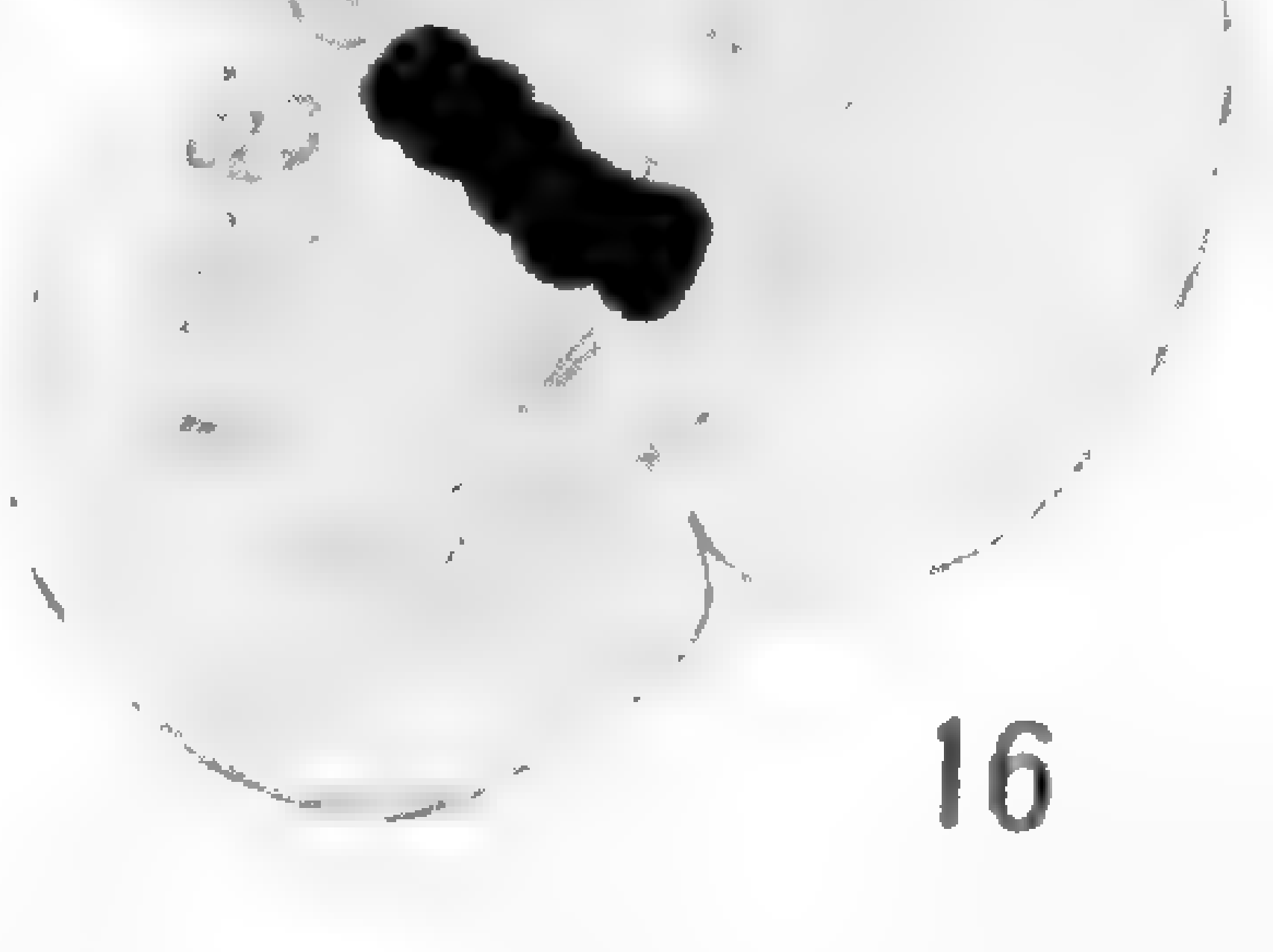
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MOORE on PALLAVICINIA

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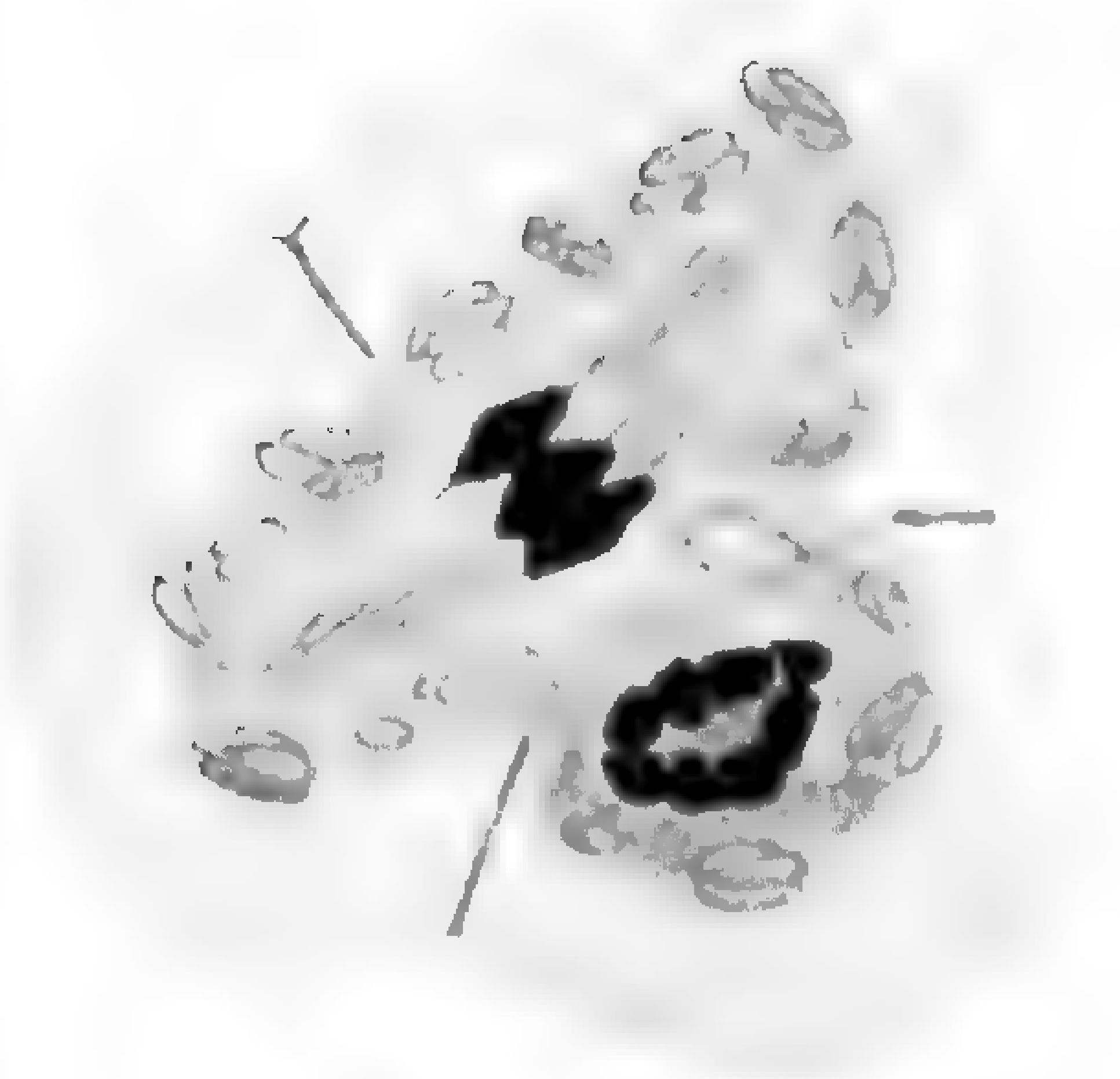

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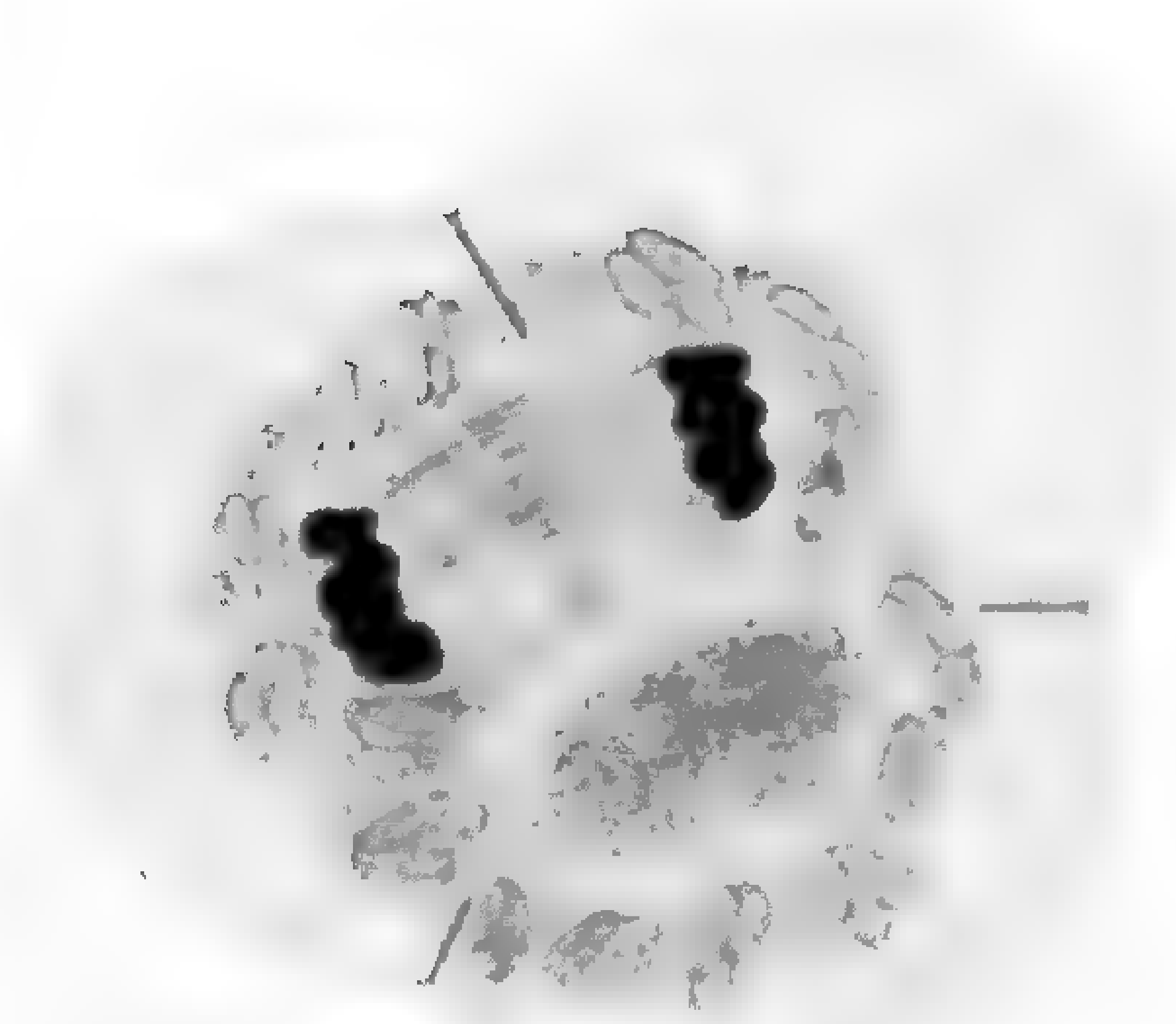

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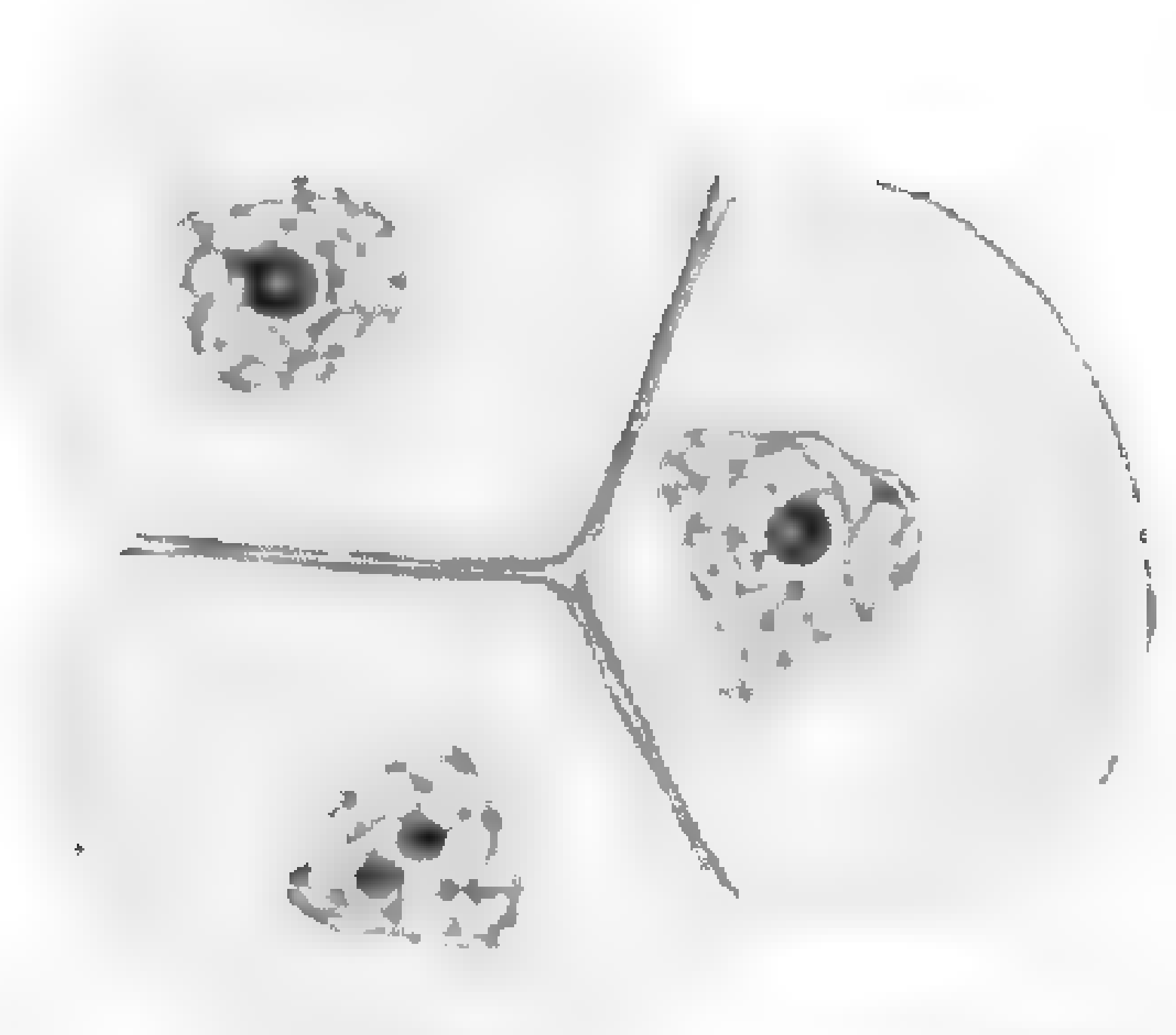

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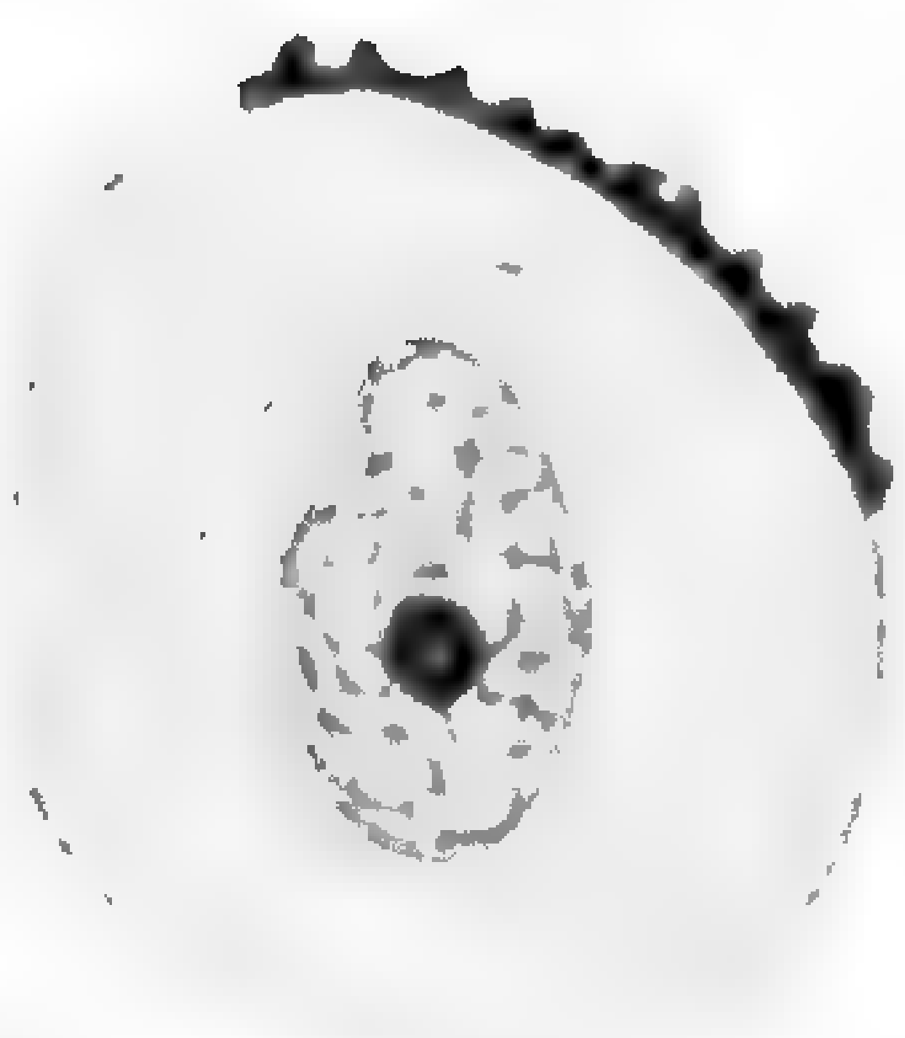

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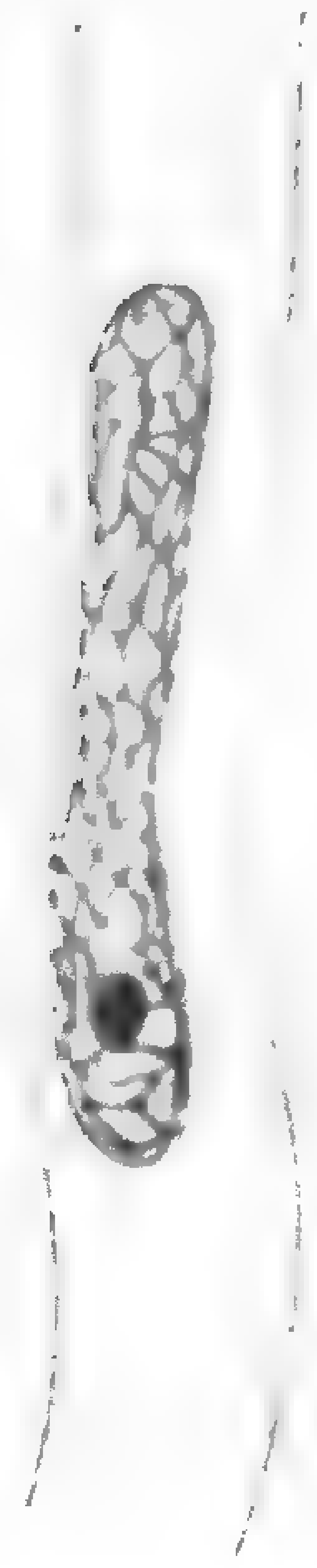

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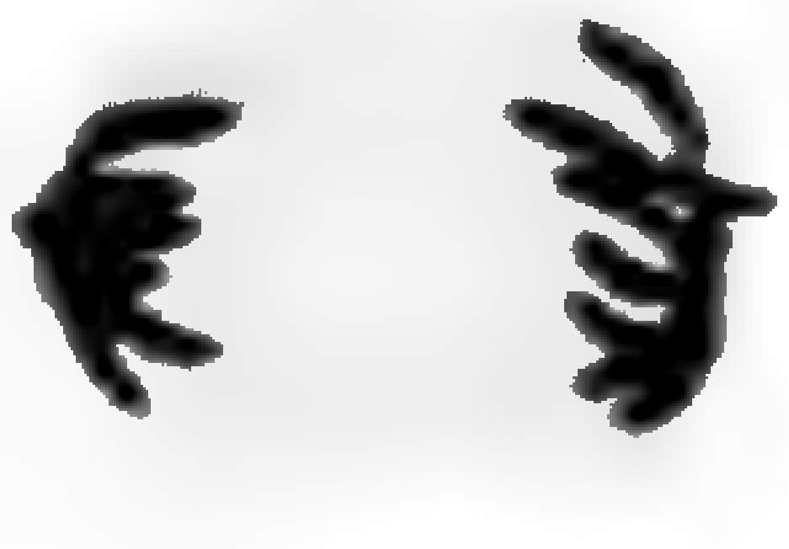

31

MOORE on PALLAVICINIA

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EXPLANATION OF PLATES III AND IV

All figures except *fig. 28* were made with a Zeiss 2^{mm} apochromatic objective and a no. 12 ocular. *Fig. 28* was made with the same objective, but with no. 8 ocular. A Bausch and Lomb camera lucida was used for all drawings. In *fig. 2* all the plastids of the cell are shown; in other cases only those immediately surrounding the nucleus.

FIG. 1. Enlarged nucleus of spore mother cell in early stage of preparation for division; the nucleolus is conspicuous and the appearance and arrangement of the chromatin indicate the condition of synapsis.

FIG. 2. Spirem condition, showing linin thread loosely wound with deeply staining chromatic droplets at intervals.

FIG. 3. Thicker and shorter spirem; chromatic droplets fewer and larger; lobes of nucleus distinctly rounded.

FIG. 4. Spirem further shortened; chromatic droplets crowded together; the thread appears double.

FIG. 5. Ends of spirem thread, showing that it is double.

FIG. 6. Aggregation of chromatic droplets just previous to segmentation of chromosomes; probably time of tetrad formation; the nucleolus seems to be fragmenting.

FIG. 7. Later stage than *fig. 6.*

FIG. 8. Equatorial plate stage, showing group of eight tetrads.

FIG. 9. Equatorial plate stage, later than *fig. 8;* tetrads not so clearly defined; nucleolus fragmenting.

FIG. 10. A group of selected tetrads, showing rings, crosses, Ys, and Ts; *a*, tetrad resolved into its elements.

FIG. 11. Neighboring tetrads of an equatorial plate; in one the fourfold character is clear, while in the other it is obscured.

FIG. 12. Prophase of first division; nucleus many-lobed; fibers over the largest lobe and at other places on the surface of the nucleus.

FIG. 13. Spindle organizing for first division; spindle fibers prominent on one end, approaching bipolar condition.

FIG. 14. Bipolar spindle of first division; nuclear membrane resolving into spindle fibers.

FIG. 15. Oblique side view, metaphase of first division; end of spindle pointed.

FIG. 16. Metaphase of first division, showing one very flat and one forked pole.

FIG. 17. Dividing chromosomes.

FIG. 18. Anaphase of first division, showing chromosomes scattered.

FIG. 19. Telophase of first division, showing grouping of chromosomes in rings at the poles.

FIG. 20. Beginning of reconstruction of daughter nuclei at completion of first division; the chromosomes do not lose their identity and no nuclear membrane is formed.

FIG. 21. Metaphase of second division, showing side view of one spindle and polar view of the other; in the side view the poles are seen to be pointed and in the polar view eight chromosomes appear.

FIG. 22. Anaphase of second division, showing blunt poles.

FIG. 23. Telophase of second division, showing nine chromosomes in the polar view of one of the spindles.

FIG. 24. Telophase of second division, showing beginning of cell plate in one spindle and transverse section of fibers in the other.

FIG. 25. Formation of cell plate.

FIG. 26. Completed spores with resting nuclei and separating walls.

FIG. 27. A single spore which has increased in size and has attained its thickened and roughened wall.

FIG. 28. Resting nucleus of elater.

FIG. 29. Segmenting spirem of cell from seta of sporophyte, showing nine chromosomes.

FIG. 30. Remainder of the same cell, showing seven additional chromosomes, making sixteen in all; chromosomes differ in shape from those of the dividing spore mother cell.

FIG. 31. Early telophase of cell from seta; only half of the cell is shown; there are eight chromosomes at one end and seven at the other; the neighboring section makes it evident that the total number is sixteen at each end.

REGENERATION IN PLANTS. I.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY.
LXXVI.

WILLIAM BURNETT MCCALLUM.

(WITH FOURTEEN FIGURES)

INTRODUCTION.

THE term regeneration has come to be used by most botanical writers with a broad and somewhat indefinite application. Its essential feature, however, is the replacement of an organ or structure that has been removed. This is accomplished in a variety of ways. PRANTL (**9**) first found and later SIMONS (**11**) determined more accurately that if the tip of a root be cut off not more than 0.75^{mm} from the end there is a complete restoration of the part removed, a new tip forming out of the tissues at the cut surface. GOEBEL (**3**, p. 503) has shown that if the young apex of the frond of Polypodium be cut in two lengthwise, the remaining embryonic tissue on each piece will completely reform the half that has been removed. The same is true of the growing point of a fern prothallium, although the older parts are not replaced. These phenomena are quite homologous with regeneration as it occurs in animals. If we cut off the root tip somewhat farther back, however, a new tip is not organized at the cut surface, but behind it one or perhaps more new root primordia are organized, and these take the place of the main root. Or if we cut off transversely a portion of the thallus of Marchantia or Lunularia (**12**), the tissues at the cut surface will not develop, but there will arise from apparently mature and differentiated cells back of the cut new outgrowths of thallus which again will complete the plant.

If the shoot with all the buds be severed from the root of Taraxacum, new shoots will arise lower down from the mature tissues of the cortex. Many fleshy roots have this capacity, and if cut into a number of pieces each will organize new primordia and develop shoots. If the young stem of Convolvulus, Linaria, and other plants (**6**) be cut off just below the cotyledons, there will arise on the surface of the hypocotyl outgrowths which develop into new shoots. These shoots also arise from mature cells which in the normal course of events remain as permanent tissue. Nor is this power of organizing new shoot primordia confined to the stems and roots, but is also possessed by many leaves, as in the well known cases of Begonia, Bryophyllum, *Cardamine pratensis*, *Tolmiea Menziesii*, and many other plants (*fig. 1*). Many stems, probably the majority, if removed from the root system and kept moist will produce new roots. In a few cases, as in Salix, there may exist on the stem primordia already organized, but in the great majority of stems these are not present. If a portion of the stem of Salix be cut out from the rest and kept moist, there will appear on it both roots and shoots, each arising, however, from buds already laid down. In the axils of the leaves of many annual shoots are very minute bud primordia, which normally do not develop. If the top of the plant be cut off, these at once form new shoots. In our trees and shrubs the buds formed in the leaf axils do not develop until the following year; but if at any time during the spring the tip of the young shoot be removed, a number of these buds, usually those near the top, at once develop shoots.

FIG. 1

We have in these cases at least three seemingly diverse phenomena: (1) the part removed is entirely restored by the growth of the cells immediately at the cut surface; (2) there is no growth of embryonic tissue at the wounded surface, but at a greater or less distance from it the organization of entirely new primordia which develop organs that replace those removed; (3) the organ removed, *e. g.*, the shoot, is restored by the development of already existing dormant buds. Between these no hard and fast lines can be drawn, for they all exhibit intergradations, and between the third case—the development of latent buds—and normal vegetative growth no sharp separation can be made, for occasionally in some species, *e. g.*, Salix, the axillary buds on the first year's growth instead of remaining dormant until the following spring will develop at once into shoots.

It will be quite apparent that as regeneration merges so insensibly into ordinary vegetative growth, the necessary limitations as to the use of the term must be entirely artificial. PFEFFER (**8**) restricts the term to those cases where an organ directly replaces that portion of itself that has been removed; all others he would call mere reproduction. GOEBEL, KLEBS, MORGAN, KÜSTER, and most other writers on the subject, give it a broader meaning, so as to include the replacement of parts or organs, whether by means of entirely new growths, or from the development of latent buds. The advantage in having some general expression to cover all these phenomena, and the fact mentioned by MORGAN, that they all accomplish the same result and are probably due to the same cause, make it a matter of convenience to use the term in its wider application.

A certain amount of confusion has arisen because it has not been kept clear that regeneration is not really different from ordinary vegetative growth. Most plants naturally tend to grow and branch indefinitely, the new members arising usually in definite places, the shoot primordia, for example, in the embryonic parts of the shoot, and the root primordia ordinarily in the younger regions of the root. The fact that this is the general rule has led to an unjustifiably rigid limitation of the origin of new members to specified regions. As a matter of fact, the ability to produce new members is distributed throughout the plant body, and in many even of the higher plants almost any part is able to produce any other vegetative part. Nor is this ability limited to embryonic parts, for in very many plants it is exercised by the older cells, as in the production of shoots on roots of Taraxacum or on leaves of Begonia. That certain conditions are necessary to bring this latent ability into activity does not make it in the least different from ordinary vegetative growth, for the latter also is dependent on definite conditions.

The whole plant body of mosses and liverworts, and many roots, stems, and leaves of the vascular plants have this capacity, and it requires only the proper conditions to become manifest.

In spite of the extensive investigations into this question, ranging as they have throughout the greater part of the plant kingdom, our knowledge of what these conditions are is very obscure. We know little enough of the external factors concerned and almost nothing at all definite about the internal ones. When a part of the plant body is removed, many factors are necessarily disturbed. The nutritive conditions may be profoundly altered, as also may be the water relation. The influence of the wound itself may be important, and independent of these the mere absence of the organ may in itself be of far reaching influence. How far any of these may be responsible for regeneration is not clear. Various theories have been proposed, but none have as yet been supported by adequate experimental evidence.

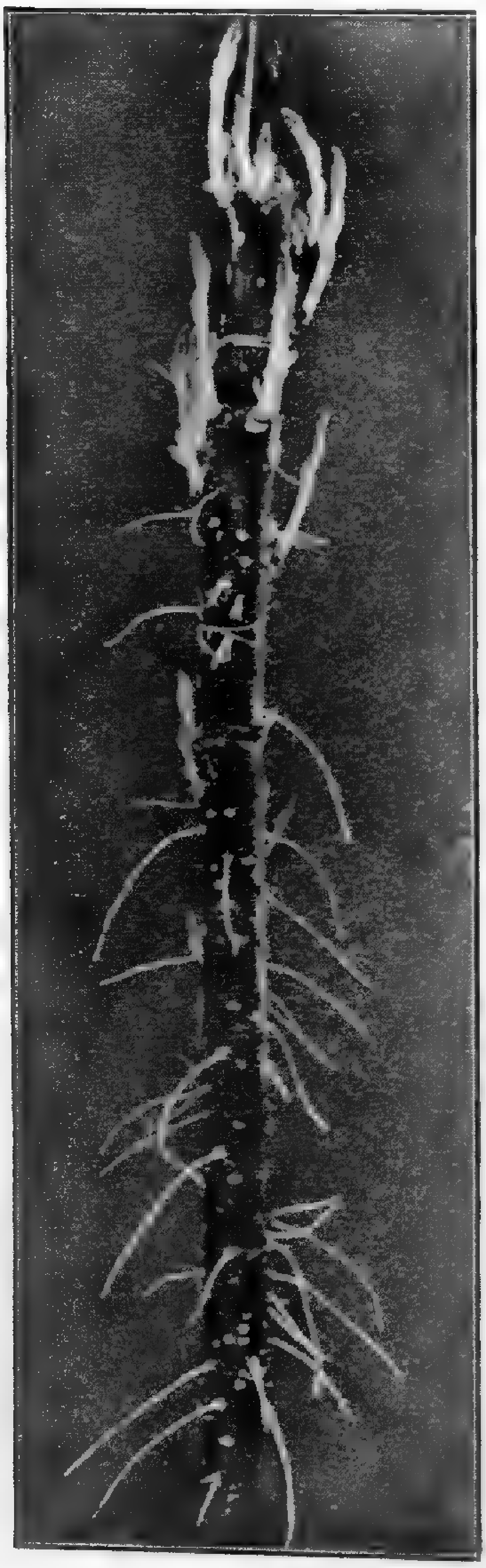

FIG. 2

Intimately associated with this problem of regeneration is that of polarity, for almost invariably the new structures occur in such a manner as to exhibit this remarkable phenomenon (*fig. 2*), and if we can determine the exact cause of the appearance of roots or shoots in an isolated piece of Salix stem, for example, the reason for their development at certain places only may be apparent. At present we are blocked at the outset by not knowing, at least under most circumstances, the stimulus which incites their development at all.

In conducting some investigations in this subject it soon became evident that the best method of attack would be to take all the possible factors and work on them separately, subjecting each, one at a time, to a more exact physiological analysis. The effort was made to determine whether the proposed cause in any given case of regeneration is a necessary part of the stimulus, by endeavoring to devise conditions under which the regeneration could be induced to occur in its absence. By this process of exclusion the essential factor might be isolated. Experiments were conducted on Phaseolus, Salix, Helianthus, Taraxacum, Tolmiea, and other plants.

If the common scarlet runner bean, a variety of *Phaseolus multiflorus*, be cut off any place along the epicotyl, there arise from within the cotyledons two shoots, which grow vigorously and may attain the size of the normal plants (*fig. 3*). Sometimes, however, one of these may grow weakly, or even be entirely suppressed. These arise from two minute primordia which are present, one in the axil of each cotyledon. Of the many hundred plants under observation scarcely a case was seen in which these primordia developed without the removal of the shoot, and in every case in which the stem was cut off they developed. Though less than a millimeter in length, in three or four days after the stem is removed they appear above the cotyledons, and in a week are often 6^{cm} long. Growth is then very rapid, and in a month they may be 60 or 70^{cm} high. In the axils of each of the foliage leaves on the plant there is, as usual, a bud. These under the condition of my experiments rarely developed. If the plant be allowed to grow until the second internode is formed, and this be cut off, these dormant buds in the axils of the leaves at its base will at once become active and give rise to two shoots; or if the plant form several internodes and the upper one be removed, the buds of the nodes below (not necessarily the first one) at once will develop shoots.

FIG. 3

Here we have one of the most common phenomena in regeneration, namely the removal of a part stimulating to development what would otherwise be dormant primordia. But this same removal or isolation of a part is followed by the growth of organs where their primordia do not exist; for if the stem of the bean be severed from the root system and kept moist, new roots appear along the stem. Similarly, when many roots and leaves or other parts are cut away, new shoot primordia are organized from cortical or other tissues, and it seems quite probable that the same stimulus which starts the development of many latent primordia will in many cases where they are absent incite their origin from already differentiated tissues.

What now are the possible factors operating in these cases? The various theories and possibilities suggested fall naturally into a few general classes: (1) wound stimulus; (2) disturbance in nutritive relations; (3) changes in water content; (4) accumulation at certain places of definite formative substances; (5) correlation; (6) relative age and degree of maturity of the different parts of a member; and (7) growth tensions. Each of these will be discussed in connection with the experiments relating to them.

Unless otherwise stated, the plant used was Phaseolus, and in every experiment a sufficient number of plants were used to insure reliability of the result, and check experiments were always carefully arranged. Where there was any diversity in the result the experiment was always repeated. Of the total number of experiments only the more striking ones will be described, and for convenience in the discussion these will be numbered in the order in which they are presented.

DISTURBANCE IN NUTRITION.

When a growing part is removed, a large part of the food that would have been used by it may now be unused in the plant, and may be accessible to other parts. If during the spring the tip of a shoot of almost any tree be removed, some of the buds which would otherwise lie dormant until the next year develop into shoots (*figs. 6* and *7*). Here, and in Onoclea where GOEBEL (**2**) secured the metamorphosis of sporophylls into foliage leaves by the continued removal of the former, KLEBS (**5**) sees an essential factor in the disturbance occurring in the nutritive conditions. In the axils of the cotyledons of *Juglans regia* there are a number of buds which, as GOEBEL (**4**, p. 209) has pointed out, do not develop unless the terminal bud be removed. This arrest of these buds is due GOEBEL says "to all the available food material being devoted to the development of one terminal bud." Many tuber- and bulb-forming plants do not normally produce seeds, but, as in *Lilium candidum*, *Lachenalia luteola*, etc., if the bulbs be cut away and prevented from forming, seeds will be produced. "In the normal condition," GOEBEL says, "seed formation is hindered because the plastic material which might be used for seeds streams into the bulb." The inference is that this material, prevented from going to the bulbs, will flow to the seeds. This conception plays a fundamental part in GOEBEL'S explanation of how the removal of one part may start the development of another. SACHS (**10**) gives a similar explanation for the development of the cotyledonary buds in Phaseolus, stating that it is due to increase of food resulting from the removal of the main axis. To demonstrate this it must be shown that these lateral buds, though in intimate contact with large cotyledons, remain undeveloped because of lack of food, and further that when the terminal bud is removed they will not develop if the possibility of an increased amount of food is precluded.

FIG. 4

The attempt is made in the following experiments to determine this experimentally. The plants used, unless otherwise stated, were seedlings, the epicotyl varying from 1 to 9^{cm} long, with the first pair of leaves not yet fully opened, and the cotyledons still full of food (*fig. 4*).

If an increase of nutritive material in the axial primordia, due to the removal of the parts using this while the source of supply is still active, is the cause of development of these structures, then while removing the central shoot, if we at the same time remove the source of the food, there should be no development of the primordia.

Experiment 1.—Twelve plants were used, the epicotyl was cut off about the middle and the cotyledons left intact. The axial buds developed in all (*fig. 3*). This was repeated later for different purposes on scores of plants, and the result was always the same, except that occasionally only one shoot would develop.

Experiment 2.—Twelve plants were used, the epicotyl was cut off, and one cotyledon was removed. In all cases shoots developed from both axils.

Experiment 3.—Seven plants were used, the epicotyl was cut off, and both cotyledons were cut off but left in their natural position so as not to introduce other factors, as light, air, or moisture from the soil. All developed shoots from both axils. This was repeated on many plants with similar results.

Experiment 4.—Three plants, almost mature, 40–50^{cm} high and with 6–8 internodes, were used. The cotyledons had been used up and had dropped away; the lower part of the stem had become quite hard, almost woody, and hollow. The plants were cut off a few centimeters above the ground, and five of the six primordia developed shoots.

Here as in the other three experiments it is clear that food derived from the cotyledons is no essential part of the stimulus which causes the young buds to develop. In the next three experiments the attempt was made to remove the terminal bud and at the same time diminish the nutritive supply of the other buds even to the point of starvation.

Experiment 5.—Five plants that had been grown with their roots in tap water were transferred to distilled water. All the cotyledons were cut off and also the epicotyl. All five of the plants slowly but completely regenerated. Here all supply of food from the substratum, from the cotyledons, and from the leaves is removed. In this experiment and others a large number of check plants showed that the cutting away of the cotyledons had no effect on the young buds if the primary axis was left intact.

Experiment 6.—Four seeds just germinating were taken, the radicle being 4^{cm} long, and the young stem with its leaves being still between the cotyledons. The cotyledons were forced open and both cut off, leaving only the small stem and root. The plants were then placed with the root in distilled water in the dark, and left for two days. Both stem and root elongated rapidly, at the expense of the food in the young plant to start with, so that part, probably most, of the food was used up, and the rest was distributed throughout the now much larger plant. Then the stem was cut off as close as possible to the buds, and two of the plants were placed in the dark and two in the light. All four regenerated slowly.

Experiment 7.—Twelve young plants were used as follows: *a*, two were cut off between the point of attachment of the cotyledons and the buds in their axils, so as to cut away the cotyledons and hypocotyl, leaving epicotyl with apex intact and primordia at the base, and set in a moist chamber; *b*, from ten plants the cotyledons were removed and the stem cut off close above the primordia, then the hypocotyl was cut off immediately below the primordia, leaving a small piece of the stem (average 8^{mm} in length) with the primordia attached; five of these were set in darkness and five in light in a moist chamber, with the base of each piece resting on wet filter paper. In *a* there was no development of the buds; in *b*, of the buds in the dark those on four plants grew to be $1–2^{cm}$ long and then died, presumably from starvation; while those in the light developed slowly at first and faster as they formed chlorophyll, finally forming shoots.

These experiments show conclusively that when the young shoot is removed the removal also of the food supply does not hinder the development of the buds at the base, and that it occurs when there is not only no increase in the food, but when the primordia and the surrounding parts are in a condition of starvation. Plants were grown in the most favorable conditions of rich soil, inorganic nutrient solutions, light, and moisture, so that vegetative growth was luxuriant, but only the removal of the apex had any influence in inciting the buds below to growth. The constant factor in every case is the removal of the apex, and neither an increase in food dependent on the removal of the growing shoot, nor any decrease that might occur in the nutritive relations constitute an essential part of the stimulus.

In Bryophyllum GOEBEL (**3**, p. 420) says that the vegetative points serve as "centers of attraction for the constructive materials." Those on the shoot, according to him, because of their more direct connections with the conducting system act as stronger attractive centers than those on the leaves. Of the buds on the shoot the terminal one exerts a stronger attraction than the lateral ones. If we cut off the terminal bud the lateral ones develop, and GOEBEL (**3**, p. 418) has shown that if we cut off all the shoot buds those on the leaves develop. His explanation is that the stronger points of attraction being no longer active, the "building material" is drawn toward the points of "weaker attraction," *i. e.*, the growing points of the leaves.

Such a conception is scarcely in harmony with the principles that control the movement of materials in plants. Any substance in solution in the plant necessarily follows the general laws of solutions, and will diffuse toward any point only when there is less of it there than at the place from which it moves. A movement of constructive materials from the leaves or cotyledons only occurs when there is more of it in solution there than elsewhere, and if the flow is directed toward the terminal bud it is only because that is the point of least concentration. If at any time there were less in the lateral buds than in the terminal one, it would diffuse into the former. The fact of any food material moving toward the terminal part and past the lateral buds is positive evidence that the terminal bud contains less of this in solution (and it is only in solution that it would be available) than the others. There is no evidence for assuming that the food is "attracted" into certain buds in sufficient quantity to start growth and not into others; for until growth starts all will contain an equal amount, and afterwards, if food continues to move toward certain buds and not toward others it can only be because growth (or some other cause) keeps the amount in the former constantly less than in the latter.

Thus there is no ground for the supposition that the buds that develop in regeneration are any better supplied with food after they start to sprout than before, and that when they do not develop, as GOEBEL'S hypothesis implies, it is because of lack of food. Frequently they are stored with food and will begin to develop so soon as isolated from the parent plant. Starvation, as we know, will not cause growth to cease until it is far more severe than it is ever likely to be on any well-nourished plant; and, as MORGAN (**7**, p. 27) has pointed out, animals regenerate even while starving to death.

Experiment 8.—From young shoots of Salix and Lycium the terminal bud and all the leaves were removed, and the shoots, separated from the parent plants, were placed in the dark. The axillary buds started to develop and continued until all the nourishment in the shoots were exhausted.

Roots of Taraxacum were cut into several pieces, and on each piece new shoots arose. We cannot say that each piece was either better or more poorly nourished than before. A Marchantia thallus grown in very weak light and plainly in a semi-starved condition regenerated when cut across transversely.

It seems clear from the experimental evidence that, at least in the plants mentioned, there need be no increase in nutritive conditions to occasion regeneration, and we must look elsewhere for the stimulus.

DISTURBANCE IN WATER CONTENT.

When the leaves or other transpiring surfaces of a plant are removed, there is often opportunity for a better supply of water in the remaining parts. The profound influence of water as a factor in growth is too well known to need emphasis. If the leaves of many trees or shrubs be removed early enough, the axillary buds will develop shoots instead of remaining dormant until the next year. DeCandolle (**1**) attributed this to the "sap" being no longer drawn away from the buds by the leaves. Wiesner (**15**) thinks that the young buds are hindered from developing because the water is withdrawn from them by the more actively transpiring leaves. In isolated pieces of Salix stems Vöchting (**13**) believes that water is the factor that determines the appearance of roots, and Klebs (**5**, p. 104) had experimentally proved this to be true in at least some species. Wakker (**14**) obtained buds on leaves of Bryophyllum by submerging them, and thinks it due to disturbances in the water current. Goebel (**3**, p. 393) obtained buds on leaves of *Aneimia rotundifolia* by either submerging them or placing them in very moist air; also on uninjured leaves of *Cardamine pratensis* by keeping the plants in moist air. Klebs attributes this to the checking of transpiration and consequent abundance of water in the leaf. By surrounding a portion of an uninjured stem of Salix by a glass cylinder filled with water, Klebs (**5**, p. 104) found that roots develop upon that part. Other plants, especially those whose natural habitat is in wet places, possess this ability to produce roots along portions of the stem that are kept wet. Sometimes, as in *Veronica anagallis*, the root primordia are already laid down, but in most plants these are not present. KLEBS believes that in these cases the development of the roots is due to the increased absorption of water, and holds this factor to be of great importance in other regeneration phenomena. The following experiments will throw light upon this.

The question was attacked by two opposite methods: the effect was determined of (1) growing plants without injury or any removal under such conditions as would increase the water in the plant to the highest amount possible; (2) of supplying the other conditions for regeneration and at the same time decreasing the water content of the plant to the least possible amount compatible with actual existence.

Experiment 9.—Six plants in pots were placed under bell jars, whose inner surfaces were lined with wet filter paper. The plants grew rapidly, but no regeneration occurred.

Experiment 10.—The same experiment was repeated with five other plants, with the same result. While this usual method of forming a moist chamber gives an atmosphere that minimizes transpiration, it does not altogether inhibit it. This objection was overcome in two ways (experiments 11 and 17).

Experiment 11.—Two plants were set in a large bell jar, and this was set over a vessel of water so that the bottom of the bell jar was just below the surface of the water. This water was heated to and kept at a constant temperature of 33°. The air of the greenhouse averaged 18–20°, while that in the bell jar was 24°, a good growing temperature for this plant. The air surrounding the plant was thus saturated from a water surface whose temperature was 7° higher than the temperature of the plant, which entirely inhibits any evaporation from the latter. The plants grew rapidly, but the primordia at the base showed no signs of developing. Here the plant is undoubtedly saturated with water.

Experiment 12.—Attempts were made to prevent transpiration by covering the leaves with vaseline, cocoa butter, or soft wax, but in no case was the development of the buds produced.

Experiment 13.—In the moist chambers described the whole plant was in the moist air. Two plants were next arranged, each in a glass cylinder, so that the lower part of the stem of each plant passed through a rubber stopper inserted in the bottom of the cylinder. Thus the stem and foliage were in the cylinder, the cotyledons were below in the air, and the roots hung down into a nutrient salt solution. The cylinder was lined with wet filter paper and covered at the top. The plants grew rapidly, but the basal primordia did not develop.

Experiment 14.—Three other plants were arranged in the same way, except that the cylinders were filled with water instead of moist air. The stems grew rapidly for a few days, then the growth gradually decreased, and finally ceased entirely. No development of the basal buds occurred until growth ceased, when they developed. This was repeated by inverting three plants with their foliage in a large aquarium, with the same result. When the shoots were killed by the prolonged submergence, however, the basal buds developed shoots.

Experiment 15.—All the foliage was cut from five plants, thus removing the transpiration surface, and no development of basal buds followed. All the leaves and also the cotyledons were removed from three other plants, with the same result.

Experiment 16.—Five large plants, with six to eight internodes and a large display of foliage were selected. The vegetative tip was removed from each and also the buds in the axils of all the leaves. In four of them the basal buds developed. Here the disturbance in the water content could only have been trifling, for careful determination before and after cutting off the tips showed no appreciable diminution in the amount of transpiration.

Experiment 17.—A second moist chamber that kept the plant saturated was formed in the following way: a glass tube was drawn to a fine end with a capillary opening and through this a fine jet of water was forced, which struck a small piece of ground glass held obliquely to it and was scattered into a fine mist. In this mist five plants were set, the fine spray continuously settling on every part of the plant, not only the upper but also the under surface, for it circulated freely on the slight air currents always present. Here the plants were covered constantly with a thin layer of water, which completely checked transpiration, but the excellent aeration allowed a healthy growth. All the plants grew rapidly, but there was no development of the buds at the base.

The experiments thus far show that the maximum amount of water in the plant will not induce the basal primordia to develop. The opposite method was then tried, *i. e.*, supplying the other possible factors in regeneration and at the same time withdrawing water from the plant.

Experiment 18.—Eight plants were used, the soil allowed to dry until the leaves wilted, and the stems then cut off a few centimeters above the ground. No more water was added and the soil became quite dry. The remaining part of the stems wilted and the cotyledons began to shrivel. In spite of this the primordia developed on six of the plants; on the other two they started but soon withered completely. The six that developed grew very slowly and apparently suffered severely from lack of water. Three of them were then watered, and at once recovered turgidity and grew normally. On the other three the young shoots reached an average length of 3^{cm} and then died. Here the buds started to develop with a turgidity much below the normal, and continued slowly against a decreasing turgescence until the death point was reached. This part of the experiment was repeated on several occasions and always with the same result. Check plants under the same conditions, but with the stems not removed, showed no development of the buds. The following more accurate method was then used.

Experiment 19.—To the weak nutrient salt solution in which the plants were frequently grown was added KNO_3 to make up solutions of the following gram-equivalent proportions: $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{8}$, $\frac{1}{9}$, $\frac{1}{10}$. To each of these were transferred plants whose roots had been grown in the usual nutrient salt solution. In four days the roots in the $\frac{2}{3}$, $\frac{1}{2}$, and $\frac{1}{3}$ gram-equivalent solutions were entirely plasmolyzed and killed, and the stems and leaves wilted. In the $\frac{1}{4}$ solution the roots were partially plasmolyzed, though not killed, and the leaves were just flaccid. In the $\frac{1}{5}$ solution the roots seemed quite healthy, and also the shoots, but growth was very slow. In all the other solutions the plants were vigorous and grew rapidly. Another set of these solutions was made up, and in each were placed plants with vigorous roots that had been developed in nutrient salt solutions, and each stem was cut off. As before, those in the $\frac{2}{3}$, $\frac{1}{2}$ and $\frac{1}{3}$ solutions were killed by plasmolysis; in the $\frac{1}{4}$ solution the roots at the end of the week were killed, but the stem was still alive, though wilted, and the buds were developing; the cotyledons were much shrunken from loss of water which had been drawn out by the strong solution. The plants lived for several weeks, the young shoots slowly developing, and then died as the solution became stronger through evaporation. In the $\frac{1}{6}$ solution the development of the buds was slow but normal. In all the others it was quite active.

Experiment 20.—The nutrient salt solution mentioned was made up in concentrations which approximate the following: $\frac{25}{100}$, $\frac{30}{100}$, $\frac{35}{100}$, $\frac{37}{100}$, $\frac{40}{100}$, $\frac{45}{100}$, $\frac{48}{100}$, $\frac{50}{100}$, $\frac{55}{100}$, $\frac{60}{100}$ gram-equivalent solution. These concentrations are only approximate, for probably ionization is not complete in any, certainly not in the stronger solutions, and also sufficient KOH was added to make them neutral. As it is only the relative strengths of solution that are required, it was not necessary to determine the actual osmotic pressure. One plant was used for each solution, and as before the roots were in the solution and the cotyledons and the rest of the plant in the air. Each plant was cut off a few centimeters above the cotyledons. In the three strongest solutions the plants were entirely killed, wilting very rapidly. In the $\frac{43}{100}$ gram-equivalent solution, after two weeks the roots were still alive but very much twisted and contorted, and so far as could be seen no growth had occurred in them. The development of the buds was slow but complete. In the next solution below this the growth of the buds was considerably faster, and in all the others it was normal. Similar plants with their shoots and leaves intact were put in the $\frac{45}{100}$ and $\frac{48}{100}$ solutions and in two days the leaves had wilted down.

Experiment 21.—The last experiment was repeated by cutting off not only the stem but also the cotyledons. The result was the same, new shoots slowly forming while the water was being withdrawn.

The result of these experiments shows (1) that the buds in the axils of the cotyledons will not develop under the influence of maximum turgidity of the cells so long as the upper part is still functioning, and (2) that if the stem be cut off the buds will develop against a partial plasmolysis of the plant. With the shoot intact no change in the water content will start the buds into activity, so that the stimulus to their development does not need to include any change in the water content of the cells. The factor that is constant in all the cases is the removal of the growing points above.

If **Wiesner's** conception that checking transpiration and consequent accumulation of water is the cause of the development of buds when the leaves are removed is correct, we should expect to find the same development if we occasion an equal accumulation of water without the removal of the leaves. But this does not happen. Experiments were conducted on young shoots of Salix, Populus, Cornus, Ulmus, Solidago, Silphium, and other plants. These need not be described individually, it being sufficient to say that when grown in the moist chambers described above, including the one in which the chamber was filled perpetually with fine spray, the buds showed no tendency to develop. In some cases cuttings were used, and in others plants with roots in soil or in nutrient water cultures. No loss of water was possible anywhere, and every part of the plant capable of taking in water was doing so. On the other hand, as will be discussed later, the buds promptly develop even when very plainly suffering from lack of water, if the tip of the shoot be removed.

Roots of Taraxacum with all buds removed were left in rather damp air, but yet allowing a slow evaporation of water from the surface. While thus slowly drying they all regenerated new buds and shoots. **Wakker** obtained buds on leaves of Bryophyllum when submerged, but, as **Goebel** has mentioned, we do not know what other factors come into operation in the course of such drastic treatment. One of the most striking cases of the direct influence of water in inciting regeneration is that of *Cardamine pratense*, which, as **Goebel** (**3**, p. 425) showed, produces shoots on the leaves while still intact, when the plant is placed in a moist chamber. Bud primordia in this case are already formed on the leaves, and in their moist shady habitat in nature, where vegetative growth is luxuriant, develop abundantly, so that here we are probably only dealing with the usual precocious vegetative growth of this plant.

It is in the case of root production that we get what at first seems to be the most striking examples of the direct influence of water on the origin of new parts. It is well known that many stems form roots when cut off and placed in water, and **Klebs**, as mentioned above, has shown that in Salix the application of water to local areas of the stem, without any wounding, is followed by a copious appearance of roots. But even here a closer analysis of the condition may reveal other factors than those which have been considered the most important. Experiments on this connection are to be mentioned. KLEBS (**5**, p. 109) says that when through wounding or separation roots or shoots either infold themselves or are produced entirely anew, it is because through this separation just those conditions are brought about in the cells which under all other circumstances would start into operation the same "building processes;" and this condition in Salix he asserts lies in the necessary accumulation of water in the parts concerned. Experiments in this connection are to be mentioned. VÖCHTING (**13**), in his classic experiments on Salix, obtained roots on pieces of stem when placed in moist air, and concluded that the cause of root development was the increased moisture. This assumes that the stems absorbed moisture from the atmosphere, and also that if they had not absorbed this the roots would not have developed.

FIG. 5

Before we can attribute a result to any factor it is necessary to show (1) that that factor is always present when the result occurs, and (2) that when it is absent the result will not occur. Will roots of Salix, for example, develop on the stem only after "the necessary accumulation of water;" or can we produce them without this, or with even a decrease of water in the parts producing them? The following experiments were to determine this. For convenience, those on Phaseolus will be described first. If the stem of this plant be cut off anywhere and placed in water, roots come out abundantly at the lower end (*fig. 5*). These arise from the pericycle entirely anew, no root primordia existing anywhere on the stem.

Experiment 22.—Entire plants, with roots in soil or water cultures, were placed in the three moist chambers described above. They grew rapidly and no roots formed on the stems. There can be no doubt that the stems were entirely saturated with water.

Experiment 23.—Plants with roots grown in water culture were placed in water so that the stems were submerged. From several the cuticle and outer part of the cortex was peeled off, so that water would enter freely, and in some the foliage was enclosed in a moist chamber. No roots developed.

Experiment 24.—Stems with roots intact were submerged as in the last experiment, but some of the stems were slit through the middle longitudinally, while from others a slice out of the side the length of the internode and one-third the diameter was taken. Thus free absorption of water was possible all along the stem, but no roots developed. If, as will be discussed again, the cut be a transverse one, severing some of the bundles, roots promptly develop just above this; or if the roots be removed new roots form along the stem.

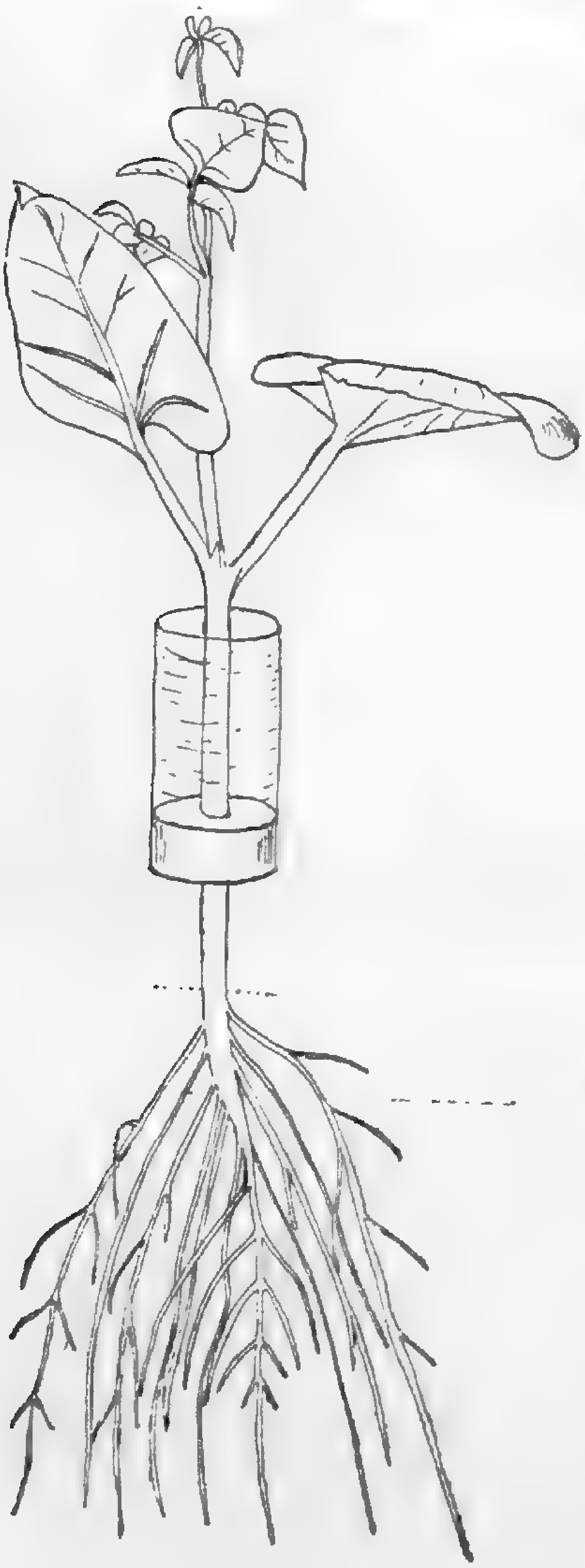

FIG. 6

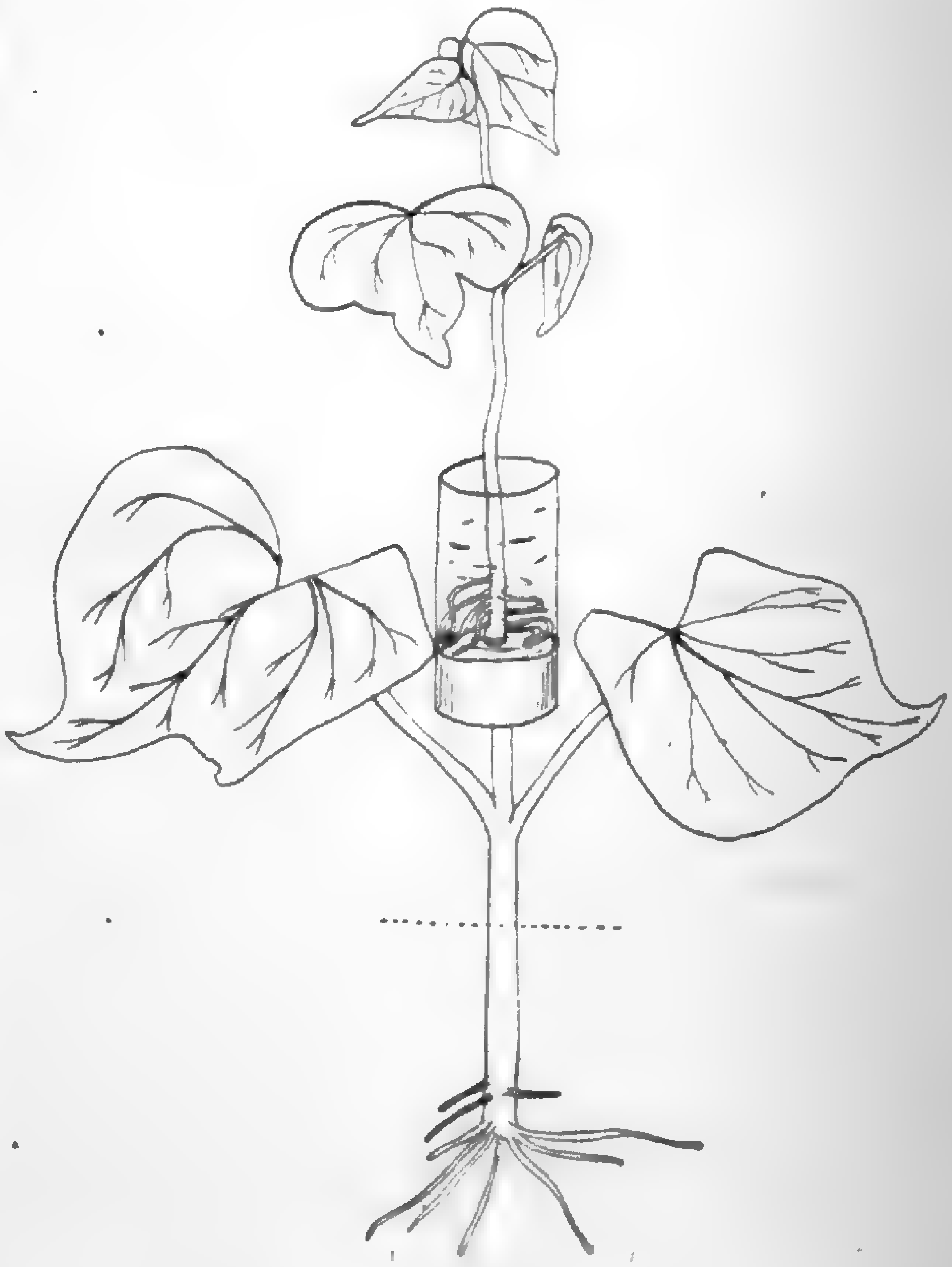

FIG. 7

Experiment 25.—Stems with roots intact below were surrounded at local regions by water in glass cylinders (*fig. 6*), and the cortex was removed so as to allow free absorption. No roots developed. If, however, as in *fig. 7*, stems were used from which the root system had been removed, roots promptly came at these watered areas.

These experiments show that contact with or the free absorption of water by the stem, or the complete saturation of the stem and whole plant, will not induce root development on the stems when the roots below are intact.


FIG. 8

On the other hand, the roots may develop when the parts from which they arise not only do not absorb any water, but are actually wilting. From a considerable number only four experiments will be mentioned.

Experiment 26.—Plants were cut off near the base and the whole plants placed in damp air, the lower free end of the stem being suspended in the air and not in contact with water. A slow transpiration necessarily occurred and the plants gradually wilted. The lower end of the stem became quite dry, yet from it roots arose.

Experiment 27.—Three pieces of internodes were placed in damp air. They wilted until there was a conspicuous shrinkage, and yet at the basal end of each roots developed. The weight of the pieces at the beginning of the experiment was 8.7^{gr}, and eight days later, when roots had just appeared, 7.9^{gr}.


FIG. 9

Experiment 28.—Stems were cut off near the base, and a portion of the upper part of the internode was surrounded by water, as shown in *fig. 8*. The lower part projected downward through a hole in a glass plate and was in the rather dry air of the laboratory; while over all the rest of the plant was placed a bell jar to keep the air moist so that the plant would not wilt. Roots soon came out from the part of the stem surrounded by water. The basal end projecting down into the air became somewhat wilted, especially toward the base where the end for about 1^{cm} was completely dried up. In spite of this, roots formed just above this dried portion, and broke through the epidermis but could not continue in the dry air.

Experiment 29.—Stems were cut off and the lower part placed in water. Above the water a deep notch was cut in each stem. Roots developed abundantly at the lower end in the water, and also just above the notch. The vessels being cut off from the water supply, the tissues were quite wilted and shrunken. In the dry air the roots did not elongate more than 1–2^{mm}, but if the air is moist they grow vigorously (*fig. 9*). If, as stated, a portion of the stem is surrounded by water, no roots appear on this part so long as the roots are intact below (*fig. 6*); but if the latter are cut off, roots appear at the former place as well as at the place below from which they were removed. But the cutting off of the root system in this case cannot influence the amount of water in the stem, unless it be to diminish it.

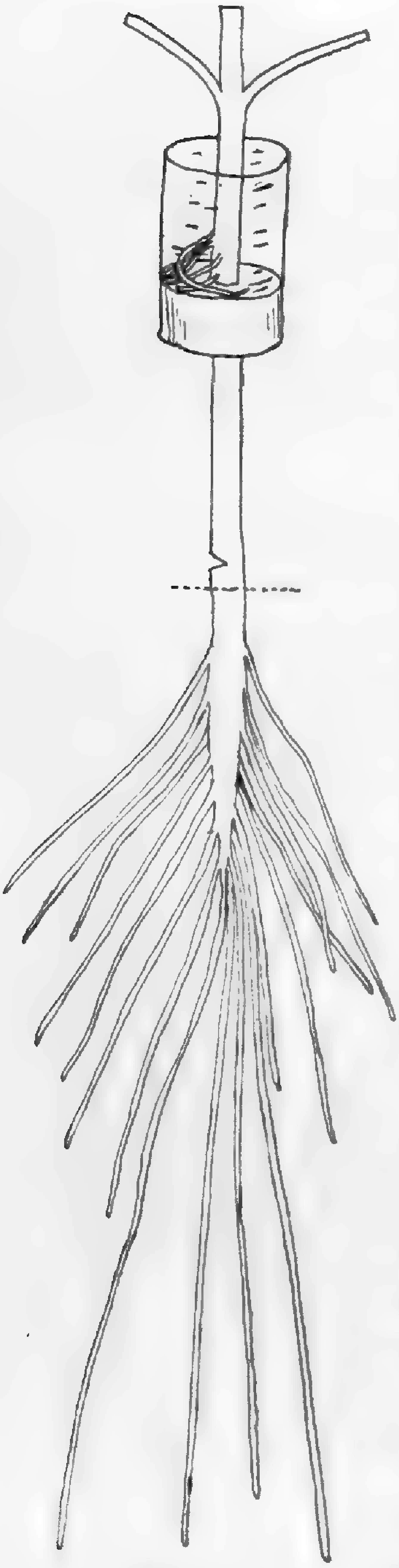

FIG. 10

Experiment 30.—The plant was fixed as shown in *fig. 10.* Below the cylinder of water surrounding the stem a notch was cut about one-third the way through the stem. This severed the connection with the root, along these bundles, from this point upwards. Roots appeared in the water above, on the side directly above the notch, and from the bundles severed by it. Here again, if the cutting of the notch had any effect on the amount of water in the part of the stem directly above it, it would only be to diminish it, yet its effect was to produce roots there.

Experiment 31 (fig. 11).—Both portions *a* and *b* are in the water, and if there is any difference *a* has the better chance of becoming saturated; yet *b* alone produces roots.

Experiment 32 (fig. 12).—The apical end is inverted in water and the basal in somewhat damp air, but allowing considerable evaporation. No roots at all come on the former, but on the latter many primordia are formed and break through the cortex, and a few grow out into the air. If the air be kept saturated, or the end surrounded by water, many roots grow out vigorously.

These experiments all show, at least in the bean, that an increase of water at any point along the stem will not in itself incite the formation of roots, and that root primordia will be organized when the cells there contain much less water than when growing normally. Their subsequent development depends on sufficient external moisture to prevent them from wilting.

In Salix, root primordia are laid down early along the stem in the vicinity of the buds. In some species, at least, contact with water, as **Klebs** has shown, will incite these to active growth. It does not necessarily follow, however, that this is due to the increased absorption of water by these cells, as **Klebs** maintains. The following experiments throw some light on this.

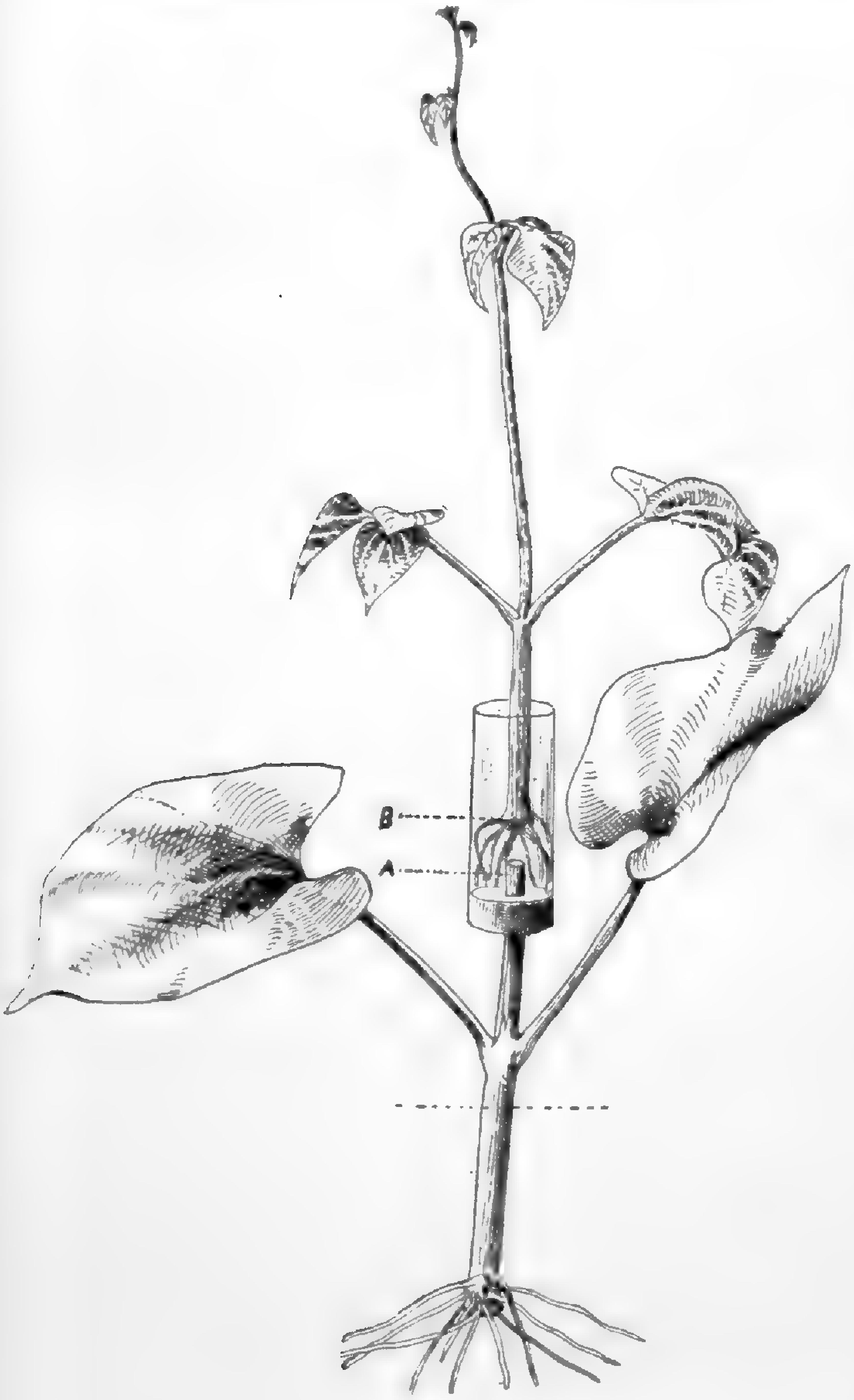

Fig. 11

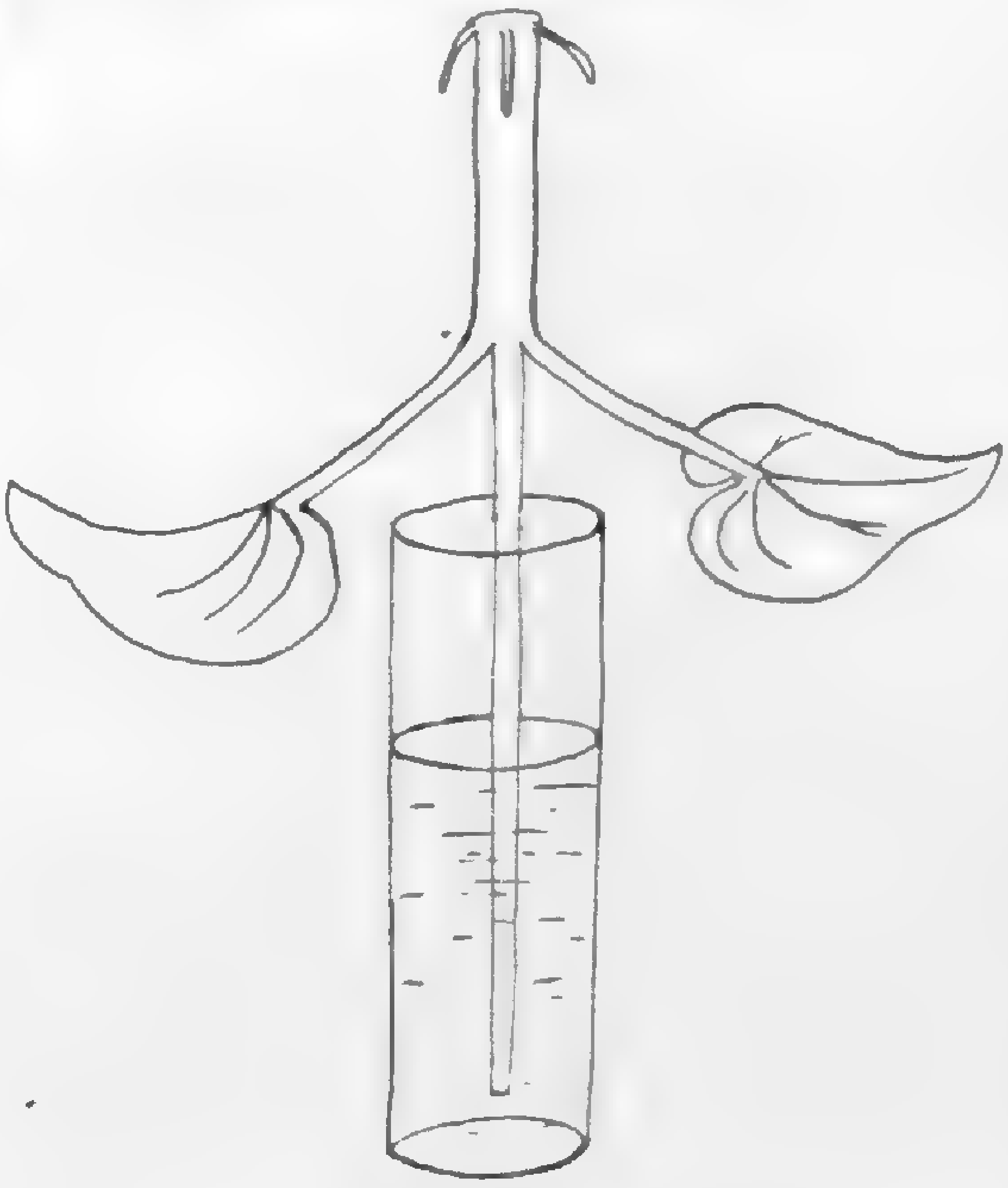

Fig. 12

Experiment 33.—Three pieces of *Salix glaucophylla* stem two years old were cut off from plants which were growing in pots in the greenhouse and weighed. The aggregate weight was 27.5^{gr}. These were placed horizontally in a chamber where the air was just moist.

In less than a week roots had appeared on all three near the base. The weight now was found to be 26^{gr}, a loss of 1.5^{gr}, most of which certainly was water. Another piece at first weighed 10.5^{gr}; and when the roots coming out on it were 1^{cm} long the weight was 10.1^{gr}. Thus, with the piece as a whole losing water, but with a moist atmosphere outside, roots develop.


FIG. 13

Experiment 34.—Two pieces of stem 30^{cm} long were fastened with their basal ends connected with the water faucet, so that the water was forced into them under high pressure. This pressure was sufficient to cause water to ooze slowly from the opposite end of the stem. The air surrounding the stem was that of the laboratory. No roots anywhere enlarged enough to break through the cortex to the surface. Here a greatly increased amount of water in the stem does not start the roots.

Experiment 35.—Stems growing with vigorous roots in water cultures were selected. A few inches above the water a ring of bark 5^{mm} wide, cutting into the wood, was removed. Just above this for about 1^{cm} the bark (*i. e.*, all outside of the wood) was plainly drier than at any other point, yet the root primordia in this part in a few days enlarged and broke through the cortex and epidermis, but went no farther; but when one of the pieces was put in moist air they grew out rapidly.

Experiment 36.—Five pieces of stem of *Salix fragilis*, each 30^{cm} long and one and two years old, were cut off from larger branches growing with roots in water. Two of the pieces bore young leaves, while on the other three the buds had not yet opened. Each piece, carefully freed from any water on the surface, was placed inside a dry glass tube as small in diameter as would admit the piece (*fig. 13*). Each tube was sealed air tight at each end by a rubber stopper and wax. Here there was no possibility of any absorption of moisture; on the other hand evaporation was constantly going on from the surface of the stems, and the moisture condensed in little droplets on the inside of the tube. The air in the tube under these circumstances must have been saturated with moisture, all of course at the expense of the water in the stem. Within a week three of the stems and a few days later a fourth showed vigorous roots coming out, which grew rapidly and soon were several centimeters long. Here again the stimulus certainly was not any increased water in the stems. It seems as though a moist atmosphere outside of the stem can act as a stimulus without any increase, in fact even a decrease, inside. How this could act through the epidermal and outer corky layers is not clear. At first it seemed that the real cause lay in the removal of the piece from all influence of the roots below, but glass tubes similarly placed around portions of longer pieces whose roots were intact and active below resulted in the production of roots just the same. Similar pieces covered with a thin coat of wax to prevent any evaporation showed no signs of root development.

FIG. 14

In submerged aquatics, where there is no current of water through the plant, but where the absence of a cutinized epidermis allows free diffusion in and out at every point, and where all the cells are constantly saturated, the removal of a part of the stem does not cause any change in the amount of water present. If such plants regenerate it is not due to disturbances in the water content.

Experiment 37.—Portions of the stems of the extreme aquatic forms of *Proserpinaca palustris* and *Ranunculus multifidus* were severed from the parent plants and left submerged. In all cases new roots were at once organized and grew rapidly at or near the basal end, and at the other end shoots started from the latent buds in the leaf axils (*fig. 14*). Isolated pieces of roots of Taraxacum, *Rumex crispus*, and stems of Zamia all organized new shoots while they were still losing moisture. In cases like Salix there is no doubt that contact with water will start the development of roots along the stem, yet these can also be started by other causes while the cells are losing water. In the great majority of instances where regeneration occurs, however, it cannot be due to any disturbance in the amount of water present in the parts concerned. Several leaves of Begonia and Bryophyllum were kept in the air of the room, but with their petioles in water. The blades quite plainly were not more turgid than those left on the plants, and not so much so as those on plants grown in moist air; yet they produced buds while the latter did not.

The results of experiments with the other factors mentioned will be presented in the second paper of this series.

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ON PROTEOLYTIC ENZYMES. II.

ARTHUR L. DEAN.

SINCE the writing of the previous paper[1] on the vegetable proteolytic enzymes, an article by VERNON[2] has appeared in which he gives an account of his investigation of the distribution of erepsin in the animal body. Comparative tests were made of glycerin extracts from thirteen different tissues of the cat, eight of the rabbit, eight of the guinea pig, seven of the pigeon, eight of the frog, seven of the eel, six of the lobster, and three of the fresh water mussel. In every case an erepsin was found to be present. The comparison of the activity of the various extracts was effected by means of colorimetric estimations of the intensity of the biuret reaction after certain periods of digestion. The tissue extracts from the warm blooded animals were more active than those from the cold blooded animals; the extracts from the invertebrate tissues had a relatively slight action. In the warm blooded animals it is not the intestinal mucous membrane which is richest in erepsin, but the kidney in the cat, rabbit, and pigeon, and the pancreas in the case of the guinea pig.

It might be noted that VERNON gives no record of experiments made with the various extracts to determine whether or not they are incapable of digesting the proteids of the tissues in which the enzymes occur. His experiments, being all conducted with Witte peptone solutions, do not conclusively show that the enzymes whose activity was observed are incapable of acting on any proteids except albumoses and peptones.

In a former communication evidence was given to show that *Phaseolus vulgaris* contains in its seeds a fairly active proteolytic enzyme. No action of this protease on the proteids of the seed could be demonstrated. Its power to act on Witte peptone as a whole, and on the albumose fractions separated from it, could be readily shown. Moreover, as germination progressed the cotyledons at all stages contained this ereptase and at no period of germination could

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[1] DEAN: BOT. GAZETTE **39**:321. 1904.

[2] VERNON: Jour. Physiol. **32**:33. 1904.

any evidence of a tryptic enzyme be obtained. Further studies have been made of this seed enzyme in the hope of throwing light on the processes occurring during germination.

FURTHER EXPERIMENTS WITH THE GERMINATING SEEDS OF *PHASEOLUS VULGARIS*

The following experiment was carried out to demonstrate the action of the seed ereptase of the bean on the proteoses to be obtained from phaseolin, the principal globulin of the seed. Phaseolin was prepared according to OSBORNE'S[3] method from white medium field beans, the yield from two kilograms of beans amounting to something over 75^{gm}. A small amount of phaselin was also obtained by the alcoholic precipitation of a part of the solution from which the phaseolin had separated on dialysis. This albumin gives a marked Adamkiewicz reaction.

By mixing a known weight of phaseolin with fifty times its weight of 2 per cent. sulphuric acid and heating for three and a half to four hours in a steam sterilizer, a slightly brown gelatinous fluid was obtained having the odor characteristic of acid proteid hydrolysis. This fluid was cooled, diluted with water, and the gelatinous antialbumid removed by filtration. The filtrate from the antialbumid was neutralized with barium hydroxide and the filtrate from the barium sulphate concentrated and treated with several volumes of alcohol. The mixture of proteoses obtained in this way was collected on a filter, washed with absolute alcohol and ether, and dried *in vacuo* over sulphuric acid.

To obtain an ereptase solution finely ground beans were extracted with water and the extract filtered through pulp filters until nearly clear. Ten cubic centimeters of this solution were placed in each of four dry test tubes and two of the portions boiled. Solutions of Witte peptone and phaseolin proteoses were prepared by dissolving $0.2^{gm.}$ of each preparation in 25^{cc} of water. The test solutions were made up as follows:

1. 10^{cc} enzyme solution + 10^{cc} phaseolin proteose solution + 9 drops of toluol.
2. Same as no. 1, using boiled enzyme solution.
3. 10^{cc} enzyme solution + 10^{cc} Witte peptone solution + 9 drops of toluol.
4. Same as no. 3, using boiled enzyme solution.

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[3] OSBORNE: 17th Annual Report of the Conn. Agric. Experiment Sta., Part IV. 186. 1893.

The corked tubes were kept in the incubator for six days. At the expiration of that time each digestion was boiled, acidified with a couple of drops of acetic acid, and filtered. Ten cubic centimeters of each filtrate were removed to a clean tube, and, after the addition of 5^{cc} of 10 per cent. sodium hydroxide solution, dilute copper sulphate solution was added to the maximum biuret reaction. After standing for several minutes the intensity of the biruet reactions was compared. The comparison showed that a marked digestion of both proteose mixtures had taken place, the one from phaseolin being rather more vigorously attacked. The unboiled digestion with Witte peptone gave a tryptophan reaction with bromine water, the other unboiled digestion did not.

Several trials were made of the digestibility of the acid phaseolin prepared by heating phaseolin for a few minutes with dilute sulphuric acid. The results obtained indicated that the enzyme of the seed had, at the most, but a feeble action on this body.

Various observers have shown that the antiseptics used in enzyme experiments may exert an inhibiting effect on the action of the ferment. **Vines** demonstrated that in papain digestions where sodium fluoride is used the action goes but little beyond the stage where albumoses and peptones are formed; whereas with other antiseptics, hydrocyanic acid for example, a marked formation of amido-acids takes place as shown by the production of tryptophan. It might be argued that the toluol used throughout the experiments with Phaseolus had an inhibiting action on the enzyme, so that it was unable to attack the proteids of the seed and could only act on albumoses and peptones. The two following experiments were carried out to settle that point:

Experiment I.—Thirty-five grams of finely comminuted cotyledons from six-day old bean seedlings were extracted for one and a half hours with 175^{cc} of water. The extract was filtered nearly clear through pulp filters and then forced through a Pasteur-Chamberland filter into a sterile flask. Three portions of 25^{cc} each were measured with a sterile pipette into three small sterile flasks. To no. 1 nothing further was added; to no. 2 was added 0.07^{gm} of sterile citric acid, making the solution $\frac{N}{25}$ citric acid; the contents of no. 3 were boiled. The cotton plugs in the flasks were replaced corks. After keeping the three flasks in the incubator for forty-one hours, 20^{cc} of tannic acid reagent (7 per cent. tannic acid in 2 per cent. acetic acid) were run into each. After standing a few moments the contents were filtered through dry filters and duplicates of 20^{cc} from each filtrate analyzed for nitrogen by the Kjeldahl method.

Analyses of filtrates from no. 1 gave 0.0036^{gm} N
Analyses of filtrates from no. 2 gave 0.0036^{gm} N
Analyses of filtrates from no. 3 gave 0.0033^{gm} N

Experiment II.—Another extract from cotyledons of six-day old seedlings was prepared by treating 28^{gm} of finely ground tissue with 140^{cc} of cold water for three hours. The extract was filtered as in the previous experiment and 25^{cc} of the filtrate removed into two sterile flasks. The contents of one flask were boiled and both were corked with sterile corks and kept in the incubator for three days. To test the ereptic activity of the bacteria-free filtrate 15^{cc} were placed in a test tube with 0.5^{gm} of Witte peptone and a little toluol. At the end of the digestion period the fluid in this tube was found to give a strong tryptophan reaction with bromine water, showing that the enzyme had not been held back by filtration through porcelain. The contents of the two flasks were treated as in the previous experiment:

Analyses of filtrate from unboiled digestion gave 0.0036^{gm} N.
Analyses of filtrate from boiled digestion gave 0.0030^{gm} N.

The differences between the boiled and unboiled digestions in these two experiments are so slight as to be within the limits of error of the method used and cannot be taken to show any hydrolysis of the proteid in the cotyledon extract.

PROTEOLYSIS DURING THE GERMINATION OF *PHASEOLUS VULGARIS*

We have every reason for believing that the germination of the bean is accompanied by a hydrolysis of the proteids therein contained, a hydrolysis which our experimental evidence leads us to conclude must be started, at least, by some other agency than an enzyme. That proteolysis does accompany germination of this seed is shown by the following experiments, where the amounts of coaguable and non-coaguable nitrogen were determined in the seeds and in the cotyledons of young seedlings.

About 75^{gm} of beans were soaked in water and the cotyledons separated from the skins and embryonic plants. The cotyledons after being washed were dried at 60° C. and ground in a hand mill, yielding the preparation *A*. Another part of the same lot of beans was planted in the greenhouse and allowed to germinate for seven days. At the end of this time the somewhat shrunken cotyledons had been pushed above ground, had begun to turn green, and were separating to allow the plumules to push out. These cotyledons were removed from the plants, washed, and dried at 80° C. When dry they were ground in the mill, giving preparation *B*. Portions of both *A* and *B* were rubbed to the finest powder possible in the mortar and dried at 100° C. to constant weight. Duplicate portions of 1^{gm} each of *A* and *B* were then weighed into small beakers, 15^{cc} of water added, and, after bringing to a boil, 2 drops of 10 per cent. acetic acid were stirred in. After allowing the coagulated proteids to settle for a moment or two the contents of each beaker were transferred to a dry washed filter paper in a funnel held in a Kjeldahl digestion flask. The washing of the precipitates and their quantitative transfer to the filters was effected by the use of six portions of 5^{cc} each of boiling distilled water. After thoroughly draining, the filters with the contained precipitates were transferred to Kjeldahl flasks; the precipitates and filtrates were then analyzed for nitrogen with the following average results:

Total nitrogen in *A* = 0.0407^{gm} = 4.17 per cent.
Total nitrogen in *B* = 0.0396^{gm} = 3.96 per cent.
Percentage of nitrogen in *A* as coaguable proteids = 90.7 per cent.
Percentage of nitrogen in *B* as coaguable proteids = 61.4 per cent.
Percentage of nitrogen in *A* as soluble compounds = 9.3 per cent.
Percentage of nitrogen in *B* as soluble compounds = 38.6 per cent.

It is worth noting that in the germination of the bean the consumption of nitrogenous foods proceeds at practically the same rate as that of the non-nitrogenous materials stored there; as a consequence the percentages of nitrogen in the cotyledons in the various stages of germination are nearly constant. After the cotyledons have become emptied the percentage of nitrogen changes, since the cell walls of the shriveled cotyledons make up so large a percentage of the dry weight.

The experiment described above shows that proteolysis actually does occur as a step in the process of the utilization of the stored proteid. It is of interest in this connection to see if this process occurs when the cotyledons are removed from the young seedlings and kept under sterile conditions. A series of preliminary tests showed that if the cotyledons of germinating beans are treated for twenty minutes with a 0.5 per cent. solution of mercuric chloride and then repeatedly washed with sterile water and kept in sterile tubes they will remain free from bacterial or fungal infection. The procedure kills the peripheral cells of the cotyledons, as shown by the fact that they do not turn green if kept in the light; whereas unsterilized cotyledons show a gradual development of chlorophyll under the same conditions of light and moisture. Comparative tests of the sterilized and unsterilized cotyledons showed that both contained ereptase, but that there was a noticeably smaller amount in the ones treated with mercuric chloride. It is probable that the poison not only killed the outer layer of cells, but also destroyed the enzymes contained in them.

Three-day old seedlings of Phaseolus were removed from the soil and the cotyledons separated. A quantity of these were washed, dried between 70° and 80° C., and ground in the mill, yielding preparation *C*. Ninety other perfectly sound cotyledons were selected, forty-five placed in each of two previously sterilized flasks, and kept covered with 0.5 per cent. mercuric chloride solution for twenty minutes. After pouring off the sublimate solution the cotyledons were washed five times with sterile water in quantities as great as that of the mercuric chloride solution used. In pouring off the last wash water sufficient was left in the flasks to keep the cotyledons moist. The flasks were closed with sterile corks and kept at room temperature—about 20° C. After three days one flask was opened and the contained cotyledons dried and ground, giving preparation *D*. The contents of the flask were judged to be sterile by the absence of any foreign growth and by the results of a transfer of a drop of the fluid from the bottom of the flask to a sterile agar tube. The second flask was kept unopened for five days longer and then the cotyledons in it were treated as the other portion, yielding preparation *E*.

Samples of preparations *C*, *D*, and *E* were finely ground, dried to constant weight and estimations of the coaguable and non-coaguable nitrogen were made in the same way as the similar determinations on *A* and *B*.

Total nitrogen in 1^{gm} of *C*	0.0426
Total nitrogen in 1^{gm} of *D*	0.0426
Total nitrogen in 1^{gm} of *E*	0.0432
Percentage of nitrogen in *C* as coaguable proteids	81.7
Percentage of nitrogen in *D* as coaguable proteids	88.0
Percentage of nitrogen in *E* as coaguable proteids	79.9
Percentage of non-proteid nitrogen in *C*	18.3
Percentage of non-proteid nitrogen in *D*	12.0
Percentage of non-proteid nitrogen in *E*	20.1

These results would indicate that under the conditions of the experiment there is no proteolysis occurring, although, as previously stated, the cotyledons still contain ereptase. A small increase in coaguable nitrogen was observed, followed by a rise to about the original amount. There seems to be no evident explanation for these small variations. Two facts may be noted: the oxygen supply to the living cells in the interior of the cotyledons was probably curtailed by the presence of the layers of dead cells on the surface; the correlation of the parts of the organism had been destroyed and the influence of that factor on the metabolic processes is not known. The results tend to emphasize the dependence of proteolysis in this seed upon the normal life of the organs.

DISTRIBUTION OF THE PROTEASES IN VARIOUS PARTS OF PLANTS OF *PHASEOLUS VULGARIS*

A large number of qualitative tests for proteolytic enzymes in various parts of the plants of Phaseolus were carried out, using the tryptophan reaction as an indication of proteolysis. It seems scarcely necessary to detail the methods and results in every instance. The experiments were conducted in a way analogus to those on the cotyledons in the various stages of germination, a full description of which was given in a former paper. In testing for a tryptic enzyme the tissues were sometimes allowed to autolyze without the addition of any further proteid, but in most cases edestin, phaseolin, or uncoagulated egg albumin was added. In searching for evidence of tryptic action the filtrates obtained after coagulating the proteids of the digestion mixture were frequently tested with Millon's and the biruet reactions, as well as with the tryptophan reaction. The ereptic activity was tested with Witte peptone. The antiseptic used was toluol. Tests were made of the following tissues:

1. The embryonic plants in the seeds (exclusive of the cotyledons).
2. The hypocotyls and plumules from three-day old seedlings; the hypocotyls were from 2 to 4^{cm} long.
3. A mixture of the hypocotyls and plumules from six-day old etiolated seedlings.
4. The roots, stems, and buds of seven-day old seedlings grown in the light were tested separately; the roots were copiously branched and the buds were just opening from between the cotyledons.
5. Whole young plants, exclusive of cotyledons, of ten-day old etiolated seedlings.
6. The leaves and buds, and the roots and stems, of eleven-day old seedlings grown in the greenhouse.
7. The leaves and buds, stems, and roots of thirteen-day old etiolated seedlings.
8. The same tissues of fourteen-day old non-etiolated plants.
9. The leaves and the stems of plants twenty-two days old.
10. The leaves and buds, the upper parts of the stems, the stems from the root crown to a centimeter above the scars of the cotyledons.
11. The roots, stems, and leaves of plants just coming into bloom.
12. The developing seeds and pods.

In every case a good tryptophan reaction was obtained when the tissues were allowed to autolyze in the presence of Witte peptone. In no case, with the questionable exception noted below, could evidence of the presence of an enzyme capable of attacking native proteids be obtained. The one exception was furnished by the tests conducted on young hypocotyls in which edestin was added to the mixture of minced tissues and water. In this case a very faint tryptophan reaction was obtained, sufficient to raise the question of the existence of a tryptase in these tissues. Accordingly the following experiment was carried out. Ten grams of minced hypocotyls (1 to 3^{cm} long) from four-day old bean seedlings were placed in each of two flasks and 25^{cc} of water added. One flask was heated for several minutes in the steam sterilizer and then cooled. To each flask was added 0.25^{cm} of phaseolin, 0.25^{cm} of phaselin, and 1^{cc} of toluol. The corked flasks were kept in the incubator for three days. After the digestion the contents of each flask were strained through cotton gauze, and 20^{cc} of each fluid precipitated with an equal volume of tannic acid reagent. Duplicates of 15^{cc} each from both filtrates were analyzed for nitrogen.

Nitrogen in analyses of filtrates of unboiled digestion $=0.0036^{gm}$
Nitrogen in analyses of filtrates of boiled digestion $=0.0035^{gm}$

It is therefore evident that no enzyme capable of acting on the native proteids of the bean is present in the young hypocotyls.

COMPARATIVE CONTENT OF EREPTASE IN VARIOUS TISSUES OF *PHASEOLUS VULGARIS*

In making any study of the relative quantities of ereptase in different tissues it is necessary to have some basis of comparison. Manifestly the dry weight of vegetable tissues is not a very satisfactory standard, since in many cases the cell walls constitute the greater part of the dry weight. The ideal way would be to use the weight of protoplasm as a basis for comparison, but this is out of the question. The best substitute seemed to be the quantities of the nitrogen in the tissues. The first measurements of the amount of ereptic activity in the tissues were carried out in the following manner. Nitrogen determinations were made on the fresh tissues to be tested, and then portions of each tissue, of such a weight that each portion contained 0.02^{gm} of nitrogen, were weighed out into small tared flasks. Into each flask 10^{cc} of a 10 per cent. Witte peptone solution were measured and the total weight of the digestion made up to 25^{gm} by the addition of distilled water. After the addition of 1^{cc} of toluol to each digestion the flasks were tightly corked and kept in the incubator for twenty-four hours at 41° C., the contents of each flask being shaken twice during that period. At the close of the digestion each mixture was strained through dry cotton gauze, and 20^{cc} of each fluid mixed with 20^{cc} of tannic acid reagent. The precipitates were filtered off on dry filters and the filtrates analyzed for nitrogen in duplicates of 15^{cc} each. Minor changes were made in this procedure in the subsequent series of determination, so that the results obtained thereby were not strictly comparable with the first series; since it was impossible to test the same tissues again the results of the first, and less satisfactory series, are nevertheless given:

Tissue	Percentage of N	Weight of tissue used	N in 15^{cc} of filtrate from tannic acid precipitate
Leaves of mature plants........	0.68	2.941^{gm}	0.0204^{gm}
Developing pods..............	0.39	5.130 "	0.0240 "
Developing seeds..............	0.95	2.105 "	0.0283 "

From such results as these it is impossible to tell how much of the nitrogen found in the filtrates from the tannic acid precipitation is due to products of the digestion of Witte peptone and how much is non-proteid nitrogen present in the tissues used. Moreover, Witte peptone is not completely precipitable by tannic acid, certain of the very soluble peptones not being thrown down by that reagent. In the remaining estimations of comparative ereptic power two digestions were made with each tissue, one a boiled control. As before, the quantity of tissue taken was that which should contain 0.02^{gm} of nitrogen. The digestion mixtures were made up to 30^{gm} instead of 25^{gm}, as this quantity was found to be more convenient. Moisture determinations were also made on each tissue so that comparisons of the dry weights could be made. The results of this study are given in the accompanying table.

The table shows that although the method is not absolutely exact, yet fairly good duplicates are obtained in different digestions with the same tissue. The digestion in a number of cases was vigorous, noticeably so with the roots where more than half of the Witte peptone in the digestion mixture was hydrolyzed. It should be said that the roots bore a few small tubercles which were removed so far as possible, yet the minute ones remaining may have had some influence on the results. It is suggestive to note that it is not the seeds and cotyledons which contain the most enzyme per unit of nitrogen, but rather it is those tissues where active metabolism is occurring. It is unfortunate that we are unable to use the weight of protoplasm as a basis for comparison. The use of the nitrogen content as a standard is well enough between the various active tissues, but when these are compared with tissues gorged with storage proteids it is evident that the storage tissue contains far less protoplasm to a given weight of nitrogen. The error which the presence of stored proteids introduces into our comparative results is evident in the case

Tissue used	Percentage of nitrogen	Weight of fresh tissue	Dry weight of the tissue used	N in 15^{cc} of filtrate from tannic acid ppt. unboiled	Calculated amount for whole unboiled digestion	N in 15^{cc} of filtrate from tannic acid ppt. boiled	Calculated amount for whole boiled digestion	Nitrogen converted by the digestion	Witte peptone corresponding to nitrogen converted[1]
Ungerminated seeds I	3.80	0.526^{gm}	0.499^{gm}	0.0141^{gm}	0.0564^{gm}	0.0108^{gm}	0.0432^{gm}	0.0132^{gm}	0.0911^{gm}
Cotyledons of 5-day seedlings	1.74	1.149	0.455	0.0156	0.0624	0.0117	0.0468	0.0156	0.1076
Cotyledons of 10-day seedlings	0.72	2.777	0.653	0.0213	0.0852	0.0120	0.0480	0.0372	0.2567
Ungerminated seeds II	3.80	0.526	0.499	0.0141	0.0564	0.0111	0.0444	0.0120	0.0828
Cotyledons of 3-day seedlings	1.71	1.170	0.494	0.0144	0.0576	0.0102	0.0408	0.0168	0.1159
Hypocotyls of 3-day seedlings	0.62	3.226	0.286	0.0174	0.0696	0.0114	0.0456	0.0240	0.1656
Roots—blossoming stage	0.31	6.452	0.807	0.0321	0.1284	0.0123	0.0492	0.0792	0.5465
Leaves—blossoming stage	0.72	2.777	0.404	0.0199	0.0796	0.0096	0.0384	0.0412	0.2843
Stems—blossoming stage	0.23	8.696	1.304	0.0240	0.0960	0.0126	0.0504	0.0456	0.3146
Ungerminated seeds III	3.80	5.26	.499	0.0138	0.0552	0.0111	0.0444	0.0108	0.0745
Stems—plants mixed age	0.23	8.696	1.304	0.0240	0.0960	0.0132	0.0528	0.0432	0.2981

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[1] The Witte peptone used in these experiments was found to contain 14.5 per cent. of nitrogen; the figures in this column were accordingly obtained by multiplying the values of the preceding column by 6.9.

of the emptying cotyledons. The cotyledons of ten-day old seedlings contain much more ereptase than those of the three and five-day old ones. The ten-day cotyledons were green, shriveled, and probably contained no proteids except those of the protoplasm. As a consequence, the number of cotyledons needed to contain 0.02^{gm} of nitrogen was far larger, the number of cells used much greater, and the amount of protoplasm probably far in excess of the amount in the digestion with younger cotyledons and ungerminated seeds. It is doubtful if there is any increase of ereptase per cell during the process of germination; if that is the case, the amount of ereptase per unit of protoplasm contained in the seeds and young cotyledons is much more clearly indicated by the results obtained with the exhausted cotyledons than by those obtained with the storage tissues themselves. In many cases it is evident that there is no special quantity of ereptase formed in the germinating seeds for the purpose of digesting the reserve proteids. The unexpected activity of the root tissue is probably connected with some processes, as yet unknown, which occur there and which are associated with the nitrogenous metabolism of those organs. VERNON obtained just such a suggestive result with the kidneys of several warm blooded animals; it is probable that there are processes occurring in that organ which are now unknown, but which involve a rapid nitrogenous metabolism.

CONCLUSIONS.

The results of this study have shown that, as was to be expected, the proteids of the seeds of *Phaseolus vulgaris* undergo proteolysis during germination as a preliminary to the transportation of the nitrogen and its utilization in the formation of new organs. There are three ways in which this process might be carried out: by the action of a tryptic enzyme; by the combined action of the protoplasm and of an enzyme which is, by itself, incapable of carrying out the whole process; or by the action of the protoplasm alone. The results of a study of the proteolytic enzymes of the resting and germinating bean show that there is no enzyme present which is able to digest the proteids of the seed. There is present, however, an enzyme of the ereptase group which is capable of digesting the proteoses resulting from the partial hydrolysis of the seed proteids. It may be, therefore, that the protoplasm of the cells starts the process of proteid decomposition, and carries it to some stage at which the ereptase takes up the work and completes the process. That the protoplasm has some hand in the process is made evident by the fact that killing the protoplasm is sufficient to stop the proteolysis, although the means taken are those which do not inhibit the action of enzymes. Moreover, when the cells of the cotyledons are placed under abnormal conditions, the hydrolysis of the proteids ceases. It is, of course, possible that the complete hydrolysis is carried out by the protoplasm and that the ereptase has no share in it. There is something to be said for either view. It might be pointed out that the ereptic activity as shown by the tissues of the cotyledons when acting on Witte peptone is quite sufficient to accomplish the ereptic part of the complete proteolysis. Moreover, the very fact that an enzyme is present which is capable of doing part of the work of cleavage would lead one to infer that it had some part to play in the process. On the other hand, it has been shown that the cotyledons contain relatively less ereptase than the ordinary vegetative organs, and that there is no increase, or at the most a very slight one, in the enzyme content during germination.

The investigation of the other ograns of the plant shows that they all contain the ereptase in somewhat varying quantities, the roots containing the most per unit of nitrogen. There is no evident explanation for these quantitative variations, nor for the function of the enzyme in the metabolism of the cells.

We have good reasons for believing that the life of every active cell is intimately bound up with a round of chemical changes of which one part consists in a cleavage of the protoplasmic proteids. It is quite conceivable that the means by which the cleavage is effected may vary in different cells; in some the whole process may be carried out by the protoplasm itself, unassisted by any of its enzymatic tools; in other cells the protoplasm may start the process and split off proteoses from itself which are subsequently attacked by an ereptic enzyme and broken down to the amido-acids, hexon bases etc.; in still other cases it may be that the complete hydrolysis is carried out by an enzyme or combination of enzymes. The bridging of the gap between widely different forms by a series of small variations is a characteristic of the morphology of living organisms. That same sort of bridging is no less characteristic of their physiological processes. For example, we find all stages of dependence upon oxygen, from plants which are killed by its absence to those which are killed by its presence. It is not inconceivable that there exists an analogous range of differences in the means which various plants take to accomplish the cleavage of their metabolic proteids.

At any rate it has been shown by the researches of various investigators that enzymes are present in animal and vegetable tissues of both the tryptic and ereptic type. There has not yet been found a tissue which has been definitely shown to contain no proteolytic enzymes whatever, and which must therefore complete its processes of proteolysis by the activity of its protoplasm. Our knowledge is too limited to allow us to say that such tissues do not exist; that point must be left for future investigations.

The investigation, of which this is a report, was carried out with the assistance of a grant from the Carnegie Institution of Washington.

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CONTRIBUTIONS TO THE BIOLOGY OF RHIZOBIA. IV: TWO COAST RHIZOBIA OF VANCOUVER ISLAND, B. C.[1]

ALBERT SCHNEIDER.

(WITH THREE FIGURES)

LEGUMINOUS plants are comparatively rare on Vancouver Island. Two species, beach vetch (*Lathyrus maritimus* Bigel.) and beach clover (*Trifolium heterodon* Gray), were more carefully examined with regard to root nodule formation and proved rather interesting. Of these two plants, the vetch is by far the more common and more widely distributed. It is creeping, climbing, and spreading in habit, thus being endowed with certain advantages in the struggle for existence. It climbs upon and spreads over the smaller and less fortunate herbs, thus gaining access to the desirable air and sunlight. The beach clover, in common with the majority of clovers, was originally adapted to the sunlit open ground, but the tree vegetation of the island has compelled it to occupy an extreme shore position. In the struggle for existence it has evolved into a hardy persistent plant, clinging tenaciously to the scant soil in the crevices of rocky shore slopes, approaching the high tide mark. During the often prolonged heavy inland winds of the winter months, these plants are thoroughly drenched by the salt waves and salt spray without suffering any inconvenience whatever. In appearance beach clover is not unlike our familiar white clover (*T. repens*); the plants however are larger, and the flowers are larger and more showy.

The roots of both plants were well supplied with rhizobia-bearing nodules. Sections were made of these and examined microscopically. In the case of beach clover the rhizobia presented the general morphological characteristics of those found in the nodules of red and white clover (*fig. 1*). That is, they were of the very characteristic Indian club form, with very distinct bodies described by some as granules

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[1] The work here recorded was done at the Minnesota Seaside Station, session of 1904.

of amylodextrin or degenerate proteids, and which I have elsewhere designated as sporoids. The etiology and function of these bodies still remains to be determined. Some of the rhizobia showed distinct traces of forking (Y-forms), but the majority were of the Indian club form, derived from Y-forms, while a few were of uniform width, evidently derived from simple unbranched rod forms.

FIG. 1.—Rhizobia from the root nodules of beach clover (*Trifolium heterodon* Gray), showing extreme form variation of *R. mutabile*, due to hyper-nutrition; same organisms with the so-called sporoids.

The rhizobia of beach vetch were rather remarkable for their branching (*fig. 2*). They present the general morphological characteristics of the rhizobia of sweet clover, bur clover, and other vetches. The branching, however, is more pronounced than in any other form of this type hitherto examined. The branching is dichotomous and may be either unipolar or bipolar. The highly refractive sporoids are not present, nor have they ever been observed in rhizobia of this type.

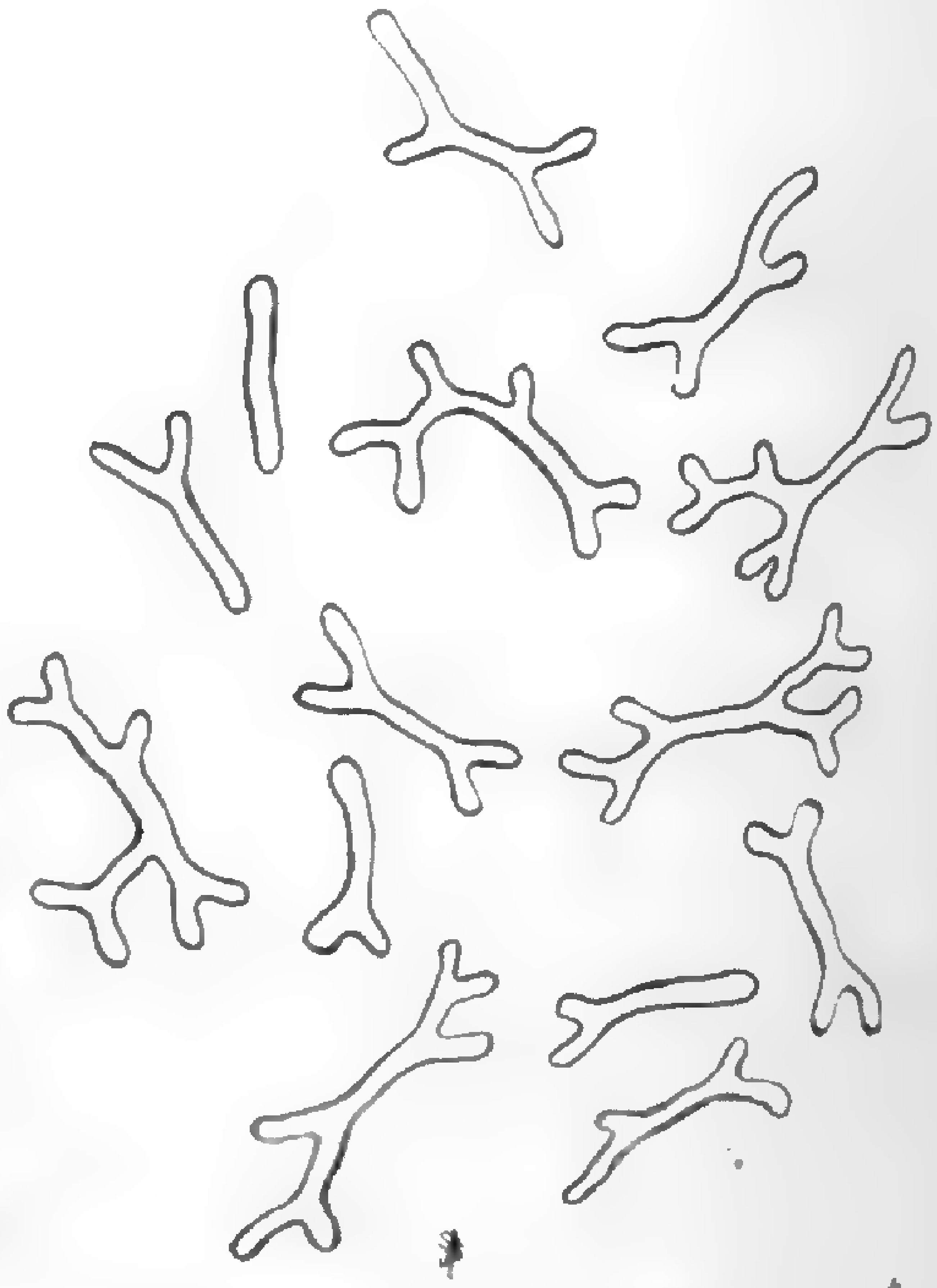

FIG. 2.—Rhizobia from the root nodules of beach vetch (*Lathyrus maritimus* Bigel.), representing the extreme branching form of *R. mutabile*, due to hyper-growth.

It is highly probable that these two rhizobia (of beach vetch and beach clover) represent two extreme natural form types of *Rhizobium mutabile* (*R. leguminosarum* Frank). Assuming that the rod forms and simple Y-forms are the original normal types, we have in the rhizobia of beach clover (and in other clovers) the extreme form deviation, apparently due to hyper-nutrition; and in the rhizobia of beach vetch the extreme branching form, due to hyper-growth. This supposition is strengthened by the study of rhizobia in artificial culture media. Grown in the same culture media the rhizobia of sweet clover and red clover are morphologically identical. Whether they are physiologically identical has not been determined, although this is also probable according to the inoculation experiments of NOBBE, HILTNER, and HOTTES, of Germany, which are supported by the research of MOORE of the Department of Agriculture. It is quite apparent that these variations in form are due to the food-supply or nutritional changes, variations in the supply of oxygen and moisture, variations in chemical reaction, temperature, light, and other ecological factors. It is possible by means of special culture media to augment very decidedly the branching in the rhizobia of sweet clover and to induce other morphological variations, as has frequently come under my observation. It should be noted that the so-called sporoids do not appear in the rhizobia in artificial culture media. This is of considerable importance, as it was once believed that these bodies were of sufficient significance to be of specific rank. It would appear from these observations that they are more likely by-products stored within the cell, having perhaps food value, derived from the host plant. If this supposition is correct, the theory that they are etiologically sporoidal in nature is untenable.

It seems very probable, and wholly within the range of the possible, that the two extreme form types here described are phylogenetically derived from an original form type similar to, but not necessarily identical with, the form found in *Cassia Chamaecrista, Robinia pseudacacia, Trigonella foenum graecum*, and *Amphicarpaea comosa*, which were formerly described as distinct species. From this it does not follow, of course, that these form types are of necessity variations of one and the same species, although the evidence thus far deduced points in that direction.

The presence of the *Infectionsfäden* was noted (*fig. 3*), and nothing new regarding their significance was discovered, only I wish to state, by way of readjustment of what was stated in previous papers, that in all probability these threads are merely a phenomenon dependent upon the infection of the root cells by the rhizobium. The action of the motile forms in the apical area of the root nodule (formerly described as a distinct species, *R. Frankii*) causes the appearance of the threads in a manner already explained.

The question of Rhizobia species is not yet settled, and cannot be settled until our information regarding their biology is much more complete. The fact that extensive research work has already been done by a large number of investigators without coming to any conclusion regarding species should serve as a very suggestive lesson to species hunters. In the case of *R. mutabile,* the question is now arising as to whether it is a microbe (Schizomycete) or a hyphal fungus, a question which we hope to discuss more fully in some future paper. All investigators are agreed that *R. mutabile* is an organism showing extreme polymorphism. It would appear to be an organism wonderfully adapted to test the De Vriesian theory of mutation as it applies to low organisms. At this time the only statement ventured is that apparently constant natural variations in *R. mutabile,* as above indicated, at once become transformed into "variable or unstable vari-

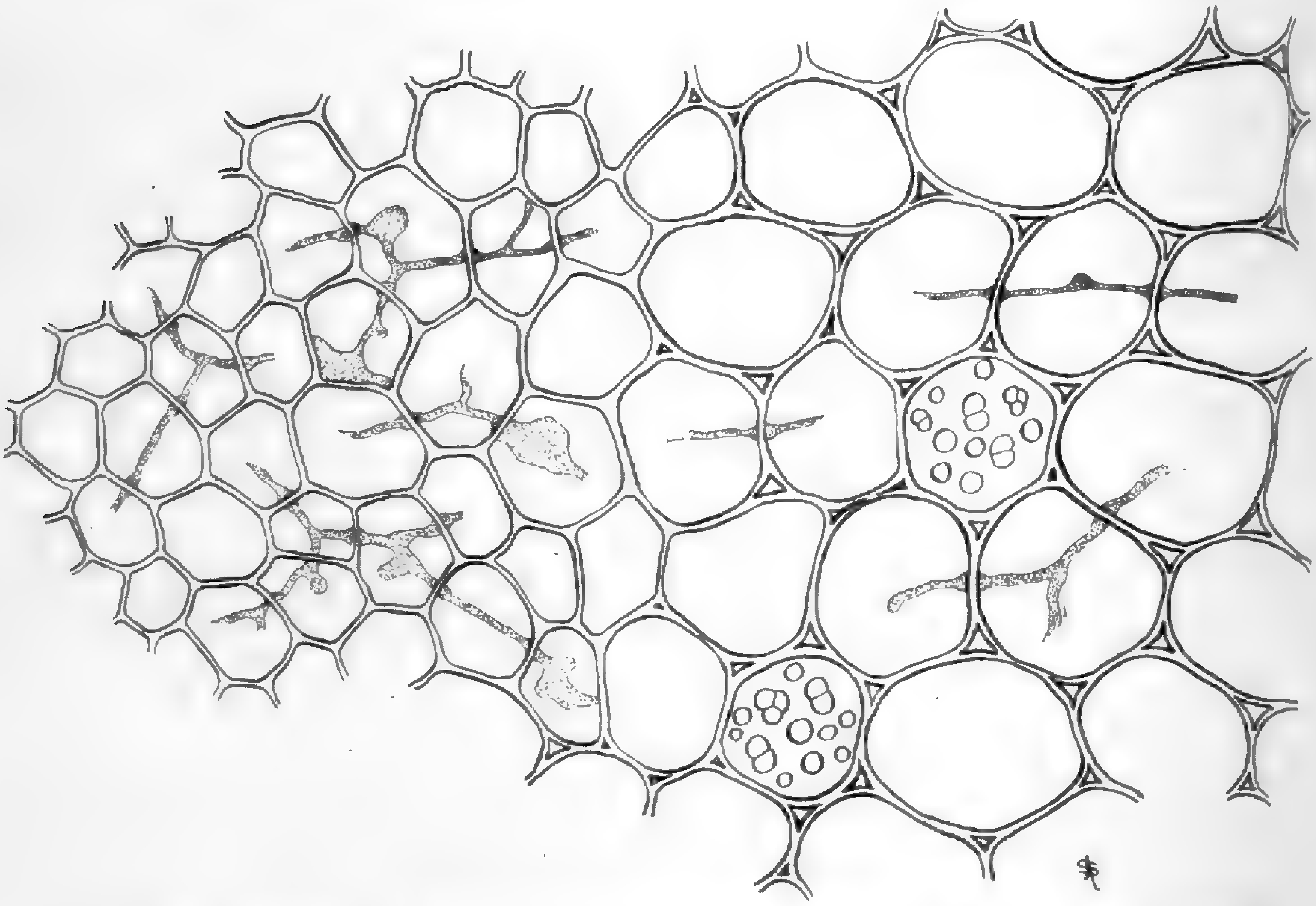

FIG. 3.—Portion of longitudinal section of root nodule of beach vetch (*Lathyrus maritimus* Bigel.) showing *Infectionsfäden,* more abundant in the apical area; rhizobia are not shown; two starch-bearing cells.

ability" in artificial culture media. It would appear that the newer conception of species as based upon the facts of ecology; study of mutation, constant and variable; crossing, artificial and natural, etc., will necessitate a complete change in our present systems of classification.

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BRIEFER ARTICLES.

THE VITALITY OF SEEDS.

In the autumn of 1879 I began the following experiments, with the view of learning something more in regard to the length of time the seeds of some of our most common plants would remain dormant in the soil and yet germinate when exposed to favorable conditions. I selected fifty freshly grown seeds from each of twenty-three different kinds of plants. Twenty such lots were prepared with the view of testing them at different times in the future. Each lot or set of seeds was well mixed in moderately moist sand, just as it was taken from three feet below the surface, where the land had never been plowed. The seeds of each set were well mixed with the sand and placed in a pint bottle, the bottle being filled and left uncorked, and placed with the mouth slanting downward so that water could not accumulate about the seeds. These bottles were buried on a sandy knoll in a row running east and west, and placed fifteen paces northwest from the west end of the big stone set up by the class of 1873. A bowlder stone barely even with the surface soil was set at each end of the row of bottles, which were buried about twenty inches below the surface of the ground. I should make an exception in the case of the acorns, which were placed in the soil near the bottles, and not inside bottles. At the end of five, ten, fifteen, twenty, and now twenty-five years, sets of these seeds were tested for vitality. The names given in the following table were those in use when the seeds were buried. Some of those marked *x* germinated; none of those marked *o* germinated.

In all the species in the five tests made, eight out of twenty-two failed to germinate; and of the remaining fourteen, some of ten species germinated, often when they had been buried twenty-five years. The acorns buried near the bottles were all dead at the end of two years. I soon began other experiments with acorns, and in addition planted some black walnuts with the acorns. On a sandy knoll these nuts were buried at various depths in a hole the depth of which was equal to the length of a spade and handle, some of them three feet or more below the surface. After they had remained nearly two years, some of them were examined with the following results: Some of the walnuts and acorns planted only a few inches beneath the surface had come up the next summer after planting, while those planted at

[AUGUST

Names of seeds tested	5th year	10th year	15th year	20th year	25th year
Amaranthus retroflexus	x	x	x	x	x
Ambrosia artemisiaefolia	o	o	o	o	o
Brassica nigra	o	x	x	x	x
Bromus secalinus	o	o	o	o	o
Capsella Bursa-pastoris	x	o	x	x	x
Erechthites hieracifolia	o	o	o	o	o
Euphorbia maculata	o	o	o	o	o
Lepidium virginicum	x	x	x	x	x
Lychnis Githago	o	o	o	o	o
Maruta Cotula	x	x	x	o	x
Malva rotundifolia	x	o	o	x	o
Oenothera biennis	x	x	x	x	x
Plantago major	o	o	x	o	o
Polygonum Hydropiper	o	x	x	x	x
Portulaca oleracea	o	x	x	x	x
Quercus rubra	o	o	o	o	o
Rumex crispus	x	?	x	x	x
Setaria glauca	x	x	x	o	x
Stellaria media	x	x	x	x	x
Thuja occidentalis	o	o	o	o	o
Trifolium repens	o	o	o	o	o
Verbascum Thapsus	x	?	x	x	o

a depth of about eight inches to two feet or a little over had all decayed. All the walnuts deeply planted had decayed, but some of the acorns planted two or three feet below the surface were still alive, or rather the young plants were alive. They had probably started soon after planting, as the cotyledons were exhausted, their nourishment having been used in developing roots and pushing up an ascending axis.

On August 12, 1889, after a part of the nuts had been planted and undisturbed for two months less than four years, I examined them. Eight acorns were found alive, with the roots about like the roots of those dug up two years before. The ascending axis in most cases was slender and crooked, with a delicate white apex. In one case there was no ascending axis, but a solid, fleshy root, apparently alive.

In all tests of the seeds buried in bottles, the results have been indefinite and far from satisfactory. I mean by this that I have never felt certain that I had induced all the sound seeds to germinate. I moisten the sand containing the seeds, and forthwith a goodly number germinate, and then they come slowly straggling along. I dry the soil and wait a few days, and after moistening, in a few days more seeds germinate. Why was I unable to induce them to start when treated to various degrees of temperature and moisture for seven months?

We see this important point. It is to the advantage of the plants not to shoot up all of their seeds at one time, but to retain a good portion alive in the soil to be ready for stocking the earth in successive years. Again, we must consider that it makes very little difference whether all the seeds live over for a time or only a small proportion of those which were produced, as a living seed now and then left is enough to save the stock and produce new crops of seeds.

The seeds I began testing in August 1894 were kept in trial until November of that year, when the plates containing the dry sand were set away dry until the next spring, and kept in test for that year until November 1895. In this second year some seeds of eight species germinated.

In the sets of seeds which were put in condition, as I supposed, to germinate in July 1899, after being buried twenty years, some seeds of eighteen species grew during the following four months, when the plates were set away till the next April (1900), at which time the sand was occasionally wet. During this period, some seeds of mustard, mallow, shepherd's purse, and chickweed germinated.

In September 1882 I selected of the second crop of red clover five plants within a few feet of each other, which seemed much alike. The seeds of fifty good heads of each, containing 1260–1820 seeds, were shelled, and ever since, till tested, they have been kept, each lot by itself, in a two-ounce bottle well corked. For a portion of the time they were exposed to the light; for some years they have been kept in a dark closet. Nearly twelve years after collection, fifty seeds of each lot were tested for vitality, with the following results:

Of no. 1 - - - - -	24	germinated
Of no. 2 - - - - -	8	"
Of no. 3 - - - - -	34	"
Of no. 4 - - - - -	25	"
Of no. 5 - - - - -	0	"

Two weeks later another test of fifty seeds each was made:

Of no. 1 - - - - -	31	germinated
Of no. 2 - - - - -	10	"
Of no. 3 - - - - -	32	"
Of no. 4 - - - - -	21	"
Of no. 5 - - - - -	4	"

This is an average for both tests of 35.8 per cent. The difference in germination percentage of these lots of seeds perhaps may be accounted for by the presence of weevil in a few seeds; by difference in the size of seeds, or the stage of maturity; by individual peculiarities of the different plants. By some means, since testing, the bottle no. 4, containing the seeds, has been lost.

On November 16, 1904, over twenty-two years from collecting, I began tests of 100 seeds of numbers 1, 2, 3, 5, with the following results:

Of no. 1 - - - - -	0	germinated
Of no. 2 - - - - -	0	"
Of no. 3 - - - - -	5	"
Of no. 5 - - - - -	1	" possibly a second one

—W. J. BEAL, *Agricultural College, Michigan.*

SOME MEXICAN SPECIES OF CRACCA, PAROSELA, AND MEIBOMIA.

(WITH PLATE V)

THE genus name Cracca of Linnaeus (1753) has of late years been restored in place of the Tephrosia of PERSOON (1807), which is clearly a synonym, as has been well pointed out by Mr. E. G. BAKER.[1]

Dalea, although first proposed by LINNAEUS in 1737, was reduced by him in 1753 to Psoralea. It was not restored until after PATRICK BROWNE in 1756 had published his Dalea, and therefore the next available name, Parosela, must be used.

The Meibomia of ADANSON (1763) has properly been taken up in place of Desmodium (DESVAUX, 1813), which must be treated as a synonym, though there is some ground for regarding the two names as representing different genera.

An examination of these three genera by Mr. ROSE in connection with his *Studies of Mexican plants* has shown that they are greatly in need of revision, and considerable work has been done with a view to meeting this want. Mr. PAINTER has a revision of the Mexican and Central American species of Meibomia well advanced. It was not the intention to publish any notes on these genera until our revisions were completed; but there has been considerable demand, both from general collectors and from botanists who have been working on Mexican fungi, for correct names for certain species; and we have concluded to publish a few of the new combinations and new species at the present time.

Cracca talpa (S. Wats.) Rose.—*Tephrosia talpa* S. Wats. Proc. Am. Acad. **22**:405. 1887.

Cracca macrantha (Rob. & Greenm.) Rose.—*Tephrosia macrantha* Rob. & Greenm. Proc. Am. Acad. **29**:383. 1894.

Cracca Pringlei Rose, sp. nov.—Herbaceous perennial much branched at base; branches 10 to 20^{cm} long, appressed-pubescent: leaflets 7 to 10

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[1] Jour. Botany, Jan. 1900.

pairs, oblong, 8 to 15^{mm} long, green above and with scattered hairs, densely cinereous beneath, rounded and mucronate at tip: infloresence short and compact, not much exceeding the leaves: calyx lobes narrow: corolla purplish, the banner 15^{mm} long: ovary very hairy; pods (immature) 4^{cm} long.

Collected by C. G. Pringle on hills of Las Sedas, Oaxaca, July 22, 1897 (no. 6741).

Type in the U. S. National Herbarium.

Parosela mutabilis (Cav.) Rose.—*Psoralea mutabilis* Cav. Ic. **4**:65. *pl. 394.* 1797. *Dalea mutabilis* Willd. Sp. Pl. **3**:1339. 1801.

Parosela acutifolia (DC.) Rose.—*Dalea acutifolia* DC. Prod. **2**:245. 1825.

Parosela uncifera (Schlecht. & Cham.) Rose.—*Dalea uncifera* Schlecht. & Cham. Linnaea **5**:580. 1830.

Parosela triphylla (Pavon) Rose.—*Dalea triphylla* Pavon, Linnaea **12**:289. 1838.

Parosela procumbens (DC.) Rose.—*Dalea procumbens* DC. Prod. **2**: 246. 1825.

Meibomia (HETEROLOMA) **Metcalfii** Rose & Painter, sp. nov.—Herbaceous, erect with ascending, striate branches: leaves trifoliolate, narrowly ovate-lanceolate, 3 to 5^{cm} long, 0.6 to 1.5^{cm} wide, obtuse at base, acute at apex, margins revolute, upper surface sparsely hirsute with short hairs, dark green, under surface lighter green and glabrous, veins more prominent below than above; petioles angled, of lower leaves 3^{cm} long, of upper leaves nearly wanting; stipules deciduous: inflorescence in open panicles, its racemes terminal and lateral: flowers small, on pubescent pedicels; bracts acuminate, pubescent, early deciduous: calyx purplish, of 5 unequal teeth: corolla small, purplish: ovary pubescent, stipitate; loment decidedly stalked, of 2 to 5 joints, these much longer than broad and covered with uncinate hairs.

Collected by Mr. O. B. Metcalf in the Black Range, Animas Creek, Grant County, New Mexico, on ditch banks, altitude 1,500^{m}, July 13, 1904 (no. 1137).

A species with the aspect of *M. paniculata* (L.) Kuntze, but more closely related to *M. Lindheimeri* Vail.

Meibomia (HETEROLOMA) **pinetorum** Rose & Painter, sp. nov.—Herbaceous, stem glabrous, trailing, 1 to 2^{m} long, with ascending branches: leaves trifoliolate; leaflets 1 to 3.5^{cm} long, 1 to 3^{cm} wide, thin, broadly oval, obtuse and mucronate at apex, very sparingly hirsute on the upper surface with scattered appressed hairs, the lower surface lighter green with the primary veins prominent, covered with fewer scattered appressed

MEIBOMIA PALLIDA ROSE and PAINTER

hairs; petioles 1 to 3^{cm} long, glabrous; petiolules of lateral leaflets 1 to 3^{mm} long, of terminal leaflets 8 to 15^{mm} long, pubescent; stipules persistent, small, long-acuminate, glabrous: inflorescence in a simple terminal or lateral axillary raceme; flowers purple, on filiform pedicels; floral bracts deciduous, ovate, acuminate, somewhat puberulent: calyx unequally 5-toothed, pubescent: loment 3 to 4, rarely 5-jointed, almost sessile, the joints covered with uncinate pubescence.

Collected by Mr. C. G. Pringle about Trinidad Iron Works, Hidalgo, Mexico, in pine woods, altitude 1650^{m}, September 15, 1904 (no. 8890).

Type in U. S. National Herbarium, no. 461381.

This species is nearest *M. orizabana* (Hemsl.) Kuntze, but is easily distinguished from that species by its obtuse, oval leaves, prostrate habit, and loment more deeply constricted above.

Meibomia xylopodia (Greenman) Rose & Painter.—*Desmodium xylopodium* Greenman, Proc. Am. Acad. **39**:80. 1903.

Meibomia (Chalarium) **pallida** Rose & Painter, sp. nov.—Low, shrubby, 20 to 30^{cm} high: leaves all unifoliolate, the lowest orbicular or broadly oval, obtuse, upper oblong, mucronulate, all pale green, obtuse at base, above covered with short uncinate pubescence, less so and reticulate-veined beneath, midrib prominent, pubescent; petioles pubescent, 2 to 5^{mm} long; stipules deciduous, ovate-acuminate, pubescent and with prominent veins; stipels subulate, pubescent, 1^{mm} or less long: inflorescence in a terminal simple raceme which is densely pubescent; flowers purple; pedicels when fully matured 5 to 6^{mm} long, pubescent; bracts deciduous, lanceolate-ovate, long-acuminate, ribbed: calyx pubescent, the teeth unequal: ovary appearing spirally twisted, pubescent; loment about 5-jointed, the joints inflated, glabrous, reticulate-veined.

Collected by Mr. E. W. Nelson at Huilotepec, Oaxaca, Mexico, altitude 25^{m}, May 4 to 11, 1895 (no. 2587).

Type in U. S. National Herbarium, no. 40034.

The affinity of this species is with *M. xylopodia* (Greenman) Rose & Painter, but it differs in the glabrous loments and the paler green leaves.

Explanation of Plate V: *a*, plant (×⅔); *b*, floral bracts (×7); *c*, flower (×5); *d*, fruit (×2½).

Meibomia (Chalarium) **rubricaulis** Rose & Painter, sp. nov.—Low shrub, twigs reddish-brown, older ones with striate and whitish bark: leaves small, trifoliolate, petiolate; petioles 5 to 12^{mm} long, covered with short pilose hairs; terminal leaflets obovate, 8 to 12^{mm} long, 6 to 10^{mm} broad, the lateral leaflets mostly oval, at times somewhat obovate, rounded, mucronulate at apex and rounded at base, upper surface minutely roughened with very short hairs, beneath pilose, reticulate, the veins more prominent beneath than above; stipules long-persistent, subulate lanceolate: inflorescence terminal and lateral, of simple racemes; flowers purple, on pilose pedicels (5^{mm} long); bracts lanceolate, early deciduous: calyx lobes equal, obtuse, pubescent: ovary puberulent; loment 2 to 5-jointed, decidedly stipitate, the joints reticulate-veined, 4^{mm} long and 3^{mm} wide, with a very narrow isthmus (not quite central) rarely half as long as adjacent joints.

Collected by Dr. E. Palmer at Tequila, Jalisco, August-September 1886 (no. 398); by C. G. Pringle, on rocky hillsides near Guadalajara, Jalisco, October 1, 1891 (no. 3877); by J. N. Rose & Jos. H. Painter, vicinity of Rio Blanco, Jalisco, September 30, 1903 (no. 7492); and by C. G. Pringle on mountains about Etzatlan, Jalisco, October 2, 1903 (no. 11413; type, no. 460875 of the U. S. National Herbarium).—J. N. Rose and Jos. H. Painter, *U. S. National Museum.*

A NEW KRYNITZKIA

Mr. W. N. Suksdorf, who for a number of years has made quite extensive collections of plants in the northwest, more especially in the state of Washington, sent recently to the Gray Herbarium a consignment of specimens containing several species of particular interest. Among these rarities is a Krynitzkia which deserves an early record. Flowering specimens of this plant were first secured in the spring of 1901; and in June of the past season fruiting material was obtained. These collections have been placed at the disposal of the writer for study, and a careful comparison with the entire representation of the genus in the Gray Herbarium shows that the Suksdorf plant is most nearly related to *K. oxycarya* Benth. and *K. rostellata* Greene. From type material of both these species the Suksdorf plant differs in several important characters, and it seems best, therefore, to regard it as specifically distinct. The writer takes pleasure in dedicating the new species to its collector. The plant may be characterized as follows:

Krynitzkia Suksdorfii Greenman, n. sp.—A small annual: stem erect, 0.5 to 1.5^{dm} high, simple or branched from the base, canous-strigose: leaves opposite below, alternate above, spatulate to linear, 0.5 to 1.5^{cm} long, 1 to 3.5^{mm} broad, obtuse, entire, subappressed-tuberculate-hispid: flowers small, sessile: calyx deeply 5-parted, about 2.5^{mm} long in anthesis, pubescent with spreading slightly curved stiff hairs, persistent, becoming 4^{mm} long in fruit and surrounding the single mature nutlet; lobes of the calyx linear, acute: corolla about 3^{mm} in length; lobes subrotund, 1^{mm} in diameter: stamens adnate to the corolla-tube for about one-half its length; anthers sessile: mature nutlets narrowly ovate, 2.5^{mm} long, acuminate, smooth and shining, pale chocolate-colored, somewhat mottled with darker spots; the ventral surface slightly flattened and the groove bifurcated at the base.—WASHINGTON: on dry hillsides near Rockland, Klickitat County, 18 April 1901, *Suksdorf*, no. 1495 (flowering specimen), and 8 June 1904 (fruiting specimen); on dry hillsides near Dallas City, 17 April 1901, *Suksdorf*, no. 2346 (flowering specimen). Type in herb. Gray.

This species differs from *K. oxycarya* Benth. in having shorter broader leaves, somewhat larger corolla, more prominently beaked, darker colored and mottled nutlets which are bifurcately grooved on the ventral side near the base. From the Californian *K. rostellata* Greene, *K. Suksdorfii* differs in having somewhat smaller habit, shorter, broader leaves, much shorter branches of the inflorescence, slightly larger corolla with broader corolla-lobes, and shorter calyx-lobes in the fruiting state.—J. M. GREENMAN, *Gray Herbarium.*

CURRENT LITERATURE.

BOOK REVIEWS.

The origin of species and varieties by mutation.

PROFESSOR DEVRIES[1] has hit upon a method for presenting his experiments and theories to the English-reading public that is as happy as it is unique. It is commonly the fate of an epoch-making work, such as *Die Mutationstheorie* has proved itself to be, to undergo a translation into other tongues in the course of three or four years, without alteration except for some inevitable changes for the worse. DeVries has taken into his own hands the preparation of the English exposition of mutation, and we have as a result a book that is written for a very different audience, couched in different language, and prepared in the light of the experiments and discussions of the past four years. The investigator who desires the minutiae of DEVRIES' experimental results will still have recourse for the most part to the earlier volumes, but as investigators are supposed to be conversant with the German language and with the technical terminology there employed, no difficulty results. The investigator, however, will require the present volume for the broader viewpoint, and for the contributions that have appeared since 1901. The great and undisputed field for the present volume is the presentation of mutation to the large and important audience of intelligent people to whom German is a foreign language, and technical terminology more so.

The volume under consideration is based on a course of lectures given at the University of California in the summer of 1904, and was edited by D. T. MACDOUGAL of the New York Botanical Garden, whose experiments and contributions have done so much to make Americans conversant with the work of DEVRIES. One of the most valuable and interesting of his lectures is the preliminary one, dealing with theories of evolution and methods of investigation. Here there is an excellent portrayal of the relation that exists between his contributions and those of others; and it is at once clear that the work of DARWIN is not opposed but supplemented and strengthened; DARWIN'S comparative studies resulted in the accumulation of a vast array of material, while DEVRIES' work has systematized this material, and has given us an experimental basis for the belief in evolution. It is to be hoped that the perusal of this volume will put an end to the notion, so widely circulated in the newspapers, that DEVRIES is a destroyer of Darwinism.

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[1] DEVRIES, HUGO, Species and varieties; their origin by mutation. Edited by D. T. MACDOUGAL. 8vo., pp. xviii+847. Chicago: The Open Court Publishing Co. 1905.

The following lectures outline the characteristics of elementary species, both in nature and in cultivation, and it is shown that natural selection must play a large part in determining their survival. Varieties are shown to differ from elementary species in not possessing anything that is really new, and in originating commonly by the loss of some quality. Several chapters deal with the various kinds of varieties, retrograde, progressive, and ever-sporting; in the same connection the subject of atavism is elucidated, as well as latent characters, and vicinism or variation under the influence of pollination by neighboring individuals. The lectures on mutations deal not alone with Oenothera, but as well with the peloric toadflax, double flowers, and a great many wild and cultivated plants that are supposed to illustrate mutation. A lecture that will be read with great interest by paleontologists, as well as others, is the one that considers the periodicity of mutations, and the relation that mutation bears to the length of geological time. The final lectures present the topic of fluctuating variations, and perhaps it is here that Darwinians will find least comfort in the work of DEVRIES. The closing words of the book, quoted from ARTHUR HARRIS, will be recognized as most apt: "Natural selection may explain the survival of the fittest, but it cannot explain the arrival of the fittest."

In a review of *Die Mutationstheorie* (BOT. GAZ. **33**:236–239. 1902), it was felt to be too soon to express an opinion concerning the place which that work would occupy in the literature of evolution, although it was the reviewer's intuition that this place would be very high. Of the permanent value of that work, and of the work here under review, there is now no doubt at all. "The greatest contribution since DARWIN" is the universal testimony, and there is a feeling on all sides that the answers to many evolutionary questions are close at hand, and that through the application of experiment. To many of us the new volume brings more than did the old, because we have now seen the author face to face, and have perpetually in mind the modest, lovable man, as well as the renowned investigator.—H. C. COWLES.

MINOR NOTICES.

EMERSON[2] has published the results of experiments in the control of the rust and scab of apples. He finds that the rust of apples due to species of Gymnosporangium can be prevented by spraying with Bordeaux mixture if the first application is made when the gelatinous spore-containing projections first appear on the "cedar apples." This spraying should then be followed by a second spraying about ten days or two weeks after the first. He recommends also that the cedar apples be removed from cedar trees near orchards in the winter or early spring, and that where practicable cedar trees themselves should not be allowed to remain within one mile of apple orchards. The scab he found could be prevented by spraying twice with Bordeaux mixture, once just before the apple blossoms open and again just after the blossoms fall.—E. MEAD WILCOX.

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[2] EMERSON, R. A., Apple scab and cedar rust. Bull. Nebraska Exp. Sta. **88**: pp. 21. *figs. 9.* 1905.

Christensen[3] has begun the publication of an *Index Filicum*, which is intended to do for ferns what the *Index Kewensis* does for seed-plants. The book will contain a systematic enumeration of the genera, based upon Engler and Prantl's *Pflanzenfamilien;* an alphabetical enumeration of species and synonyms, which will include all names and combinations of names published from 1753 to 1905 and also names of garden ferns; and an alphabetical catalogue of literature containing critical notes and descriptions of new genera and species. The work will be complete in eleven or twelve parts, and the entire manuscript is ready for printing, awaiting only a sufficient subscription. The first fascicle, just issued, begins the alphabetical list of genera and species, closing with Aspidium.—J. M. C.

Merrill[4] has attacked the species described in Blanco's monumental *Flora de Filipinas*, recognizing that they must be identified and made available so far as possible. He has brought together these identifications in a conveniently arranged bulletin, calling special attention to the species that are yet to be identified. To give some idea of the results attained by this absolutely isolated worker, it may be said that in the two editions of the *Flora* (1837 and 1845) Blanco described 1127 species and varieties; about 623 of these were proposed as new, and 504 identified with species of other authors, 219 of them correctly and 285 incorrectly. A large proportion of the new species remain unknown, and only 90 are known to be valid.—J. M. C.

Hitchcock[5] has published an elaborately illustrated synopsis of the North American species of Agrostis, recognizing twenty-seven species and describing three as new. It is announced as the intention of the department to publish occasional monographs of the larger genera of grasses.—J. M. C.

Husnot[6] has published the first part of an illustrated synopsis of the Cyperaceae of France, Switzerland, and Belgium. This part contains Elyna, Kobresia, and Carex. The important characters of each one of the 123 species of Carex are illustrated.—J. M. C.

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[3] Christensen, Carl, Index Filicium sive enumeratio omnium generum specierumque Filicum et Hydropteridum ab anno 1753 ad annum 1905 descriptorum adjectis synonymis principalibus, area geographica, etc. Fasciculus 1. pp. 64. Copenhagen: H. Hagerups Boghandel. 1905. Each part 3*s* 6*d*.

[4] Merrill, Elmer D., A review of the identifications of the species described in Blanco's Flora de Filipinas. Bull. 27, Bureau of Gov't. Labs., Department of Interior. Manila. 1905.

[5] Hitchcock, A. S., North American species of Agrostis. Bulletin 68, Bureau of Plant Industry, Department of Agriculture. pp. 68. *pls. 37*. 1905.

[6] Husnot, T., Cypéracées: descriptions et figures des Cypéracées de France, Suisse et Belgique. Part 1. pp. 48. *pls. 12*. Cahan, par Athis (Orne): the author. 1905. 5 *fr*.

NOTES FOR STUDENTS.

Apogamy in the genus Alchemilla has been investigated very thoroughly by Strasburger.[7] The work was suggested by Murbeck's researches; and his statements that the embryo of the Eualchemillae develops from the egg without fertilization, and that there is no reduction of chromosomes in the life history, are confirmed. On the other hand, Strasburger reaches a different conclusion as to the origin of the embryo sac of apogamous species of Alchemilla, and has a different theory as to the nature of the embryogeny of these species.

More than forty species were studied. In the European species the pollen, except in a few species, is abnormal, the development being checked at various stages. The pollen mother-cells may disorganize or a tetrad may be formed, but the pollen grains fail to be liberated from the mother-cell. In some cases, the division into tube nucleus and generative nucleus takes place, but such pollen grains disorganize early. There are thirty-two bivalent chromosomes in the pollen mother-cells, and sixty-four univalent chromosomes in the vegetative tissues. In American and African species, an examination of herbarium material showed normal pollen, and it is probable that fertilization occurs in the usual way.

In the ovules of apogamous Eualchemillae one or more megaspore mother-cells appear. The nucleus passes through the prophases of the heterotypic division up to the synapsis stage, but here the mode of development changes and the nucleus divides by a typical vegetative division. Division in the embryo sac shows the sporophytic number of chromosomes, so that when the egg is formed it contains the vegetative number of chromosomes. When such an egg develops an embryo without fertilization, Strasburger regards the phenomenon not as parthenogenesis but as apogamy. Strictly speaking, it would not be even a case of apogamy, but we should have merely an adventitious embryo like one coming from cells of the nucellus. There is not the beginning of a new generation.

The subniveal Eualchemillae which form normal pollen show a reduction of chromosomes in the formation of the megaspores, and fertilization takes place in the usual way. Those Eualchemillae which have not lost their sexuality are chalazogams, and some of them form hybrids.

It seems probable that the extraordinary mutation of the Eualchemillae has weakened the sexuality, and that the failure of fertilization has brought on the apogamous condition.

Rubus and Rosa, which were also examined, have retained their sexuality in spite of extensive polymorphism. The reduction division and fertilization occur regularly.

Dioecism has in many cases given an impulse toward apogamous reproduction, since the separation of male and female individuals decreases the frequency of fertilization.—C. J. Chamberlain.

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[7] Strasburger, E., Die Apogamie der Eualchemillen und allgemeine Geschichtspunkte, die sich aus ihr ergeben. Jahrb. Wiss. Bot. **41**:88–164. *pls. 1–4.* 1905.

ITEMS OF TAXONOMIC INTEREST are as follows: S. LEM. MOORE (Jour. Botany **43**:137–150. *pl. 471.* 1905), in describing numerous new Australasian species, has described a new genus (*Cratystylis*) of Compositae (Inuloideae), with 3 species, and one (*Nepenthandra*) of Euphorbiaceae (Crotoneae).—H. CHRIST (Bull. Soc. Bot. France IV. **5**:1–69. 1905) has published an account of the Chinese ferns in the collections of the Museum of Natural History, Paris, describing 41 new species and a new genus (*Neocheiropteris*), to replace Cheiropteris, preempted by a genus of fossil plants.—M. A. HOWE (Bull. Torr. Bot. Club **32**:241–252. *pls. 11–15.* 1905) has described new species of Chlorophyceae from Florida and the Bahamas in Halimeda and Siphonocladus, and has established a new genus (*Petrosiphon*) related to the latter.—H. D. HOUSE (*idem* 253–260. *pls. 16–18*), in presenting Viola in New Jersey, recognizes 33 species and describes one as new.—MRS. E. G. BRITTON (*idem* 261–268) has proposed *Pseudocryphaea* and *Dendroalsia* as new genera of mosses, and has described new species in Erpodium.—A. ENGLER (Bot. Jahrb. **36**:213–252. 1905) has described the following new African genera: *Spondianthus* and *Nothospondias* (Anacardiaceae), *Magnistipula* (Rosaceae), *Pretreothamnus* (Pedaliaceae), and *Cycniopsis* (Scrophulariaceae).—M. L. FERNALD (Rhodora **7**:81–92. 1905) has begun the publication of a revision of the North American species of Eriophorum.—J. CARDOT (Rev. Bryol. **32**:45–47. 1905) has published two new genera of acrocarpous antarctic mosses, naming them *Pseudodistichium* and *Skottsbergia*, the peristome of the latter being described as most extraordinary.—A. A. EATON (Fern Bulletin **13**:51–53. 1905) has described a new species and variety of Iosetes from Washington.—J. W. BLANKINSHIP (Montana Agric. Coll. Sci. Studies **1**:35–109. *pls. 1–6.* 1905), in his "Supplement to the flora of Montana," has published new species in Sagittaria, Zygadenus, Salix, Arabis, Physaria, Sedum, Ribes, Saxifraga, Astragalus (2), Lupinus (4), Impatiens, Ammania, Bupleurum, Carum, and Petasites.—JESSIE MILLIKEN (Univ. Calif. Pub. Botany **2**:1–71. *pls. 1–11.* 1904), in a well-illustrated revision of Californian Polemoniaceae, recognizes 6 species of Polemonium, 5 of Collomia, 22 of Navarretia, 36 of Gilia, 31 of Linanthus, and 9 of Phlox, and describes new species in Gilia and Linanthus.—J. M. C.

PEIRCE[8] has studied the dissemination and germination of the seeds of *Arceuthobium occidentale* on the Monterey pine (*Pinus radiata*) of California. The structure and mechanics of the exploding fruit are described in detail; and the seeds were observed in the laboratory to be thrown fifteen feet, sticking to whatever they struck. The so-called seeds, by the way, are seeds enclosed in the inner part of the ovary. The field observations indicate that the majority of seeds strike the leaves of the pine, either of the tree on which they grow or of one near by. In germination the root is negatively phototropic and not very sensitive to contact. When growth is blocked by some obstacle the root forms a thick foot-like holdfast, into which the material in the upper end of the embryo

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[8] PEIRCE, GEORGE J., The dissemination and germination of *Arceuthobium occidentale* Eng. Ann. Botany **19**:99–113. *pls. 3–4.* 1905.

is transferred, the seedling becoming mainly a foot. Vascular elements form in the foot, and its central part grows out into the bark. Strands of infecting cells grow toward the medullary rays of the host, through these to the cambium, and finally effect an attachment with the young xylem elements. While the parasite is thus establishing a connection with the young wood, the main part of the haustorium forms a mass of parasitic cells in the cortex of the host. From this cortical mass buds arise and develop into branches that grow out through the bark into the air. The author remarks that "we have here an instance of regeneration without wounding, amputation, or other pathological stimulus. The small part of the seedling which penetrates the host forms and develops stem and leaves; a small part of one organ—the root—develops into a complete plant by forming the missing members."—J. M. C.

STEINBRINCK[9] finds that MEZ made a very imperfect study of the absorption hairs of Tillandsia, and that his erroneous conclusion could have been avoided easily by reference to published investigations of the author. According to MEZ the four central and empty cells of the hair are free from air and collapsed when dry; but when the thickened portion of the shield absorbs water the appressed walls are forced apart, leaving lumina into which water passes because of negative pressure. The author finds that negative pressure is not a factor at all, and bases this conclusion upon a study of the mechanics of cohesion involved in the shrinkage of artificial cells to which he finds natural cells are comparable. The author first demonstrates that water exercises a cohesive power, which being so well known is perhaps unnecessary. Next he shows that the shrinkage and collapse of artificial cells occurs in a vacuum as well as under ordinary pressure; also that the tension present in a membrane through which water is passing to supply evaporation is independent of air pressure. In the latter case water placed on the surface of such a transpiring membrane is quickly drawn inside because the cohesion pull of the water already inside extends through the fine pores of the membrane. Of course the greater the elasticity of the membrane the stronger cohesion pull it will support and the greater its capacity for bringing outside water within the cell. It is in this relation that the thickened *Deckel* of the scale plays a rôle and not as MEZ found.—RAYMOND H. POND.

KRASNOSSELSKY[10] has made a study of the influence of injury on the activity of the respiratory enzyme in the onion. In agreement with numerous other investigators he finds that injury does increase the respiratory activity of vegetable tissues, and points out that STOKLASA's failure to confirm this observation was due to his not allowing his experiments to run for a sufficient length of time, and that his belief that the results of other workers were due to bacterial con-

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[9] STEINBRINCK, C., Einführende Versuche zur Cohäsionsmechanik von Pflanzenzellen nebst Bemerkungen über den Saugmechanismus der wasserabsorbierenden Haare von Bromeliaceen. Flora **94**:464–477. 1905.

[10] KRASNOSSELSKY, T., Bildung der Amungsenzyme in verletzten Pflanzen. Ber. Deutsch. Bot. Gesells. **23**:142–155. 1905.

tamination is unfounded. Respiration increases gradually after injury, and it is only after several days that the maximum activity is reached. From that time the process goes on more slowly and finally returns to the normal. By grinding the onions with sand and expressing the juice with a Buchner press, he obtains solutions which liberate carbon dioxide, apparently through the agency of an enzyme. After injury this respiratory enzyme shows an increase in its activity, an increase which reaches a maximum somewhat later than the maximum respiration of the tissues from which the extracts are obtained. Onions whose cells are killed by freezing yield more active enzyme solutions than those not previously frozen. These expressed juices give the oxidase reaction with guaiacum, the juices from injured tissues more vigorously than those from uninjured ones.—ARTHUR L. DEAN.

VINES[11] has given the results of a number of experiments carried out for the purpose of throwing light on the nature of the tryptic enzymes of plants. He assumes that if the powers of a plant extract to convert native proteid into proteases and peptones on the one hand, and to reduce protones to the final cleavage products on the other, do not vary concomitantly under the influence of outside influences, then the two processes are carried out by separate enzymes. Experiments were conducted with the enzymes of *Carica Papaya*, *Ananas sativus*, *Saccharomyces Cerevisiae*, *Agaricus campestris*, *Hordeum sativum*, *Hyacinthus orientalis*, and *Nepenthes*. The proteids used were blood fibrin as a native proteid, and Witte peptone as a proteose and peptone mixture. The factors used to produce variation in proteolytic activity were changes in reaction. In every case it was found that solution of fibrin and cleavage of Witte peptone were affected differently by changes in reaction. VINES concludes that the two processes are carried out by different enzymes; the first stage by enzymes of the pepsin type; the second by those of the erepsin group. He is of the opinion, therefore, that pepsin-like enzymes do occur in plants and that the tryptic action is due to the combined action of such enzymes and those of the erepsin group.—ARTHUR L. DEAN.

MASSART'S[12] interesting experiments with geophilous plants should have been noted long since. In the case of the subterranean stock he sees a conflict between the depth of its burial and the development of aerial shoots. In each plant, therefore, there is a most favorable depth of the subterranean stock which is secured and maintained. Experiments were performed involving about two hundred species of plants, well distributed throughout monocotyledons and dicotyledons. Each species was treated in three lots: one lot very near the surface; another 10^{cm} deep; the third 20 to 30^{cm} deep. The results are outlined very briefly under two heads: methods of ascending when planted below the normal depth; and methods of descending when above the normal depth. The

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[11] VINES, S. H., The proteases of plants. III. Ann. Botany **19**:171–188. 1905.

[12] MASSART, JEAN, Comment les plantes vivaces maintiennent leur niveau souterrain. Bull. Soc. Roy. Bot. Belgique **41**^{2}:67–79. *figs. 12.* 1903.

methods of ascending from too great a depth are stated in outline as (1) elongation of internodes, (2) elongation of internodes and position of buds; (3) localization of buds, (4) curving of the rootstock, and (5) curving of the winter shoots. The methods of descending to a greater depth are (1) localization of the buds, (2) curvature of the rootstock, (3) curvature of the winter shoots, and (4) contraction of the roots.—J. M. C.

JOHNSON[13] has published a preliminary note in reference to his study of the Piperales. In addition to Peperomia, Piper, Heckeria, and Saururus, previously studied, he has studied recently Anemiopsis and Houttuynia (Saururaceae), and also representative genera of Chloranthaceae and Lacistemaceae. The general result is a confirmation of the view that the development of the megasporangium and female gametophyte of angiosperms is not a satisfactory index of genetic relationship, for it may vary widely within a single family or genus. In the genera of Piperales studied there is a variety in the development of the tapetum, megaspore, embryo sac, and endosperm nearly as great as can be found in the whole range of angiosperms. The development of the seed, however, suggests relationships of Piperaceae and Saururaceae to other dicotyledonous families; and the author concludes from such evidence that the Piperales are not very primitive angiosperms, and that they are probably most nearly allied to the four dicotyledonous orders with perisperm-containing seeds—Aristolochiales, Polygonales, Centrospermales, and Ranales.—J. M. C.

MISS RIDDLE[14] has investigated *Batrachium longirostris*, more often regarded as one of the white-flowered species of Ranunculus. So many of the Ranunculaceae have been studied from this point of view that the essential features of the family seem to be well in hand, and in no important respect does the species investigated by MISS RIDDLE change the situation. In the development of the microsporangium there is probably the interesting combination of parietal and sporogenous tissue to form the tapetal layer. It is noteworthy, also, that the male cells, or at least their nuclei, appear just before pollination. In the development of the megasporangium two or more archesporial cells often appear, and no parietal cell is cut off. The antipodals have the character that belongs to the family, retaining the primitive number, but increasing much in size. In the development of the embryo the suspensor is short and somewhat massive, the longitudinal division of the end cell of the proembryo occurring when it consists of three cells.—J. M. C.

SABLON[15] has studied the development of the sporogonium of mosses with the view of comparing it with the development of the stems of vascular plants,

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[13] JOHNSON, DUNCAN, S., Seed development in the Piperales and its bearing on the relationship of the order. Johns Hopkins Univ. Circ. No. 178. pp. 28–31. 1905.

[14] RIDDLE, LUMINA C., Development of the embryo sac and embryo of *Batrachium longirostris*. Ohio Nat. **5**:353–363. *pls. 22–24.* 1905.

[15] SABLON, LECLERC DU, Sur le développement du sporogone des mousses. Rev. Gén. Bot. **17**:193–197. *figs. 3.* 1905.

carrying forward a point of view suggested in 1878 by KIENITZ-GERLOFF. The sporogonium described is that of *Funaria hygrometrica*, although *Bryum nutans* was also studied. SABLON states that the first periclinal division of the apical segments differentiates a cortical-epidermal region from a central cylinder. The former region continues centrifugal periclinal divisions until the last or so-called epidermal layer is differentiated. This late differentiation of the outermost layer is a feature of the pteridophytes and not of seed-plants. The innermost or oldest layer corresponds to the endodermis of vascular plants. The central cylinder, on the other hand, shows a centripetal succession in its periclinal divisions, the outermost layer, giving rise to sporogenous tissue, being the oldest and corresponding to the pericycle of vascular plants.—J. M. C.

NEWCOMBE[16] has applied three methods to the determination of the angle for maximum response of primary roots and stems. The method of noting the perception time did not give decisive results, although a shorter perception time for a deviation of 90° was indicated than for 135°. The method of noting the after effect did not yield satisfactory results. The method of alternate stimulation at 90° and at 135° deviation from position of stable equilibrium gave very positive results in favor of the former angle. These results discredit the conclusion of CZAPEK that the strongest stimulation occurs at a deviation of 135°. The author's conclusion, recently announced, that orthotropic roots and stems do not receive equal stimulation at equal angles above and below the horizontal, is withdrawn, and support is given to FITTING'S view that equal stimuli are received at equal angles above and below the horizontal.—RAYMOND H. POND.

FIGDOR[17] finds that the sheathing leaf base of grasses, in addition to protecting and supporting the unfolding bud, performs the function of a guiding organ. While the growing apex of the young shoot is still enclosed by the cotyledon, the latter, being sensitive to light and gravitation, assumes a favorable position into which the emerging leaf is directed. Coincident with the protrusion of the leaf the growth of the cotyledon ceases and its sensitiveness to light and gravitation disappears. This guiding function of the cotyledon is then assumed by the sheathing leaf base, as the author finds, by virtue of its sensitiveness to light and gravitation. The blade is not sensitive to light, but the vaginal portions of the sheath are and in such portions the sensibility is uniform. The evidence for regarding the sheath as sensitive to gravitation might be more convincing.—RAYMOND H. POND.

HIGHLY SPECIALIZED plant cells and their peculiarities are discussed by DAVIS[18] in a continuation of his studies upon the plant cell. The forms con-

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[16] NEWCOMBE, F. C., Geotropic response at various angles of inclination. Ann. Botany **19**:311–323. 1905.

[17] FIGDOR, W., Ueber Heliotropismus und Geotropismus der Gramineenblätter. Ber. Deutsch. Gesells. **23**:182–191. 1905.

[18] DAVIS, B. M., Studies on the plant cell. III. Section 3. Highly specialized plant cells and their peculiarities. Amer. Naturalist **38**:571–594, 725–760. 1904.

sidered are the zoospore, sperm, egg, spore mother cell, coenocyte, and coenogamete. Sperms and eggs are compared with the zoospores with which they are phylogenetically related. After considering the literature of the blepharoplast, the writer is inclined to the view that it does not represent a centrosome. The statement that the synergid may possibly represent portions of a reduced archegonium is somewhat surprising. The author believes that there is no qualitative reduction during the mitoses in the spore mother cell. Pallavicinia receives particular attention. About one hundred and twenty papers are cited in the bibliography of this section.—C. J. CHAMBERLAIN.

SHREVE[19] has investigated the morphology of *Sarracenia purpurea*. The microsporangium passes the winter in the mother cell stage, a two-layered tapetum is developed, the reduced number of chromosomes is twelve, and the tube and generative nuclei appear before the shedding of the pollen. In the megasporangium the integument is single, no parietal cell is cut off, and a linear series of four spores usually appears, although there are variations in number and arrangement. The functional megaspore (innermost one) destroys the overlying nucellar layer at the micropylar end and comes to lie directly against the integument. The endosperm has developed extensively when the embryo is two-celled. In germination the cotyledons act as haustoria, "and survive as simple liguliform leaves bearing chlorophyll."—J. M. C.

FRITSCH[20] claims that the cells of the Cyanophyceae are provided with a delicate cell immediately investing the protoplast in addition to the sheath, which is characteristic of many forms or of mucilaginous envelops. The inner investment is regarded as a modified plasma membrane of a viscous gelatinous nature. The outer envelop is called the cell-sheath, and is believed to be a modified innermost layer of the external mucilaginous investment. This view is quite different from that of most algologists, who regard the sheath as directly derived from the protoplast. FRITSCH also believes that the intercellular protoplasmic connections described by other authors are due to peculiarities in the staining of the gelatinous partitions between the cells.—B. M. DAVIS.

THE LAMINARIACEAE pass through several phases in their life histories, which have been grouped as the embryonal and the post-embryonal. The embryonal stages include the periods up to the time when the simple laminarioid frond is developed; and the post-embryonal the later changes leading to the adult condition which is so various in the different genera. Considerable attention is likely to be given to the post-embryonal stages of development, which promise to throw much light on the problems of relationship. YENDO's work in 1902–3 on Echlonia, Eisenia, and Hedophyllum has recently been supplemented by an

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[19] SHREVE, FORREST, The development of *Sarracenia purpurea* L. Johns Hopkins Univ. Circ. No. 178. pp. 31–34. 1905.

[20] FRITSCH, K., Studies on the Cyanophyceae. II. Structure of the investment and spore-development in some Cyanophyceae. Beih. Bot. Centralbl. **18**: 194–214. *pl. 1.* 1905.

investigation of SETCHELL[21] on the last two genera and Thalassiophyllum.—B. M. DAVIS.

GWYNNE-VAUGHAN[22] has had the opportunity to study the anatomy of the Chinese marattiaceous genus Archangiopteris, established in 1899 by CHRIST and GIESENHAGEN. Only a single small specimen was available, but if it represents the structure of the larger stems, the genus has a simpler anatomical structure than any of the other Marattiaceae. The single internal vascular strand characteristic of young plants of Angiopteris, Marattia, and Danaea, persists in the mature stem of Archangiopteris. The sporangia were examined by Professor BOWER and reported as corresponding very closely in structure to those of Angiopteris.—J. M. C.

IN AN INVESTIGATION of the fluctuations in the number of ray-flowers of *Chrysanthemum segetum*, LUDWIG[23] has attempted to answer the question how large a number of heads must be counted to insure trustworthy determination of the modes. By counting in lots of fifty heads and adding the results, he comes to the conclusion that in this species 500 heads may be considered the lower limit; that in most species 1000 counts are necessary; and in some 10,000 or even 20,000. He deprecates the work done by American and English investigators who have contented themselves with biometric analysis of a couple hundred observations.—G. H. SHULL.

SETCHELL[24] gives a brief account of several parasitic red algae found on the coast of California and describes a new genus, *Peyssonneliopsis epiphytica* Setchell and Lawson, "growing in small dark red pustules scattered over the surface of membranaceous Rhodophyceae, sending rhizoidal filaments deep into the tissue of the host plant; antheridia and cystocarps unknown." The form is said to differ from Cruoria "only in its parasitic habit and consequent possession of rhizoidal filaments penetrating the host plant." It may perhaps be questioned whether such characters alone justify the establishment of a new genus.—B. M. DAVIS.

WHITE[25] has narrated again for the benefit of the general public his interesting experiences with tomatoes. He describes two separate instances in which seed from the Acme variety of *Lycopersicum esculentum* produced only plants of the potato-leaved tomato, which he calls *L. solanopsis*, and the latter then bred

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[21] SETCHELL, W. A., Post-embryonal stages of the Laminariaceae. Univ. Calif Pub. Botany **2**:115–138. *pls. 3.* 1905.

[22] GWYNNE-VAUGHAN, D. T., On the anatomy of *Archangiopteris Henryi* and other Marattiaceae. Ann. Botany **19**:259–271. *pl. 10.* 1905.

[23] LUDWIG, F., Zur Biometrie von *Chrysanthemum segetum*. Festschr. zu Ascherson's 70 stem Geburtstag. pp. 296–301. 1904.

[24] SETCHELL, W. A., Parasitic Florideae of California. Nuova Notarisia. **16**: 59–63. 1905.

[25] WHITE, C. A., The mutations of Lycopersicum. Pop. Sci. Monthly **67**:151–161. *figs. 2.* 1905.

true to its new characters. The author gives repeated assurance that the care taken with these plants leaves no possibility of error. He does not consider the theoretical possibility that his plants were the "extracted recessives" in second-generation Mendelian hybrids instead of mutations.—G. H. SHULL.

STEINER[26] has found intumescences on the leaves of *Ruellia formosa* and *Aphelandra Porteana*, and traced their development. Excessive humidity is found to be the determining condition, as is already known in the case of several other plants. Submersion and darkness each inhibit the appearance of such swellings, while wounding or poisoning cannot be used to induce their formation. The author has evidently overlooked ATKINSON'S work of several years ago, in which excessive humidity was found to be important in causing oedema of tomato. —RAYMOND H. POND.

BARBER[27] has given an account of the haustoria of the roots of *Santalum album*. It seems that those in charge of sandal plantations were for a long time uncertain as to the parasitic nature of this tree. There is a certain amount of selection as to hosts, certain plants being much more efficient "nurses" than others. The haustorium arises independently of the presence of any foreign rootlets. When there is contact with such a rootlet the haustorium applies itself closely to its surface, enlarges, and assumes a "conical or bell-like form."—J. M. C.

MISS BERRIDGE[28] has discovered and studied two new specimens of the Carboniferous strobilus described by SCOTT as *Spencerites insignis*, of which only four specimens were known. In consequence, the original diagnosis is considerably modified, but the relationship to other paleozoic Lycopods as outlined by SCOTT remains unaffected.—J. M. C.

THE FISHER FOLK of the Hawaiian Islands apply the term "limu" to the seaweeds of their coasts. They make use of a large number of forms as food and garnishes with fish, shrimps, and limpets. SETCHELL[29] gives a lengthy list of the native names, identifying them in many cases with particular species.—B. M. DAVIS.

LEAVITT and SPALDING[30] have announced their determination of parthenogenesis in *Antennaria fallax* and *A. neodioica*, and the great probability of its occurrence in *A. canadensis* and *A. Parlinii*. A detailed account, with drawings, will be published later.—J. M. C.

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[26] STEINER, R., Ueber Intumeszenzen bei *Ruellia formosa* Andrews und *Aphelandra Porteana* Morel. Ber. Deutsch. Bot. Gesells. **23**:105–112. *pl. 2.* 1905.

[27] BARBER, C. A., The haustoria of sandal roots. Indian Forester **31**:189–201. *pls. 14–19.* 1905.

[28] BERRIDGE, MISS E. M., On two new specimens of *Spencerites insignis*. Ann. Botany **19**:273–279. *pls. 11–12.* 1905.

[29] SETCHELL, W. A., "Limu." Univ. Cali. Pub. Botany **2**:91–113. 1905.

[30] LEAVITT, R. G., and SPALDING, L. J., Parthenogenesis in Antennaria. Rhodora **7**:105. 1905.

NEWS.

Professor Strasburger has been awarded the gold medal of the Linnean Society of London.

Dr. W. B. McCallum has been appointed assistant in plant physiology in the University of Chicago.

Professor Charles R. Barnes, after spending six months in Europe, will return to his duties at the University of Chicago October 1.

Mr. J. W. Ritchie, Fellow in botany at the University of Chicago, has been appointed Professor of Biology at William and Mary College, Virginia.

Professor John M. Coulter and Dr. H. C. Cowles will spend the autumn and winter in Europe, returning to their duties at the University of Chicago April 1, 1906.

H. S. Graves, School of Forestry, Yale University, has returned from a study of the forest conditions to be observed in a trip around the world, special attention having been given to those of India.

Mr. Jesse M. Greenman, recently of the Gray Herbarium, Harvard University, has been appointed assistant curator of the Department of Botany at the Field Columbian Museum. His duties began June 1.

A very interesting account of a visit to Luther Burbank by Professor Hugo DeVries is published in *Popular Science Monthly* for August. It is translated from the Dutch, and contains a clear statement by a great scientific plant-breeder of the scientific results of the work of a great practical plant-breeder.

A new botanical institute has recently been completed for Professor Ritter von Westersheim R. Wettstein in the Imperial Botanical Garden at Vienna. The building is admirable both for the artistic beauty of its architecture and interior finish, and for the completeness of its equipment. It is well arranged for research and instruction. The museum, so often a mere accumulation of rubbish, is particularly attractive and useful.

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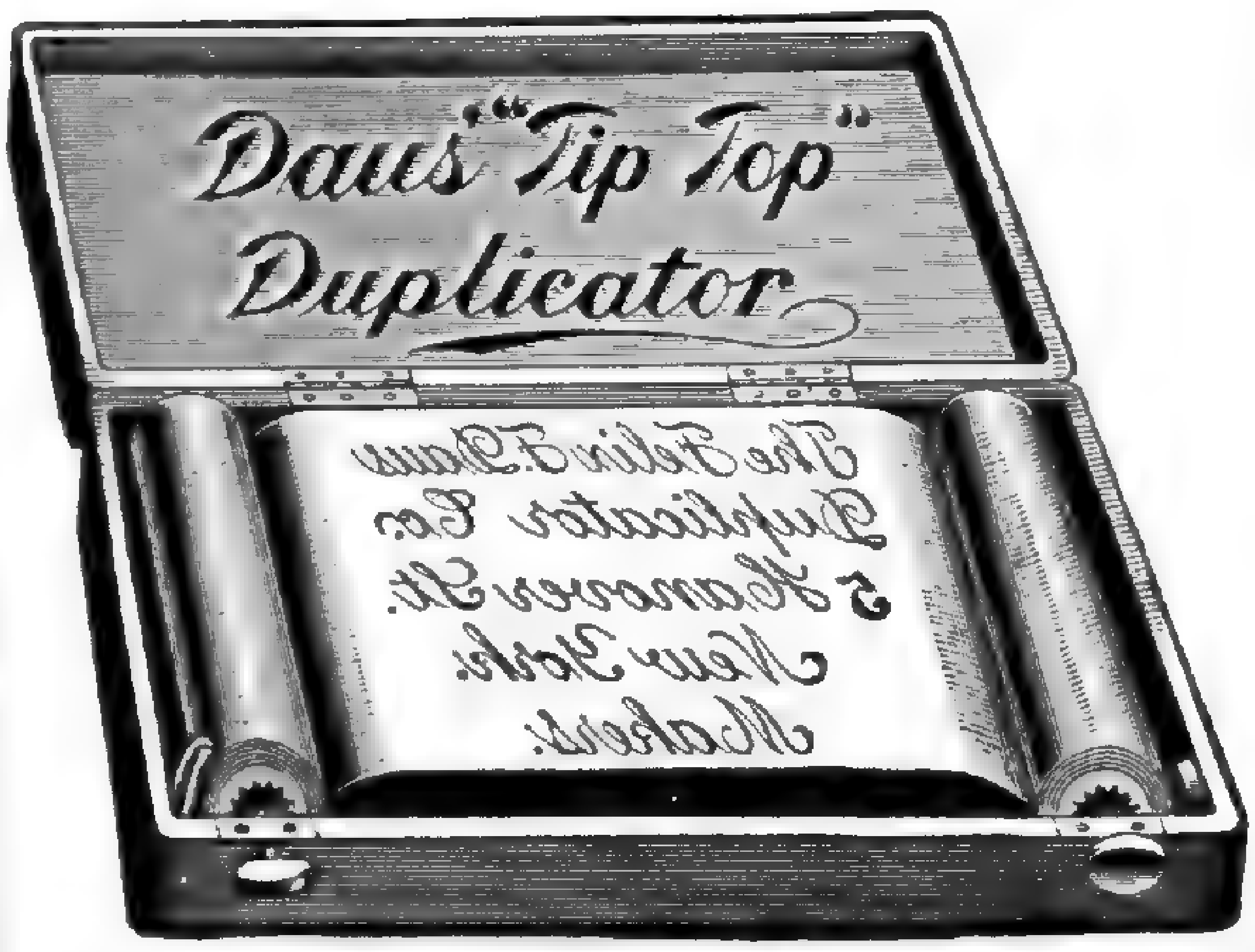

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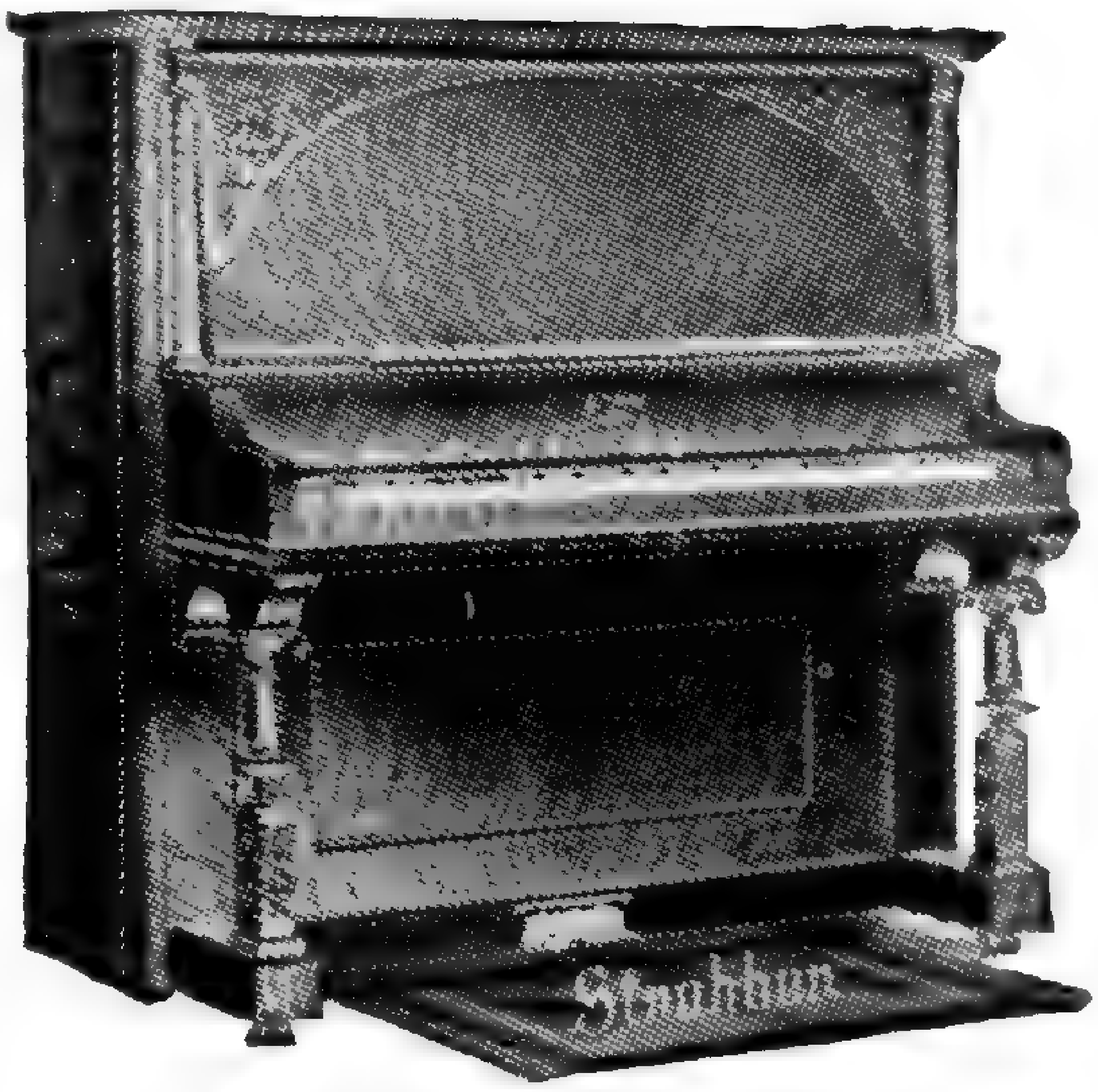

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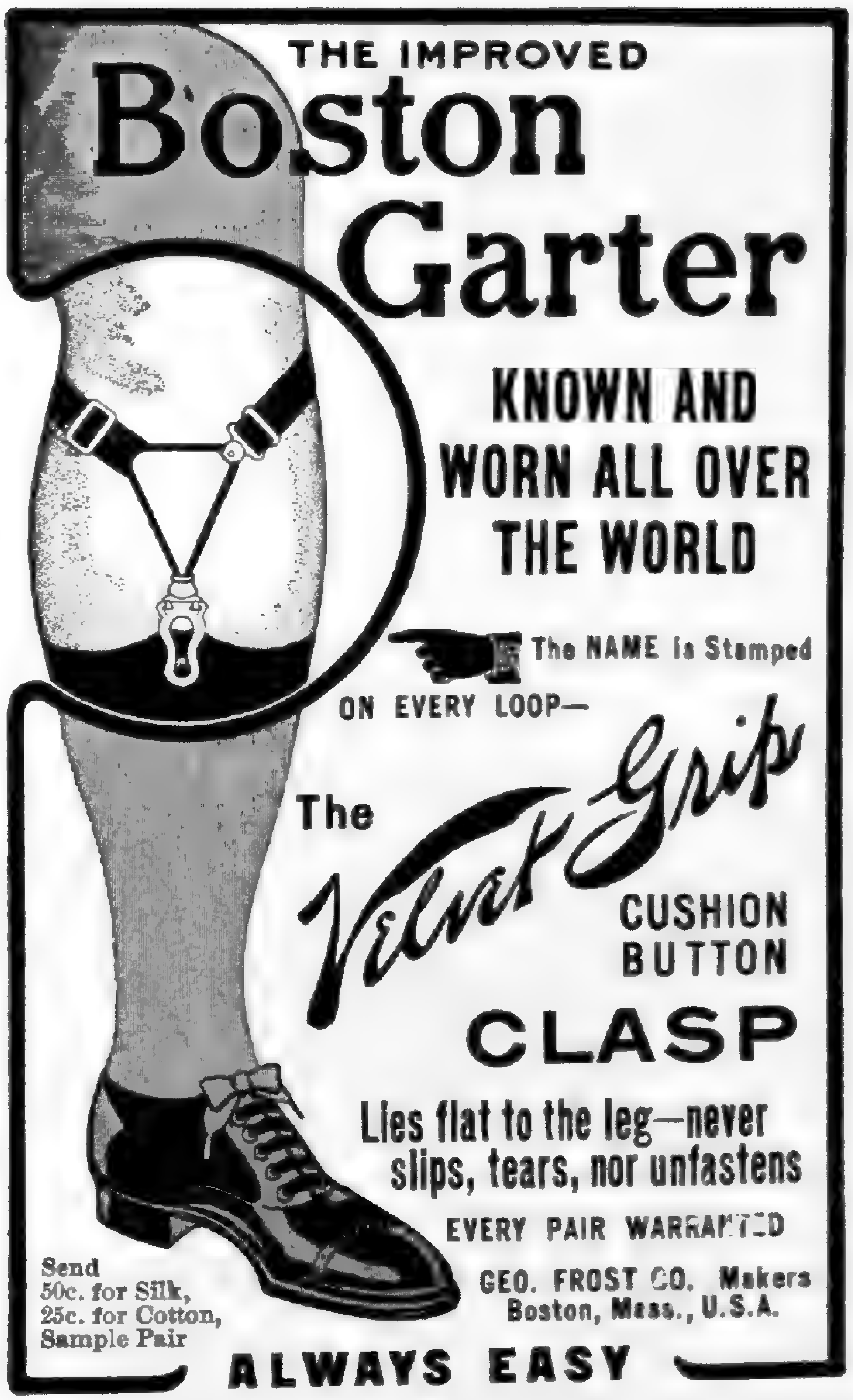

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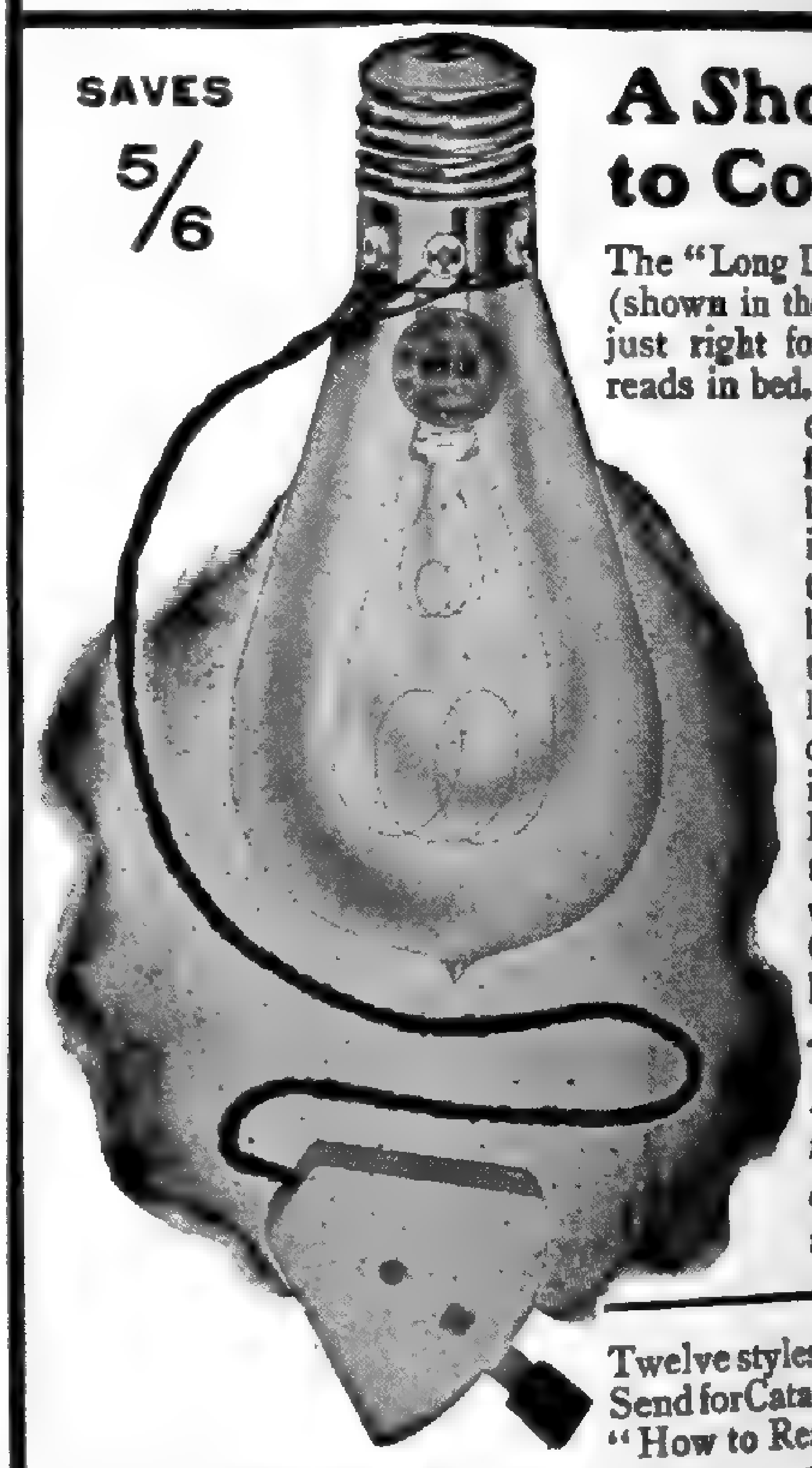

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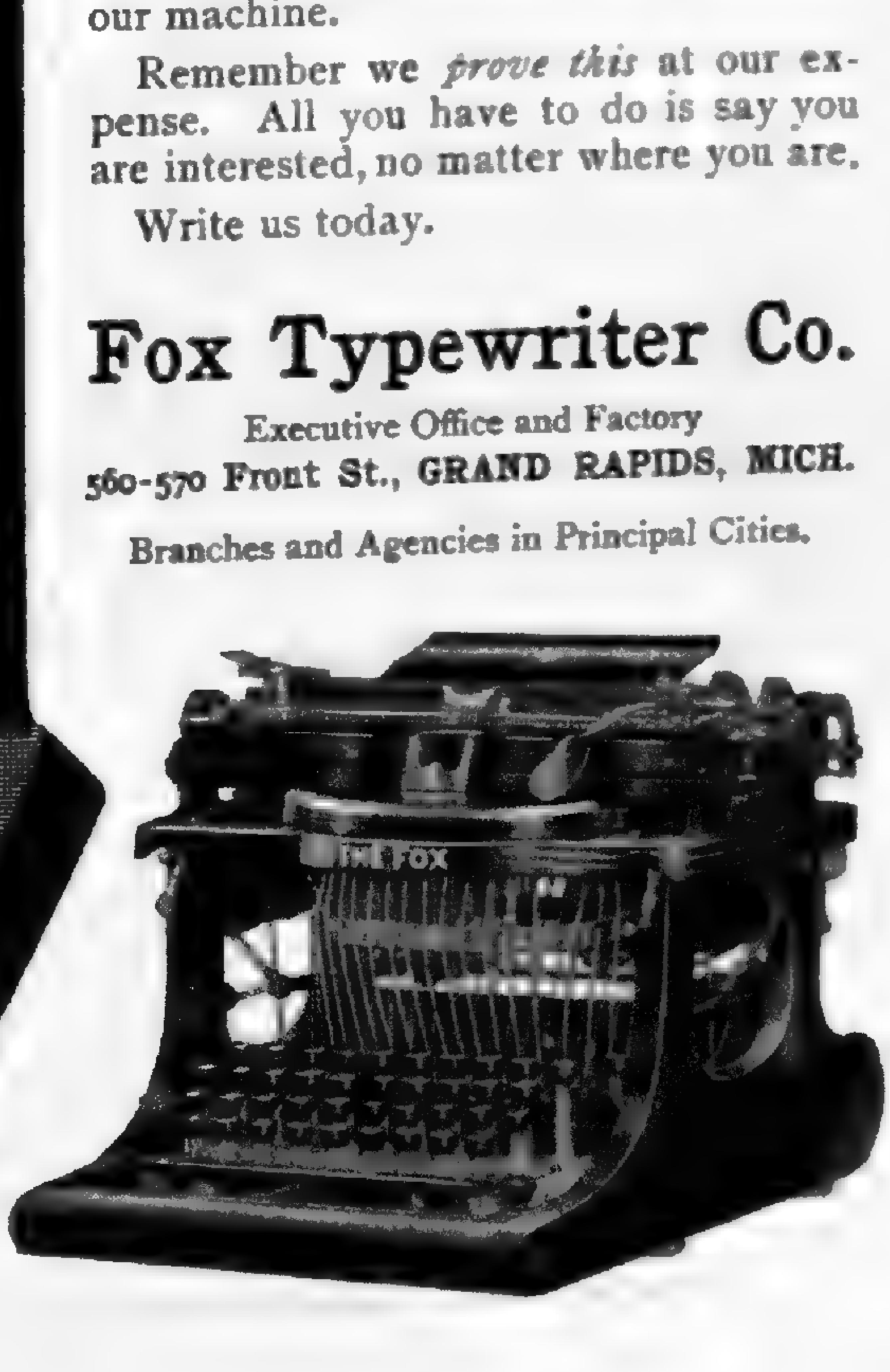

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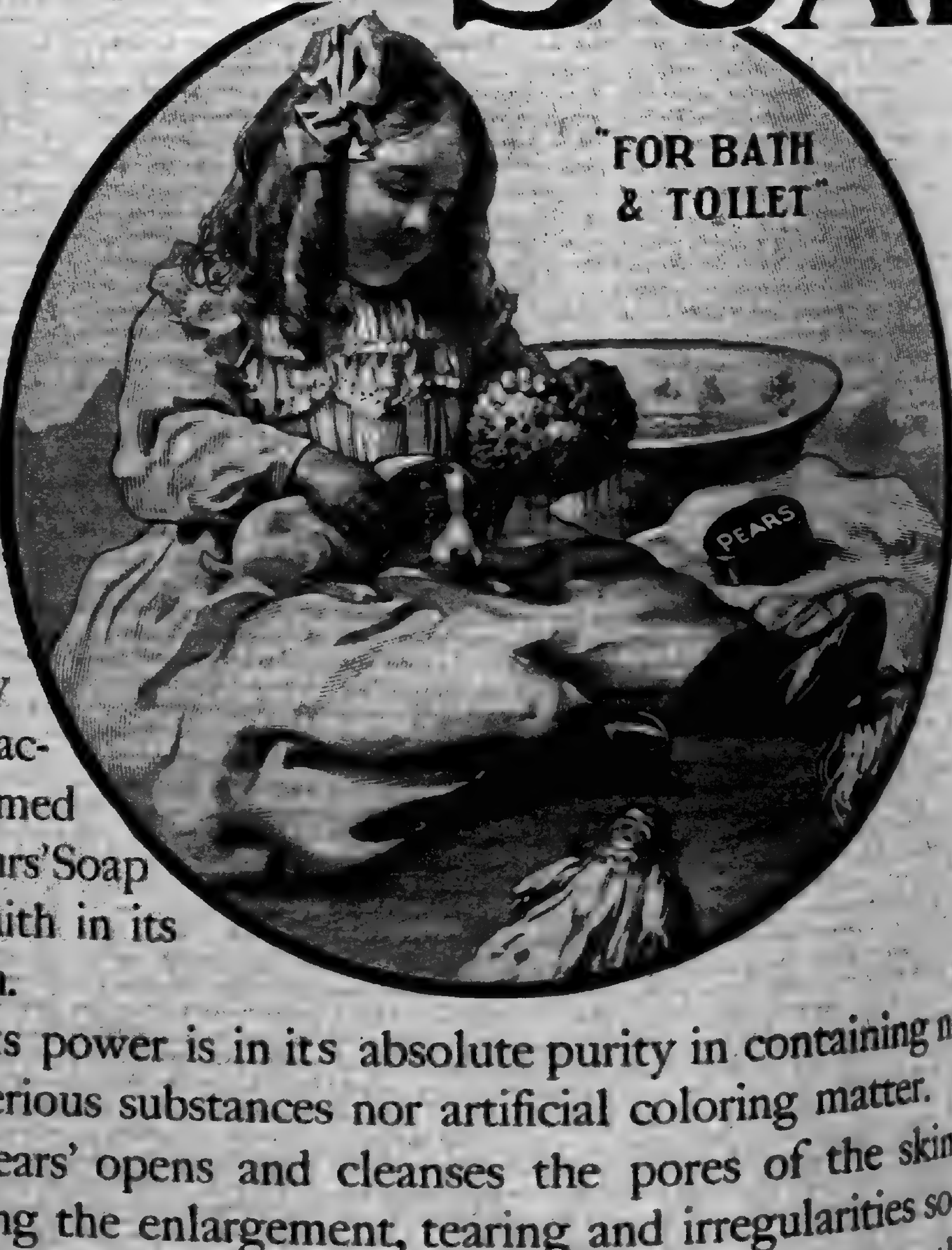

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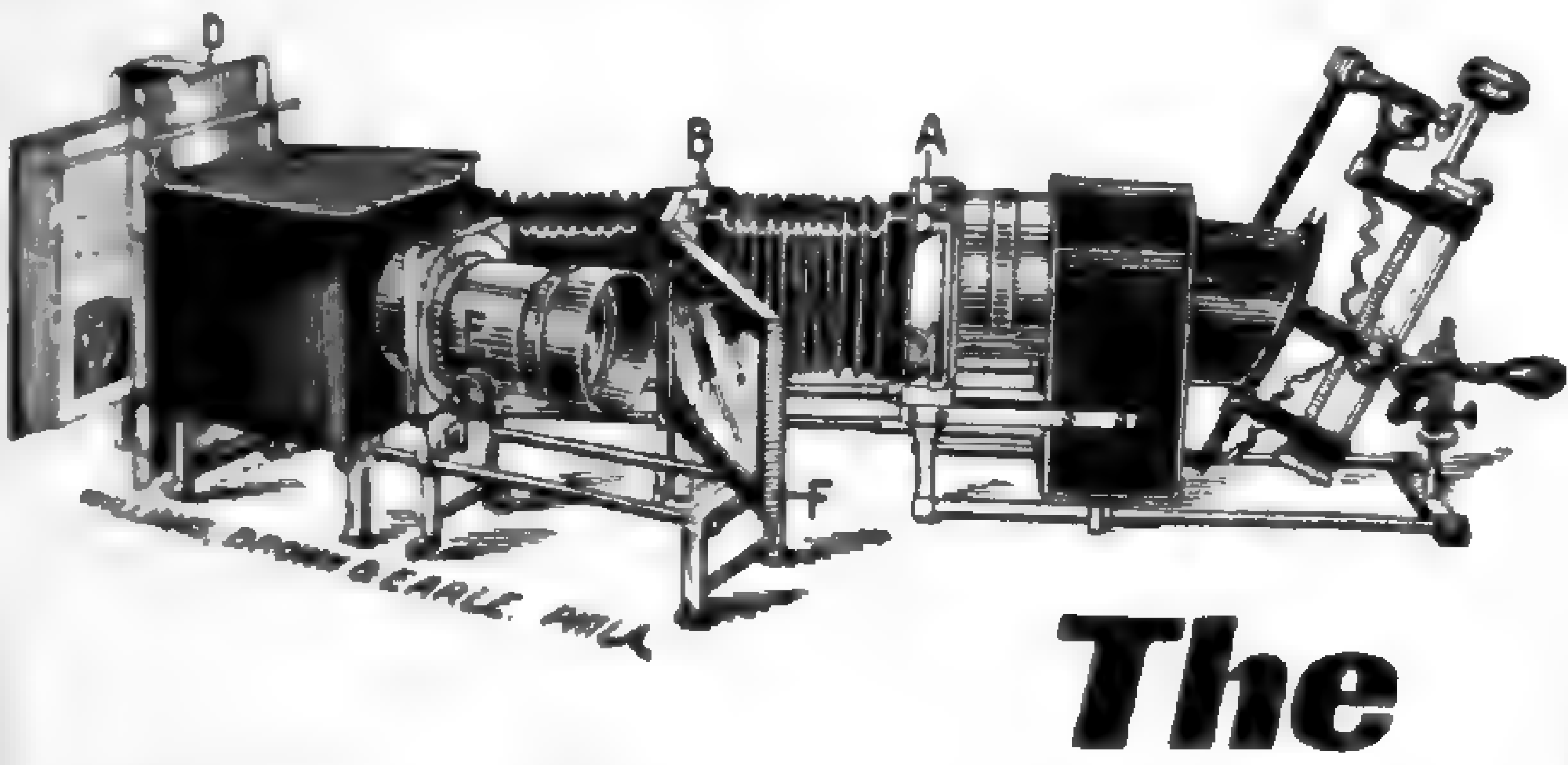

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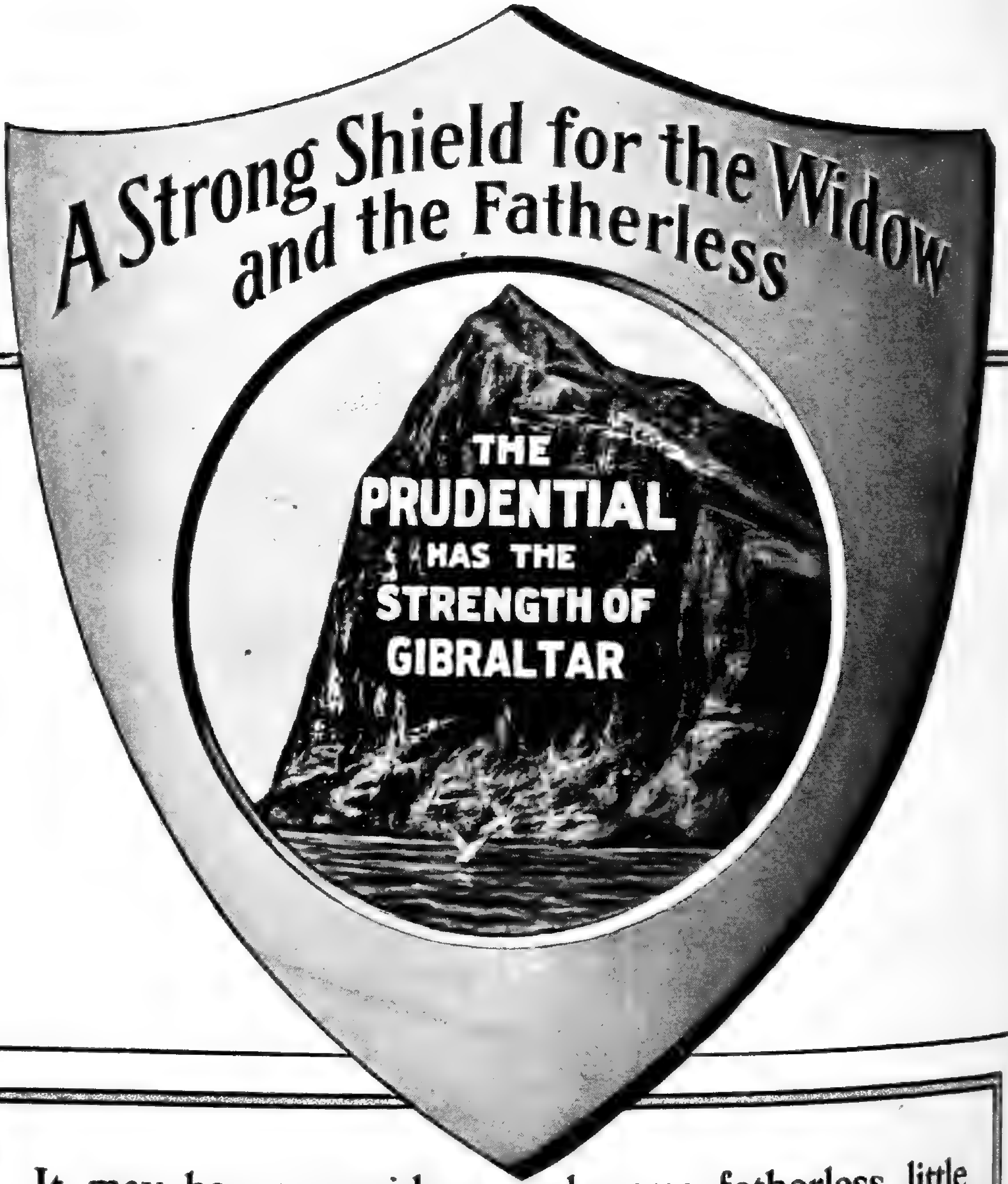
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VOLUME XL NUMBER 3

BOTANICAL GAZETTE

SEPTEMBER, 1905

TWO CONIDIA-BEARING FUNGI.[1]

CUNNINGHAMELLA AND THAMNOCEPHALIS, N. GEN.

A. F. BLAKESLEE.

(WITH PLATE VI)

CUNNINGHAMELLA ECHINULATA Thaxter.

Oedocephalum echinulatum Thaxter, BOT. GAZETTE **16**: 17. *pl. 4. figs. 8–11.* 1891; Saccardo, Sylloge Fungorum **10**: 522; Lindau, Engler-Prantl's Pflanzenfamilien **1**^{1}: 426. *figs. 220 A-B.*

Cunninghamella africana Matruchot, Annales Mycologici **1**: 45–60. *pl. 1.* 1903.

Cunninghamella echinulata Thaxter, Rhodora **5**: 97. 1903.

"Une Mucorinée purement conidienne, *Cunninghamella africana*" is the title under which MATRUCHOT (*l. c.*) has described an Oedocephalum-like fungus which on morphological and physiological grounds he considered was to be included among the Mucorineae. The species had been previously described by THAXTER, however, as *Oedocephalum echinulatum*, and with this name has been included among the Oedocephalums in SACCARDO'S *Sylloge*, where the similarity to Choanephora is pointed out.

The mucors are typically coenocytes with a non-septate mycelium at least in the early stages of development, with sexually formed zygospores, and with the characteristic production of endogenous non-sexual spores within sporangia. The absence of septa in the hyphae of the species under consideration led MATRUCHOT, despite the lack of sporangia or zygospores, to believe that he might be dealing with a member of the Mucorineae. Piptocephalis, which is an

---

[1] This paper was written while working under a grant from the Carnegie Institution.

obligate parasite upon various mucors, he found would grow on Cunninghamella as host, but on none of a considerable number of non-mucor forms from representative groups of the higher and lower fungi. From the results of this ingenious test of parasitism, and from the vegetative structure, he decided that Cunninghamella was to be placed in a distinct group of the Mucorineae alongside of Choanephora, where Oedocephalum-like fructifications occur in addition to sporangia. The discovery of the zygospores of this species by the writer[2] has established beyond question its position among the Mucorineae, and renders not improbable that a further cultural investigation may similarly give independence to others of the *Fungi imperfecti*. Since the method of finding the sexual form of reproduction in this species is that which recently the writer has adopted in obtaining, among others, the zygospores of *Syncephalastrum, Absidia repens, Helicostylum*, and *Circinella umbellata*, for which, with the exception of the last species, zygospores had never been known, it seems not inappropriate to give a brief account of their discovery in Cunninghamella. It is believed, moreover, that an application of similar methods may lead to a clearing up of some of the present anomalies in fruit production encountered in other of the fungi as well as in the algae.

According to their method of sexual reproduction, the Mucorineae have been divided into two main groups, homothallic and heterothallic, characterized respectively by bisexual and unisexual thalli.[3] In the forms known to belong to the homothallic group, zygospores are produced along with the non-sexual sporangial spores under normal cultural conditions, and for this reason the majority of them have been kept under cultivation with a constant production of zygospores for many years. No new members have been added to this group during the present year's investigation, while the accession of a number of forms to the heterothallic group further emphasizes the conclusion that this latter group comprises a very large majority of the species. The (+) and (−) sexual strains of heterothallic forms were first obtained analytically from those few fortunate cultures in

---

[2] Sexual reproduction in the Mucorineae. Proc. Am. Acad. **40**:311. 1904.

[3] *Loc. cit.* and Zygospore formation a sexual process. Science N. S. **19**:864–866. 1904.

which it had been shown, by the production of their zygospores, that the two opposite strains were present together. By a sufficient accumulation of material from different sources one may expect eventually to obtain the two sexual strains, and by their synthesis the zygospores as well of those forms in which the sexes are separate on different mycelia.

Cunninghamella, although reported by only two previous investigators, is not extremely rare. ATKINSON writes that he has had the species in cultures several times, and it has appeared occasionally in the Harvard laboratory, especially on material from the tropics. A pure culture of the fungus was thus obtained from dried flowers collected by the writer in Venezuela, and when contrasted in a culture between the (+) and (−) strains of a test species was shown to be (+) in character by the formation of imperfect hybrids with the (−) strain tested (*l. c. pl. 2. figs. 36-39*). Later a culture was secured from Porto Rico, and upon being similarly tested proved to be (−). The (+) and (−) strains thus determined were at once mutually contrasted and, as was to be expected, yielded an abundant production of zygospores. These cultures were made at laboratory temperature during warm weather in the latter part of July. In the fall the experiment was repeated; but although the two (+) and (−) strains separately continued to produce imperfect hybrids with (−) and (+) test strains respectively, yet when under the same cultural conditions contrasts were made between the two strains themselves no zygospores resulted. A series of cultures under various external conditions demonstrated that with this species the temperature is one of the most important factors to be considered in securing a formation of zygospores. At 20° C. zygospores have not been obtained; but at temperatures from 25° to 34° inclusive, zygospores readily form on the usual culture media employed in the laboratory. It is certainly remarkable that under any conditions the sexual response should be less intense when the (+) and (−) strains of a given species are contrasted together than when they are contrasted against strains of a different species, but Cunninghamella is not unique in this respect. A like condition has already been noted in a species of the genus Mucor (*l. c.* 308, diagram), and a number of other forms more recently investigated show a similar behavior.

Figs. 1–5 were taken from test tube material and illustrate stages in conjugation. The progametes, as also the gametes, are frequently unequal, but this fact, as in the case of Rhizopus (*l. c.* 269), is probably associated merely with an inequality in the amount of nutriment received from the opposite zygophoric hyphae and has no sexual significance. The zygospores vary in size from $46 \times 40\mu$ to $80 \times 63\mu$, and average about $70 \times 58\mu$, with the longest diameter at right angles to the suspensors. The mature zygospore (*fig. 4*) is nearly opaque and thickly beset with comparatively long spines, which frequently, however, seem to be more or less arrested in their development, so that individual zygospores taken from the same culture may present a considerable difference in appearance. In Van Tieghem cells, where the amount of nutrient is necessarily scant, conjugation has not been directly followed under the microscope. In test tube cultures zygospores form chiefly in the lower parts of the tube below the conidial fructifications, producing a reddish-brown mass of minute specks which singly are hardly noticeable without the aid of a hand lens. Hyphae from which progametes are developed do not as a rule take part in conidial formation, yet by a careful search one may find instances showing the two forms of fructification in direct connection with the same hypha (*fig. 3*). Whether or not the zygophoric hyphae are mutually attractive, as is the case with many forms, has not been determined. The contact, however, of sexually opposite hyphae seems to be a stimulus to an increased branching, for in the region of zygospore formation the conjugative hyphae are much branched and closely entangled. A scalariform arrangement of the zygospores is common, and progametes may occasionally form so close together on two adjacent filaments as to give rise to twin zygospores (*fig. 5*) supported apparently by forked suspensors. Instances have also been observed in which one side alone shows an apparent forking of the suspensor, and in other rare cases the suspensor of one zygospore has the appearance of a side branch from that of another. The usual condition is that figured (*figs. 1–4*), where the progametes are developed laterally from adjacent hyphae at their points of contact. One zygophoric hypha may be laterally met by the termination of the other, but it is certainly seldom the case that their contact is exactly terminal.

In many heterothallic species the (−) is distinguished from the (+) strain by any one of a number of different characters, which in general indicate a less luxuriance in vegetative growth. No characters have been found as yet, however, by which one can distinguish between the sexual strains of Cunninghamella when grown apart in pure cultures.

Sufficient material has not been investigated to enable one to determine the relative abundance in nature of the strains of this species. In addition to the two (+) and (−) strains from Venezuela and Porto Rico already mentioned, a culture originally obtained from horse dung has been kindly communicated to the writer by ATKINSON, and the same species has recently been found on a specimen of dung kindly sent from the Philippines by COPELAND. Of these two latter, one is (−) and the other (+), so that in the four cultures tested none are neutral, and the (+) and (−) strains are equally represented.

THAMNOCEPHALIS, n. gen.

Vegetative hyphae fine, continuous, anastomosing. Fructifications erect, consisting of a main stalk supported above the substratum by stout rhizoidal props and bearing a bushy crown of subdichotomously branched fertile hyphae terminated by sterile branches. Spores solitary, borne on the surface of spherical heads. Heads borne at the apex of short lateral stalks which arise at nodes from opposite sides of the fertile hyphae at right angles to their planes of branching.

Thamnocephalis quadrupedata, n. sp.

Vegetative hyphae delicate, about 3μ in diameter, branched and freely anastomosing. Fructifications scattered, rose-brown, tree-like, about 0.75^{mm} tall. Main stalk thick-walled, tapering from about 15μ at base to about 8μ wide at apex, supported at maturity by two pairs of stout rhizoidal props which are anchored to the substratum by branches given off from their lower ends. The shriveled remnant of a fifth rhizoid hangs down midway between the two pairs of props, and a beak-like projection occurs on the side opposite the main stalk as the remains of an abortive secondary erect stalk. Hyphae of the crown 7–10 times dichotomously or subdichotomously branched, the planes of dichotomy being successively at right angles to one another. At the first 6–8 nodes are laterally produced short conical or barrel-shaped branches, generally septate at base and septate terminally at junction with sporiferous head. Heads spherical, from about 19μ in diameter at first node to about 13μ in diameter toward the periphery, produced in acropetal succession and bearing the spores on slight papillae. Spores spherical, about 5.5μ in diameter, yellowish, thick-walled, very finely echinulate, ripening on the different heads in acropetal succession. Ultimate branches curved, sterile, often beset with protuberances on their convex sides, becoming septate, shriveled, and frequently abstricted before spore maturation. Hyphae of rhizoids, stalk, and crown becoming septate about the time of spore maturation.

Growing in a gross dung culture on fresh sphagnum, Cambridge, Mass.

This fungus appeared in the Harvard laboratory in the fall of 1902. An undetermined sample of dung had been placed in a crystallizing dish with fresh unsterilized sphagnum, and yielded in the course of time a scanty growth of mucors. Somewhat later the peculiar fructifications of this species were found already covering the layer of filter paper used in the culture like a grove of microscopic trees, and extending into the loosely packed sphagnum below. A large variety of substrata was tried in the attempt to obtain a pure culture of the fungus; and mass transfers from the original culture, which for several days continued to produce new fructifications, were made to dung and to fresh sphagnum, but it seemed impossible to elicit a growth in new cultures.

A few spore germinations were obtained in Van Tieghem cells on horse dung agar. The spores that germinated did so in two days, swelling to about 8μ in diameter before emitting slender germ tubes, simple or slightly branched. The longest germ tube observed reached but 170μ and no further growth could be obtained. The action of the fungus in the cultures attempted suggested that the species might have been parasitic upon the scanty growth of mucor which had developed in the original culture, and though it did not seem possible to stimulate growth by an admixture of this same mucor, the frequent irregular behavior of Syncephalis under similar circumstances does not render such a condition entirely improbable.

The origin of the fungus in the culture where it was found is uncertain. It is possible that it was introduced along with the fresh sphagnum, since its growth had no apparent connection with the dung. Fresh sphagnum was accordingly gathered at a later date from the same locality as before and used in unsterilized cultures, but failed to give further rise to Thamnocephalis. The improbability of finding the form again reconciles the writer to attempting to patch together the history of development from the somewhat scanty material at his disposal, which is especially lacking in young stages. It is believed, however, that in the main the process can be followed.

Anastomoses are common between overlying hyphae (*fig. 6*), and it is apparently at these places of anastomosing that the rudiments of the fructifications are formed. The condition shown in *fig. 7* has several representatives in the preparations saved, but the stages between it and that shown in *fig. 8* are entirely lacking. A comparison of the fructification as seen in *fig. 8* with a caricature of some giraffe-like creature will furnish terms convenient for discussion. Upwards of a hundred specimens near maturity have been examined and no deviations from the main type of fructification have been observed. A short narrow body supported by fore and hind legs bears on the dorsal side anteriorly a long neck supporting the fertile head of branches and posteriorly a short erect tail; while an umbilical cord connecting ventrally with the substratum probably serves as the chief channel for the influx of nutriment. It seems probable that in *fig. 7* we have represented the umbilical cord in the process of giving rise by branching to the short body which in turn is further dividing. Under this assumption the first branching of the stalk arising from an anastomosis would give rise to the body, the second to the neck and tail and to the short extensions of the body, from which by a further branching the two pairs of legs are developed. The tail becomes septate and shrivels at a very early stage, and in none of the material at hand has it been found entirely filled with protoplasm. In the specimen figured (*fig. 8*), however, and in one other the walls seem to be continuous around the end. This being the case, the tail arises from a branching of the same order as the neck, but becomes functionless; while the latter, perhaps because of priority in origin, takes the ascendancy and appropriates the protoplasm for the development of the sporiferous head.

That the umbilical stalk is formed directly from the stem arising from an anastomosis and is at least the chief channel through which the fructification receives its supply of nourishment is indicated by a number of facts. Its base is at first in connection with the fine anastomosing hyphae, but as the plant reaches its full size it shrivels and usually leaves at maturity little more of a remnant than shown in *fig. 9*. In cases in which its base remains, it may be seen to be somewhat raised above the attachment of the two pairs of legs, as if it had been torn out of the substratum by the growth of these latter. The legs are obviously a later production, as is seen by *fig. 8*, where the anchoring rhizoids are just beginning to be given off toward their bases. The legs, as may be seen in the left hind leg of the specimen just mentioned, are supplied with rhizoids which at times certainly are comparatively short and end blindly; although in other cases a few of the rhizoidal branches can be followed for a certain distance into delicate filaments characteristic of the mycelium. This latter condition, however, is not so typical as for the umbilical stalk.

Neither the vegetative mycelium nor the hyphae of the fructification are septate during growth. Septation regularly takes place in the neck, legs, and branches of the head when the protoplasm which they contain becomes used up in spore-formation, and mature spores showing the characteristic echinulations are to be found on fructifications in which no septa have as yet been found. The cross walls are thin in comparison with the thick lateral walls and quite irregularly disposed. Often one connects the lateral wall with an adjacent septum or extends as a shelf but part way across the hypha. The branches of the crown easily separate at their septa, and by judicious tapping with a needle the crown may be denuded of nearly all its sporiferous heads and branches.

The only known form to which Thamnocephalis shows any close relationship is *Sigmoidiomyces dispiroides* Thaxter,[4] and the two genera evidently form a group by themselves. The method of spore-

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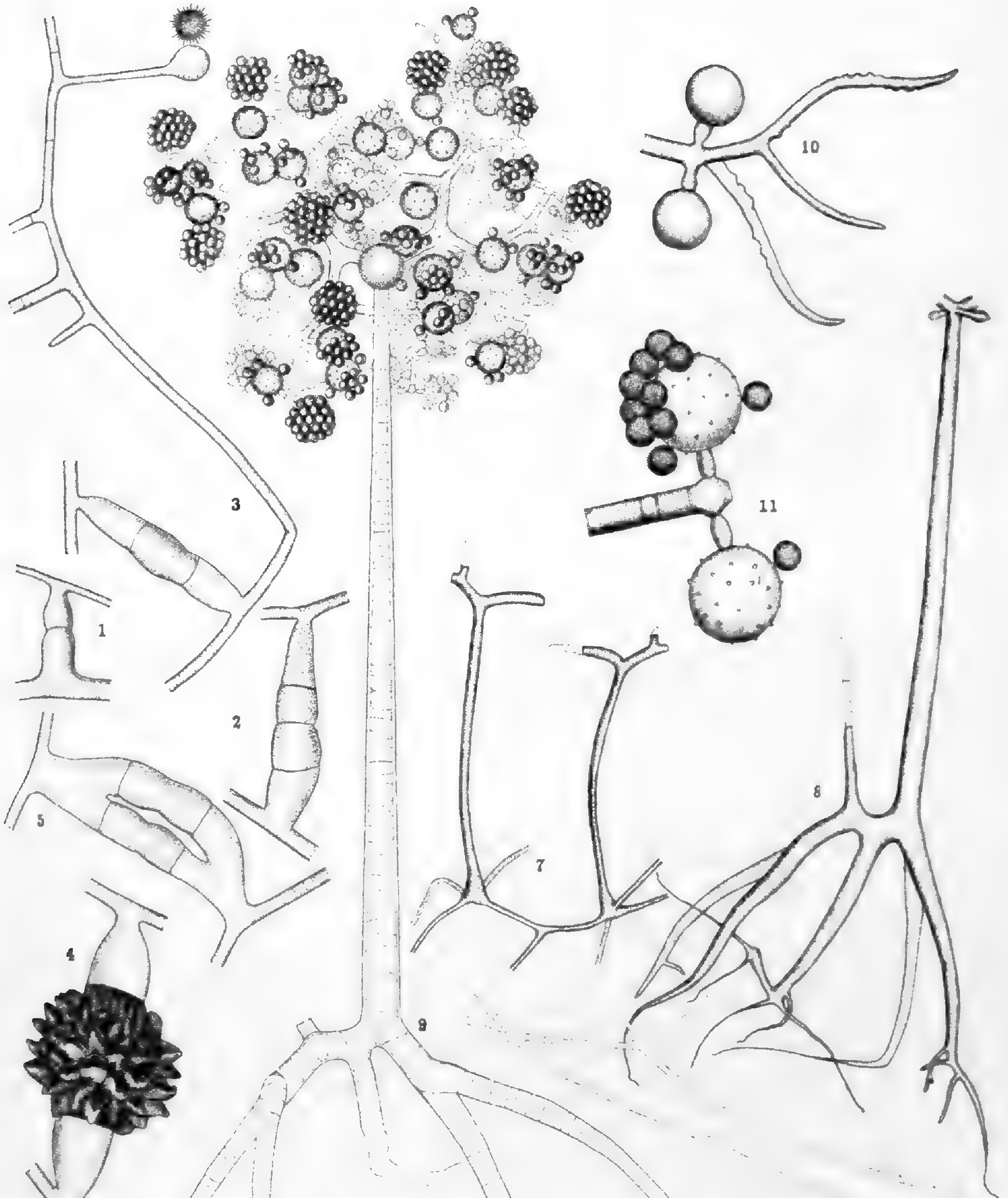
[4] THAXTER, R., North American Hyphomycetes. BOT. GAZETTE **16**:22. *pl. 4. figs. 15–18.* 1891. Figures reproduced in ENGLER and PRANTL'S Pflanzenfamilien **1**^{1}:427. *figs. 220 G–H.*



BLAKESLEE on CUNNINGHAMELLA and THAMNOCEPHALIS formation on paired heads which are located at points of branching of the fertile hyphae is essentially the same for both species. The outgrowths on the convexities of the sterile branches in Sigmoidiomyces are represented in Thamnocephalis by mere protuberances; the spores and their echinulations are much reduced in the latter; and the branches of the fertile hyphae are not markedly curved in the mature condition. Sigmoideomyces fails, moreover, to show that striking differentiation into fertile crown, main stalk, and rhizoidal props, which is a unique feature of Thamnocephalis. Sigmoideomyces was described from mature material, and it was not possible to determine the nature of the mycelium nor the time of septation of the fertile hyphae, but the similarity in the two forms would suggest that much the same condition exists as in Thamnocephalis.

MATRUCHOT has emphasized the systematic importance of nonseptate hyphae, and the condition in Cunninghamella shows that the presence of sporangia is not a *sine qua non* for admission to the company of the mucors. The absence of septa in young growing hyphae is a mucor character, but hardly less characteristic is their presence in varying abundance in older hyphae from which the protoplasm has been withdrawn. Cunninghamella is no exception to this statement (*fig. 3*), but perhaps Piptocephalis and *Spinellus macrocarpus* furnish as striking examples of septation in fertile hyphae as the group affords. The delicate anastomosing mycelial hyphae further remind one of the similar condition in Syncephalis. THAXTER (*l. c.*), MATRUCHOT (*l. c.*), and others have recognized the possibility of Rhopalomyces belonging to the Mucorineae. Without evidence from cultures the relationship of Sigmoideomyces and Thamnocephalis with the mucors must be left as only a suggestion.

Microscopic preparations and herbarium material of *Thamnocephalis quadrupedata* have been deposited in the Cryptogamic Herbarium of Harvard University.

NAPLES BIOLOGICAL STATION.

EXPLANATION OF PLATE VI.

The drawings were outlined with the aid of a camera lucida with the combination of Leitz and Bausch & Lomb lenses noted and have been reduced about one-quarter in reproduction.

Cunninghamella echinulata Thaxter.

FIG. 1. Development of progametes; obj. 7. oc. 3.

FIG. 2. Abstriction of gametes; obj. 7. oc. 3.

FIG. 3. Young zygote in connection with short conidiophore through hypha which has lost its protoplasm and become septate; obj. 7. oc. 3.

FIG. 4. Mature zygospore; obj. 7. oc. 3.

FIG. 5. "Twinned" zygotes; obj. 7. oc. 3.

Thamnocephalis quadrupedata, n. sp.

FIG. 6. Hyphae of mycelium showing anastomoses; obj. 7. oc. 3.

FIG. 7. Early stages of development of fructification; obj. 7. oc. 1.

FIG. 8. Young fructification showing basal portion and formation of sporiferous heads at first node of the crown; obj. 7. oc. 1.

FIG. 9. Mature fructification from which many of the fertile branches and spores have been shed; obj. D. oc. 2.

FIG. 10. Last fertile node of crown showing sterile terminal branches and young sporiferous heads from which the spores have not yet developed; obj. $\frac{1}{12}$. oc. 3.

FIG. 11. Fifth fertile node with sporiferous heads and spores; obj. $\frac{1}{12}$. oc. 3.

THE DEVELOPMENT OF THE HETEROTYPIC CHROMOSOMES IN POLLEN MOTHER CELLS.

D. M. MOTTIER.

(PRELIMINARY COMMUNICATION)

THE theory of a reduction division in the spore mother cells of higher plants has gained considerable ground in the past two or three years; so that at present probably the majority of observers, who have devoted themselves almost constantly to the problems of the chromosomes, seem firmly convinced that one of the two mitoses in the formation of the tetrad is a "reducing" division. There is still, on the other hand, some diversity of opinion, and several years may elapse before cytologists will be strictly in accord upon this the most difficult of cell problems.

One of the most important facts brought out by recent investigations is the shifting of the point in the tetrad formation, at which the qualitative separation of the chromosomes is held to occur, from the second, or homotypic mitosis, to the first or heterotypic division. Since it has been shown by FLEMMING and MEVES for the animal cell, and by GUIGNARD, STRASBURGER, and the writer, for the higher plants, that the daughter chromosomes of the heterotypic mitosis are split lengthwise as they separate in the metaphase, a more critical study has been devoted to the prophase of this division, and much light has been thrown upon certain obscure steps that have not as yet been satisfactorily explained. This double nature of the retreating chromosomes was regarded as a second longitudinal fission, since it could be seen that the spirem was double in a very early prophase. This apparent second longitudinal division seemed to have proved beyond any shadow of a doubt that the second mitosis is not a reducing division, as has been so insistently maintained by many zoologists. Now that it has been shown that the homotypic mitosis in the spore mother cells of plants is not a reduction division, the question to be answered is whether in the heterotypic division the chromosomes are bivalent, or whether the segments of each pair separate along the line of longitudinal fission.

Among those who are convinced of the bivalent character of the heterotype chromosomes, *i. e.*, that this is a reducing division, two views are held as to the manner in which these chromosomes are formed. According to the view advanced by STRASBURGER ('04) and FARMER ('05), the chromatin spirem splits longitudinally, the two segments or daughter spirems fusing again shortly afterwards, and segments into pieces equal to two somatic chromosomes placed end to end. Each piece, or double chromosome, folds, either during or after the cross segmentation, to form the familiar paired rods, rings, loops, etc., so often figured by the several observers. Consequently the two segments of each chromosome are not daughter chromosomes, formed by a longitudinal splitting, but two somatic chromosomes, each of which is split lengthwise; but, as stated above, this longitudinal split is not usually recognizable until the meta- or anaphase. JULES BERGHS ('04, '05) and other students of GRÉGOIRE assert that the longitudinal fission, so readily observed in the spirem of the prophase of the heterotypic mitosis, is not a real longitudinal fission of the chromatin thread, but that, during the contracted phase of the nucleus, the so-called "synapsis," the double spirem is formed by the approximation of two spirems, one being maternal and the other paternal. The chromosomes are therefore bivalent, and as they separate in metakinesis each splits lengthwise. BERGHS has studied *Convallaria majalis, Lilium speciosum, Allium fistulosum, Narthecium ossifragum, Helleborus foetidus,* and *Drosera rotundifolia,* and while he has presented an apparently closely connected series in the formation of the chromosomes, certain very important steps seem to have been omitted and others incorrectly interpreted.

STRASBURGER ('04) has based his conclusions upon a study of *Galtonia candicans,* a species claimed to be unusually favorable because of the small number of the chromosomes in the pollen mother cells, namely six. In this plant he finds that the spirem splits longitudinally in the early prophase of the heterotypic mitosis, as described by the writer several years ago, but the longitudinal splitting does not lead to the separation of the segments; so that later, as the spirem shortens and becomes thicker, no trace of this fission can be seen. The spirem now segments transversely into the six chromosomes, and each of these segments again, in a similar manner, into two pieces of equal length. Thus arise twelve chromosomes which come together in pairs to form the bivalent chromosomes.

Farmer and Moore ('05) in their joint publication have presented the results of their observations upon animals and plants. Of the latter the familiar and oft studied *Lilium candidum* heads the list, and to this form alone reference will here be made. As has frequently been described, the chromatin ribbon of *Lilium candidum* splits longitudinally, and the halves usually separate more or less widely from each other. Later the halves reapproximate, and the split closes up again. At the same time the entire spirem shortens and thickens. The contraction goes on rapidly, and the original longitudinal split soon ceases to be noticeable, being visible in exceptionally favorable cases only. A rearrangement of the thread now sets in, such that parts of the spirem become pulled into parallel positions. This is well seen in those places where, at the bend of a convolution, an attachment to the nuclear membrane has taken place. In this manner, a close and parallel approximation of lengths of the entire spirem is effected; and this parallel arrangement, it is stated, has been commonly interpreted as representing the parallel split halves of the spirem thread. As a consequence of this rearrangement of the spirem, or parts which give rise to chromosomes, the segments when isolated very often exhibit the form of a loop, open at one end, with sides either parallel to each other, or more frequently twisted over one another. All chromosomes are not formed in this way however. Sometimes two, more or less straight, rodlets may unite so as to give rise to figures of rings, ellipses, etc. The point especially emphasized by the joint authors is "that the two rods, sides of loops, or whatever other form the structure as a whole may assume, represent, not the longitudinal halves of a split thread, but the approximation of serially distinct regions of the spirem as a whole. Thus each heterotypic chromosome is a bivalent structure, and their reduced number is due to the approximation and more or less intimate, though temporary, union of the equivalents of pairs of somatic chromosomes."

Allen ('05), who has made a very detailed study of this mitosis in *Lilium canadense*, does not conclude in favor of a reducing division. He interprets his results as indicating that a longitudinal division of the chromatin precedes each of the two mitoses, the second fission occurring during the meta- or anaphase of the first, or heterotypic division.

In my first study of Podophyllum, in 1896, certain steps in the development of the heterotypic chromosomes were never clearly understood, and at that time the phenomena in question were attributed to poor fixation. On the appearance of STRASBURGER'S paper on *Galtonia candicans*, I again took up the study of Podophyllum, because of the facts just stated, and because the reduced number of chromosomes in this plant is only eight. This study has resulted in a clearer understanding of the phenomena in question, and for comparison my study is being extended to other plants, among them being *Lilium candidum*. Although my study is not yet completed, and owing to the delay in publication which may ensue, it has been thought best to make public a brief statement of the conclusions reached in reference to the heterotypic chromosomes in the pollen mother cells of *Podophyllum peltatum*.

It may be stated at the outset that my earlier description of the resting nucleus in the pollen mother cell of this plant is substantially correct. The fine linin network contains many small chromatin granules of uniform size and distribution. One or more nucleoli may be present. Following this comes the contracted condition, or synapsis. In my earlier publication this condition was regarded as being due to the action of reagents, but I am now convinced that the phenomenon is normal. Following synapsis, the loosening up of the contracted ball results in the chromatin spirem; and as soon as the spirem has emerged from the balled-up condition, or shortly afterwards, and has assumed a more regular arrangement, it is clearly seen to be split longitudinally. I am not, at this writing, prepared to state definitely whether the spirem is formed double as claimed by BERGHS and ALLEN, but in the contracted condition portions of the thread which occasionally extend out free from the mass as a loop could sometimes be seen to be double, or appearing as if split lengthwise. After all this is not strange, when we remember that the spirem is derived from a network, and nothing is more probable than that in the transformation of the net into the thread parallel threads of consecutive meshes would be approximated. It seems to me now, though the statement is made with reserve, that the double nature of the spirem at this stage, referred to by BERGHS and ALLEN is due to the phenomenon just stated, and not to the approximation of two distinct spirems.

Omitting details, the next step of importance is the clear and unmistakable manifestation of the longitudinal splitting of the chromatin spirem. In Podophyllum the segments of the spirem do not divaricate as in *Lilium candidum*, for example, but frequently parts of the two daughter spirems do separate for considerable stretches. The segments are more or less twisted about each other. Following this stage, the spirem shortens and thickens somewhat, and the longitudinal fission becomes less and less distinct, and finally almost every trace of the double nature of the thread disappears. The thread does not shorten nor thicken as rapidly, nor to the extent that it is usually supposed to shorten and thicken, before its transverse segmentation into chromosomes, and it is just at this point that the writer and many others have been led into error. The thread does, of course, shorten and thicken to some extent, and as a result its arrangement reaches its greatest regularity. This is the stage of the loose or hollow spirem so frequently observed. However, there is no well-marked regularity in the convolutions of the spirem throughout its entire length; some of its turns follow the nuclear periphery, while others traverse the interior. In the nuclear cavity the turns are often short and kinked. In sections including the whole nucleus, it is not possible to follow accurately the entire thread, but it seems that there are few or no free ends, and very rarely is any trace of a longitudinal split discernible.

The stage of the loose and more regular spirem seems to persist for some time, as it is frequently met with in the preparations. The next step in the prophase has been one of the stumbling-blocks of cytologists, and it is the one that the writer ascribed to poor fixation in his earlier studies. It may be true that this stage is difficult of fixation, and that, together with its short duration, has probably been the main reason for the failure to understand its true significance. Just before the transverse segmentation of the spirem and the final differentiation into the chromosomes, the loose spirem loses the regular arrangement it may have had and undergoes a contraction such that there is a parallel approximation of certain parts of the spirem to form long loops; while other parts, especially those near the center of the nuclear cavity, become knotted and entangled. In the closely contracted and entangled parts of the spirem it is not possible to make out clearly and definitely the arrangement of the chromatin thread, but there is no doubt as to the true nature of the longer loops. Sometimes the loops show a tendency to radiate from the more contracted entanglement of the spirem. The arrangement of these loops is very rarely so regular as figured by FARMER for *Lilium candidum* (*l. c., fig. 9*). The parallel sides of the loops are usually twisted upon each other, and the bend of the loop is often, though not always, toward the periphery of the nucleus. It is during this contracted and entangled condition that the thread segments, either partly or completely into the chromosomes. After segmentation the chromosomes begin to contract and thicken more rapidly, and as a result they become more scattered in the nuclear cavity, so that the relation of the two segments toward each other can be readily made out. It is in this and the spindle stage that the chromosomes have been most frequently figured. Those which show the greatest regularity give the impression that they have been formed by a long piece of the spirem folding over in the form of a loop and the parallel sides of the loop twisting upon each other. Others appear as two parallel rods, which may or may not be twisted upon each other; and in still others the two segments are variously oriented toward each other, as has been figured time and again, and in the greatest profusion, by the different observers.

When one considers the chromosomes in this stage and the longitudinally split spirem of the early prophase, the most natural conclusion is this, namely, that the two parallel rods, or the two segments of each chromosome, of whatever shape, represent adjacent and parallel parts of the longitudinally split spirem; that the spirem thus split merely contracted and shortened, so that the two rather thick halves of each chromosome seemed to owe their thickness to contraction and shortening alone. As a matter of fact, however, the longitudinal split of the thread in Podophyllum becomes obliterated during the formation of the loose and more regular spirem, so that scarcely a trace of the fission can be seen; and, as previously stated in the foregoing, the spirem contracts and thickens much less before its cross segmentation than has been supposed. The greatest contraction occurs after segmentation, and furthermore the two segments, or rods, of each chromosome do not represent the parallel halves of the longitudinally split spirem, but the approximation of serially distinct parts of the spirem as a whole. Each half of the chromosome is consequently double, resulting from the early longitudinal fission of the spirem, and this fission manifests itself during the meta- and anaphase. It is, therefore, the original longitudinal fission which has been regarded as a second longitudinal splitting. The heterotypic chromosomes of Podophyllum, therefore, are bivalent, and the first mitosis in the pollen mother cells is a "reducing" division. This seems to me now to be the only proper interpretation of the heterotypic chromosomes in Podophyllum. The writer has been reluctant to give up the theory that a longitudinal fission occurs for each mitosis, and he has done so only after a long and careful study of many preparations.

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RELATION OF TRANSPIRATION TO GROWTH IN WHEAT.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXVII.

BURTON EDWARD LIVINGSTON.

(WITH TWENTY-ONE FIGURES)

INTRODUCTION.

TRANSPIRATION being a continuous phenomenon in living plants, and being at the same time readily measurable, it has been suggested by WHITNEY and CAMERON[1] that here is a criterion for comparing the rates of growth of similar cultures made in different media. It was found at the start that when two cultures of wheat seedlings were prepared, exactly alike except that one was in a good soil and another in a poor, the total transpiration for a period of ten days or more was invariably much greater in the former culture, the difference between the two amounts of water lost being roughly equivalent to the difference between the agricultural values of the soils. It was deemed worth while to investigate this fact more carefully, and the present paper embodies the results of such investigations.

The Russian variety of wheat known as "chul" was used in these experiments. The soil cultures were grown in wire baskets covered with paraffin, such as those described in the paper cited above. For any one series the initial moisture content of all the soils was the same, being about the optimum for plant growth under the conditions of the experiment. The transpiration was determined daily, or at intervals of four days or less, by the method of weighing; and the necessary amount of water was then added to bring the soil back to its original moisture content. The baskets of any series stood side by side in a plant house, being thus subjected to exactly the same changes in temperature, humidity, light, and air currents. Six wheat seedlings were grown in a basket.

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[1] WHITNEY, M. and CAMERON, F. K. Investigations in soil fertility. U. S. Department of Agriculture, Bureau of Soils, Bull. 23. 1904.

Water cultures were grown in black bottles of about 50^{cc} capacity, the seedlings being first germinated in sand and then placed in cork stoppers in the manner described by the authors just referred to. Transpiration was taken by weighing, and the solutions were changed every few days. Otherwise, these were grown under the same conditions as were the basket cultures. Four wheat seedlings were grown in a bottle.

At the end of an experiment the series was photographed, the tops were removed by cutting just above the seeds, the leaf surface was determined, and also the weight of tops and leaves. The determination of leaf surface was made in the following way, which is a modification of that used by previous writers.[2] A plate of glass was coated with dextrin mucilage and the latter allowed to become nearly dry. On this was gummed the wheat leaves side by side, with their edges in contact so far as possible. When the mucilage had become thoroughly dry, but before the leaves had dried appreciably, a photographic print of the leaf outline was made by direct contact. For this the developing paper called "velox" was used; after being developed, fixed, and washed the sheets were squeegeed and dried on ferrotype plates, face down, thus giving perfectly smooth, hard surfaces. The white area of a print so prepared is equal to the area of one side of the leaves whose surface is to be determined. This area was measured by one of two methods, which were found to agree accurately: (1) it was measured directly by means of a planimeter; (2) its area was obtained indirectly by cutting around its margins with scissors and then weighing the white portion as well as the whole sheet. The area of the entire sheet having been first obtained from its dimensions, the required area of the white portion is easily obtained from the known quantities by calculation, assuming that the paper is uniform. The two weights were both obtained at the same time after cutting out the white portion, in order to avoid any errors due to changes in the moisture content of the paper. The uniformity of the latter was tested as follows: four rectangular pieces of velox paper were developed, fixed, washed, and dried as in the actual determination of leaf area. From each of these was deter-

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[2] BURGERSTEIN, A., Die Transpiration der Pflanzen. Jena. 1904. Pp. 24, *et seq.*, and the references there made.

mined, by weighing and measurement, the weight of $1^{sq\ cm}$ of paper. The results are tabulated below:

	Area, sq cm	Weight gr.	Average weight of $1^{sq\ cm}$
Sheet A.........	229.852	3.642	0.01584
Sheet B.........	109.650	1.772	0.01616
Sheet C.........	70.992	1.098	0.01547
Sheet D.........	49.210	0.771	0.01565

Average weight of $1^{sq\ cm}$, by all tests, 0.01573; greatest variation from average, 0.00043; greatest variation from average in per cent. of average, 2.7 per cent.

FIG. 1

From these figures and other similar ones it appears that this paper so treated is uniform within 3 per cent. of error. Since the planimeter method gives approximately the same results as that by weighing, the two methods can be used interchangeably. The former is the more direct and consumes less time and energy, so that where the instrument is at hand it should be used for this sort of work.

In both soil and water cultures a number of duplicates were often carried through so far as transpiration was concerned. In such cases, owing to the great amount of work involved, the other measurements were made for only one series and not for the duplicates.

The experiments, results of which are recorded in the present paper, were carried out in the laboratories of the Bureau of Soils of the United States Department of Agriculture, Washington, D. C. I am indebted to Professor MILTON WHITNEY, to Dr. F. K. CAMERON, and to all the members of the laboratory staff for facilities and assistance without which the work could not have been done. Especially am I indebted to Mr. FRANK D. GARDNER, in charge of the Division of Soil Management, for cultures from which a number of the series were obtained, and for the data themselves in case of Series IV to X inclusive.

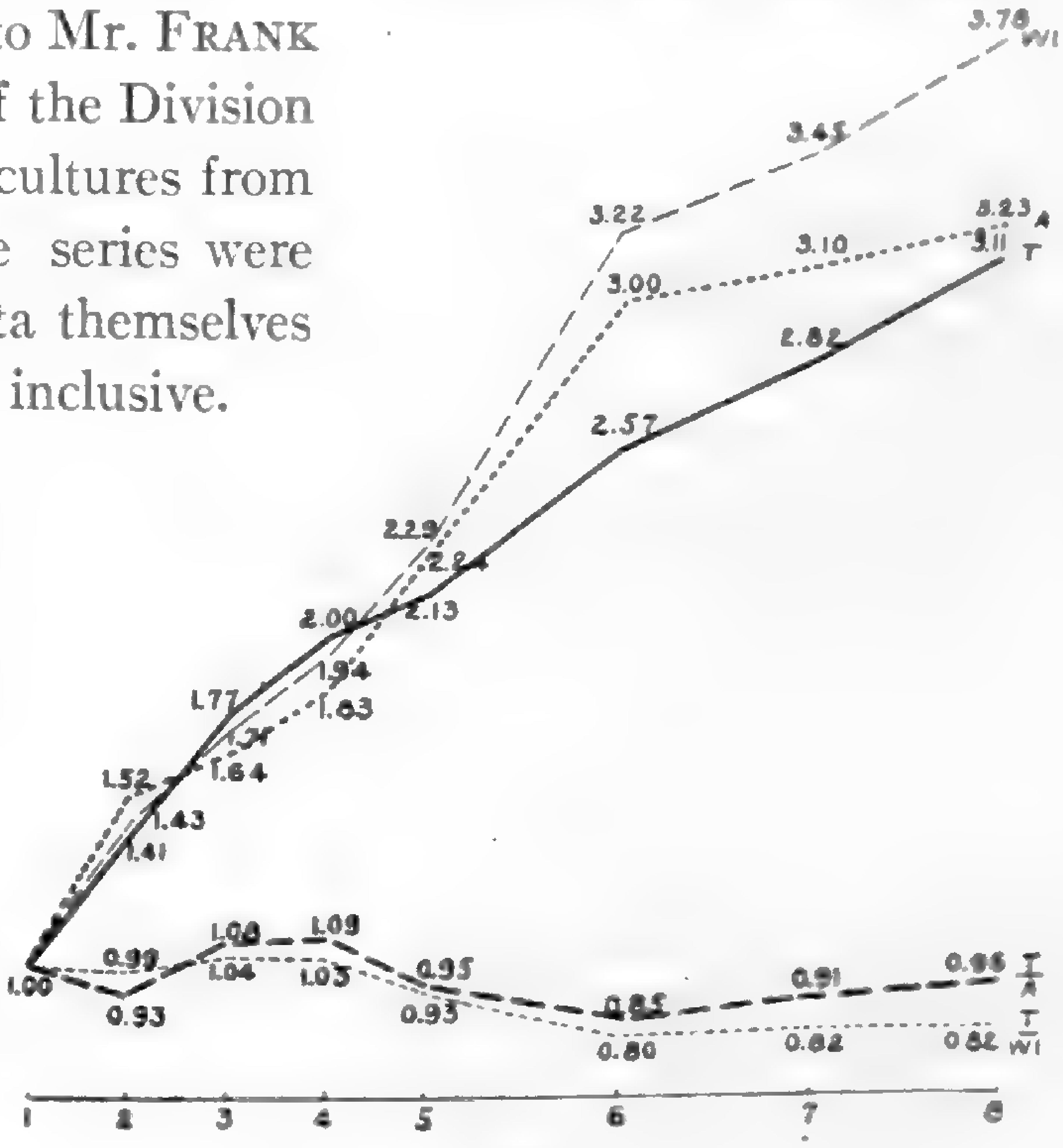

FIG. 2

EXPERIMENTS.

The cultures will be described in the following paragraphs. It is to be remembered that for any single series the only environmental factors which were varied are those connected with the nature of the medium in which the roots were growing. The criteria for comparing the growth of the different cultures of a series are (1) total transpiration during the period of the experiment, (2) green weight of tops and (3) of leaves, and (4) area of leaves. In these studies aerial growth alone is considered, the investigations into the growth of roots being reserved for another paper.

Series I.—A very poor natural soil from Takoma Park, Md., was used in this series. Basket no. 1 contained the natural soil and the others the same soil mixed with fermented stable manure in different amounts. The plants were weighed at intervals of from one to three days. The experiment lasted from October 25 to November 11, 1904. A photograph of the series at the end of the experiment is shown in *fig. 1*. Data for the series are given in the following table. The baskets are arranged according to the total transpiration for the period of the experiment.

These data are best presented in the form of curves (*fig. 2*).

DATA FOR SERIES I.

Treatment	No. of basket	Total transp. (T)[4]	Leaf area (A)[5]	Green wt. of leaves. ($Wl.$)[6]	$\frac{T}{A}$[7]	$\frac{T}{Wl.}$[8]
Takoma soil....................	1	29.7	27.657	0.51	1.07	58.2
" + 5000 p. p. m.[3] manure...	2	41.9	42.182	0.73	0.99	57.4
" +10000 " " ...	3	52.6	45.392	0.87	1.16	60.4
" +15000 " " ...	4	59.5	50.658	0.99	1.17	60.1
" +20000 " " ...	5	63.4	62.304	1.165	1.02	54.2
" +30000 " " ...	6	76.2	83.207	1.635	0.91	46.4
" +40000 " " ...	7	83.7	85.982	1.760	0.97	47.5
" +50000 " " ...	8	92.4	89.372	1.930	1.03	47.9

Abscissas are here taken proportional to the amounts of manure in the different baskets, and a curve is drawn for each column of figures in the table, these being first reduced so as to be mutually comparable by calculating each quantity in terms of that for basket no. 1, considered as unity. The numbers so obtained are plotted as ordinates for their respective curves. Thus the curves all start at the same point and their nearness to coincidence or parallelism is the criterion for judging whether or not the different sets of measurements vary in the same order. The derived numbers, from which the curves are plotted, are placed upon them and need not be tabulated. The basket numbers (which correspond to the treatments, see the table) are placed below the curves in a horizontal line. A symbol corresponding to a column in the table is placed at the right of each curve and designates the particular set of data for which it is drawn. Thus, T is the curve of transpiration, A of leaf area, Wl of leaf weight, $\frac{T}{A}$ transpiration per $2^{\text{sq cm}}$ of total leaf area, and $\frac{T}{Wl}$ transpiration per gram of green leaves.

It is seen immediately that the curves for transpiration, leaf weight, and leaf area all lie quite close to one another. Judging the relative growth of the different cultures by any one of these three curves results in arranging the baskets in identically the same series,

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[3] p. p. m. will be used throughout to denote parts per million, by weight.

[4] The transpiration figures are always in grams.

[5] Leaf area is given for only one side of the leaves, always in square centimeters.

[6] In grams.

[7] Transpiration per $2^{\text{sq cm}}$ of total leaf area.

[8] Transpiration per gram of green leaves.

which is likewise the series obtained by arranging them in accordance with the amount of manure added.

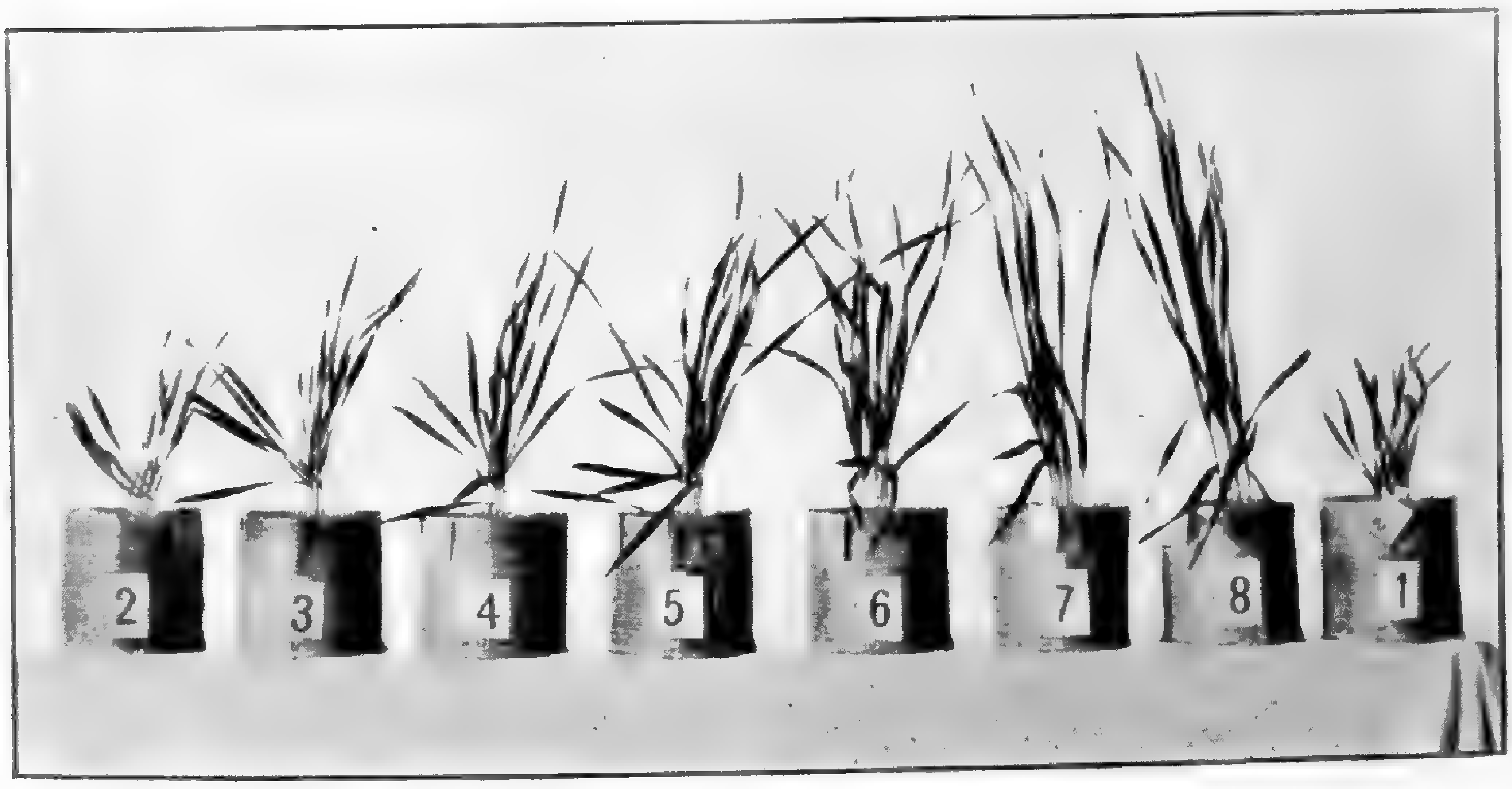

FIG. 3

The two remaining curves indicate that both transpiration per unit area of the leaves and transpiration per gram of their green weight are practically uniform throughout the series; their curves are nearly horizontal lines. Of course this uniformity is due to the nearness to coincidence of the other three curves and is a criterion for judging of the latter property. There appears to be a very slight tendency for the transpiration per square centimeter to be depressed in the better soils, and a somewhat more marked, but still slight, tendency for the other ratio to be depressed in the same way.

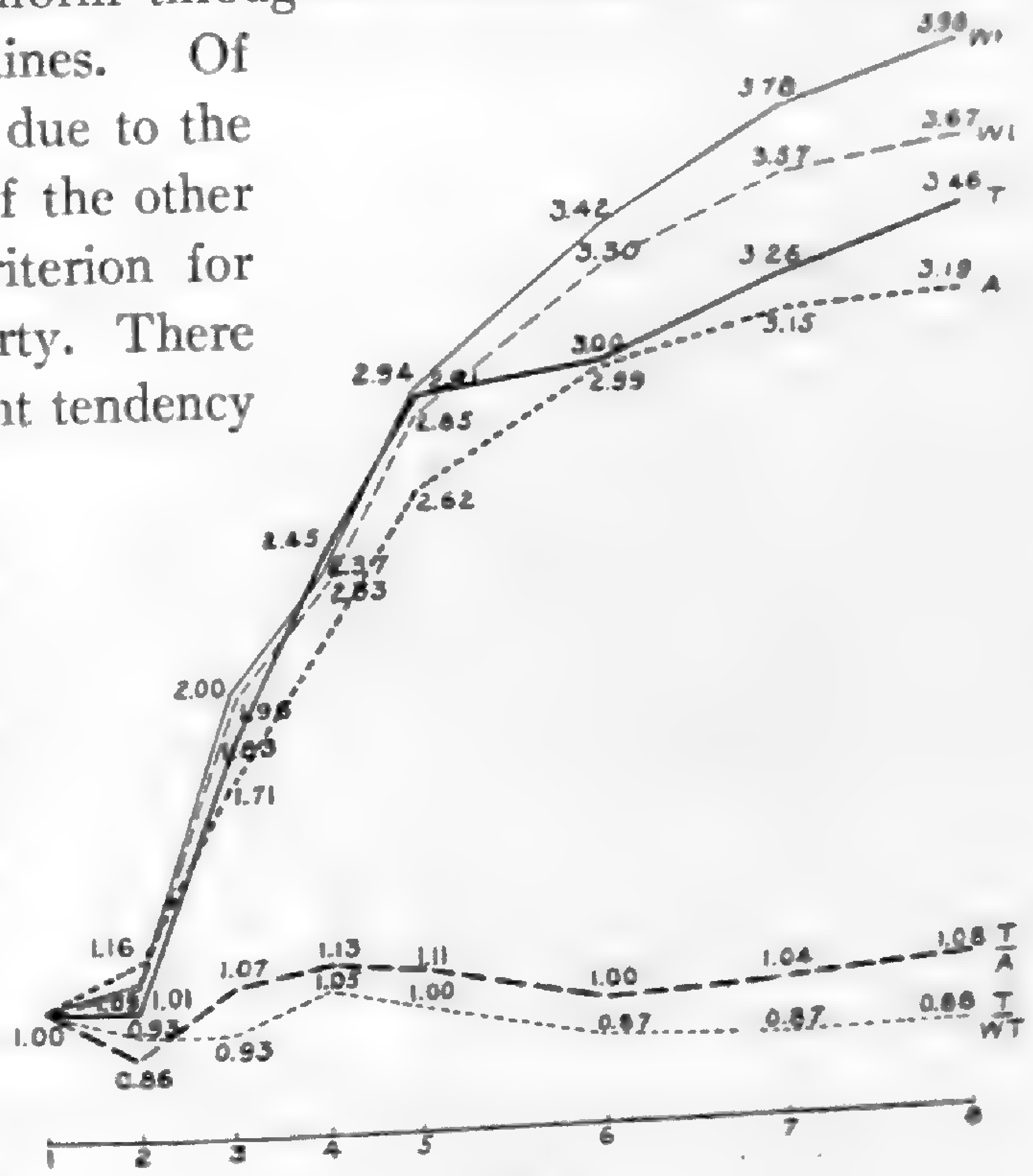

FIG. 4

In the following descriptions of series, the tables of observed data will often be omitted, the numbers placed upon the curves showing their relative magnitudes, which alone are of interest here.

Series II.—This series is identical in treatment with Series I. It lasted 18 days, from November 11 to November 29, 1904.

The plants are shown in *fig. 3*, and curves for the series are given in *fig. 4*. It will be noticed that in this case both weight of leaves and weight of tops are represented, the latter being denoted by *Wt.* Apparently the former increases somewhat more rapidly than the latter with increasing fertility of the soil. The curves of transpiration, leaf area, and the other two curves just mentioned lie so close together that according to any one of them the several baskets would fall into exactly the same series, which would again be identical with that obtained by arranging them in accordance with the increasing amounts of manure used. Transpiration per unit area is fairly uniform throughout this series, but that per gram of green tops decreases slightly with increasing fertility. The series is on the whole in harmony with Series I.

FIG. 5

Series III.—This series is another duplicate of Series I. The experiment lasted from November 23 to December 14, 1904. The plants are shown in *fig. 5*, and *fig. 6* represents the curves. If basket no. 2 were omitted from the series (and it is obvious that its data are very erratic, though wherein the error lies it is impossible to determine), the curves would take the general form as those of Series I and II. It is again seen that the order of arrangement of the baskets by amount of transpiration agrees with that obtained from the relative amounts of manure, leaf area, and weights of leaves and of tops. Here the two lower curves are again nearly horizontal lines. There is a slight tendency for transpiration per unit area to increase with increasing soil fertility, but this tendency is hardly shown at all in case of transpiration per gram.

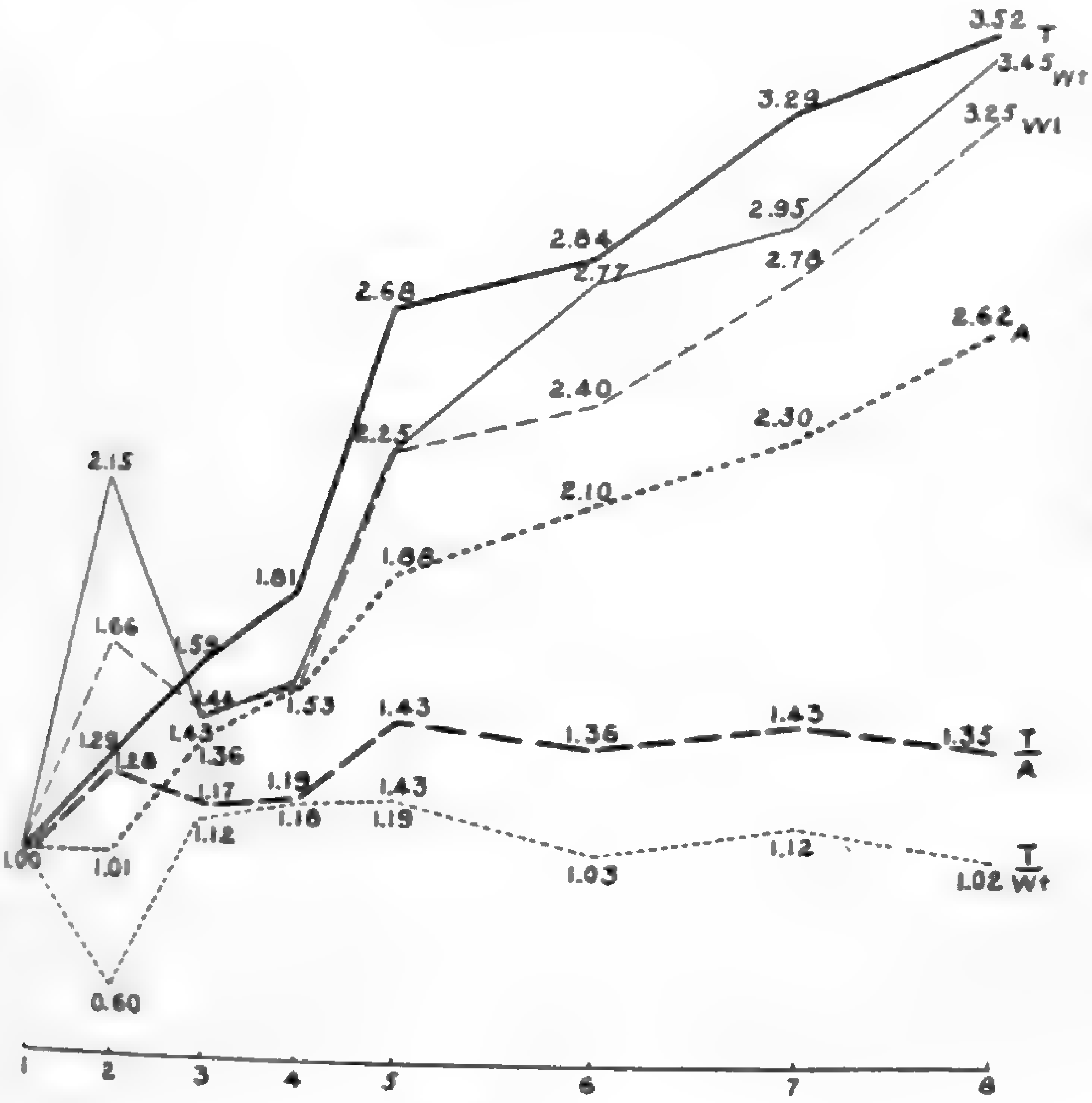

FIG. 6

Series IV, V, and VI.—These are duplicates of I, II, and III respectively, carried on at the same time and in the same place. While the three already described are based on a single basket of each treatment, those here presented are based on four baskets, containing in all twenty-four plants. Only transpiration and green weight of tops are considered; the other determinations were not made here.

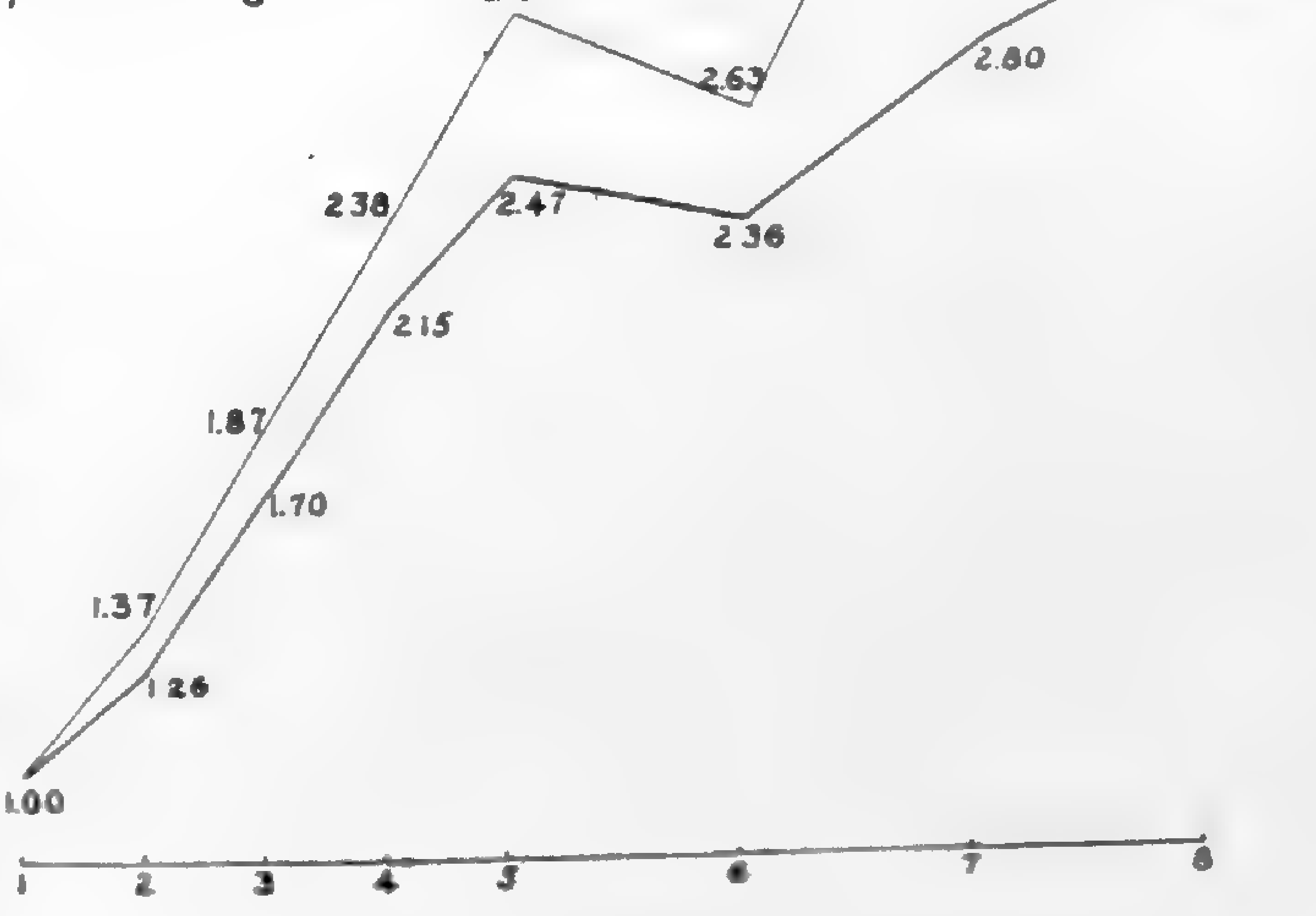

FIG. 7

Curves for these three series are given in *figs. 7, 8*, and *9*. In *fig. 7* it is to be noted that culture 6, containing 30,000 p.p.m. manure in the Takoma soil, shows a discrepancy which was not found in Series I, of which this is a duplicate. No reason for this can be given. It is obviously due, however, to soil conditions, since the curve of transpiration follows closely that of weight, both exhibiting the same drop for culture 6.

There are no discrepancies in Series V; the curves of *fig. 8* approximate each other throughout and agree very well with those of Series II.

Series VI (*fig. 9*) shows a fall in transpiration in culture 3, which does not occur in Series III. This fall in transpiration is accompanied by a very much diminished relative weight, although this does not amount to an actual depression in the curve. Aside from this culture the series is in agreement with the preceding, and the two curves are seen to be very closely similar throughout.

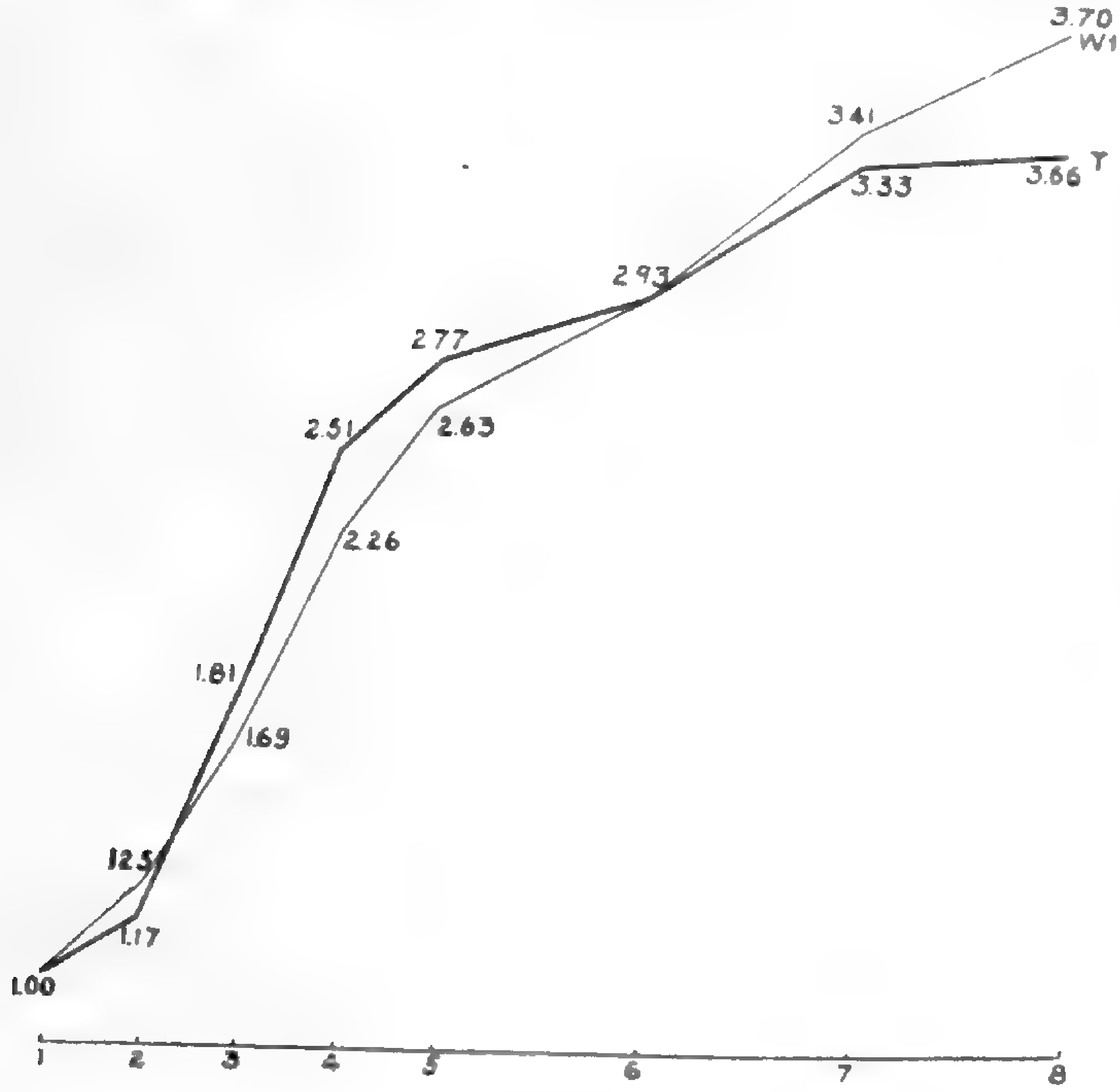

FIG. 8

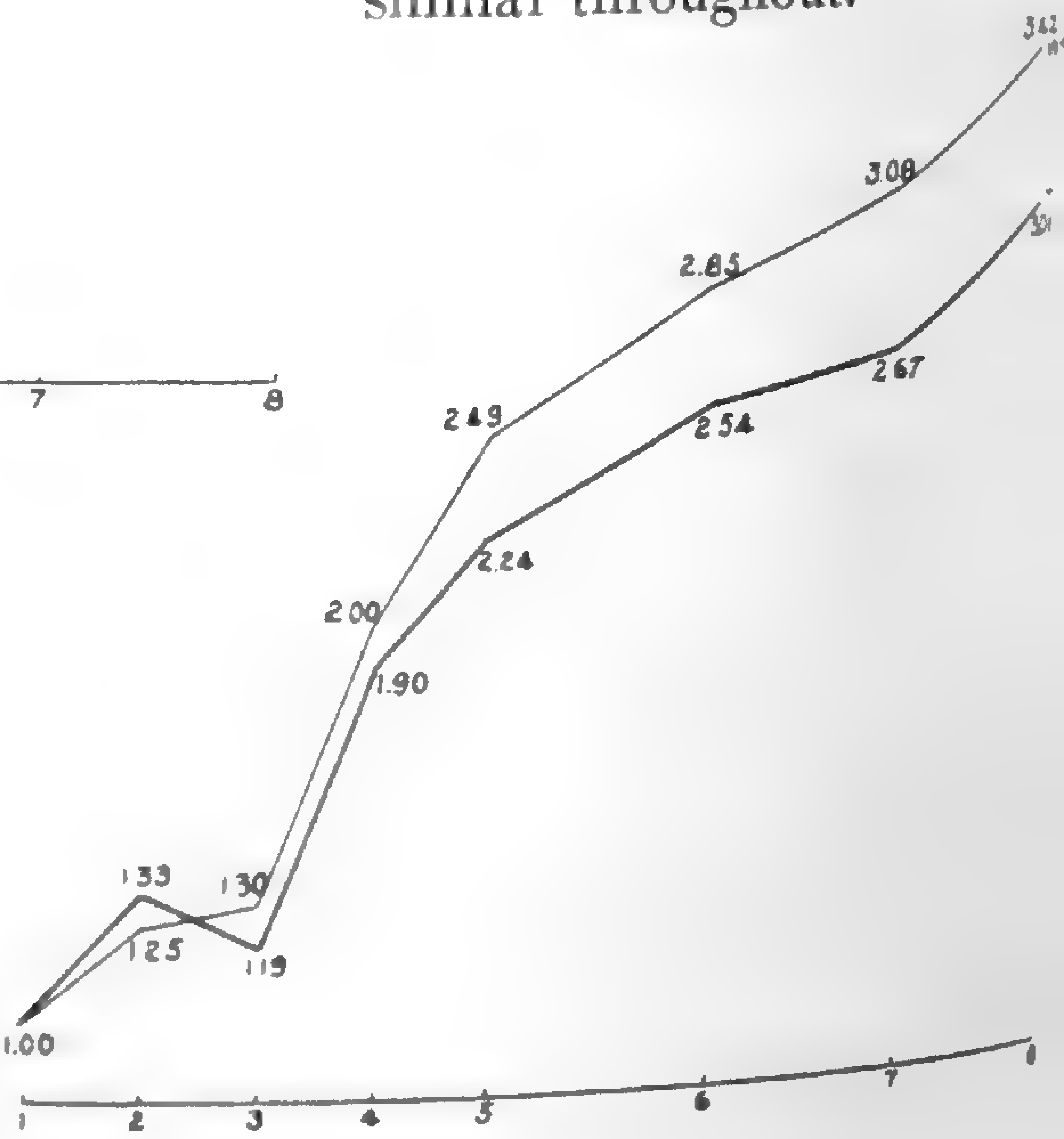

FIG. 9

For the six similar series so far described, it appears that total transpiration is as good a criterion as green weight for judging of the relative growth in these soils. The differences are generally somewhat more marked by the weight criterion than by that of transpiration. Series III is an exception to this, however.

Series VII.—This series consists of Cecil clay[9] poor with various treatments as given in the following table. The samples which

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[9] This soil is from near Statesville, N. C. It is a stiff reddish clay, considered the best soil of the Piedmont Plateau for general farming purposes. The good and poor varieties are markedly different agriculturally, but appear to be identical so far as soil analysis can determine.

received fertilizers were mixed with the latter, moistened, and allowed to stand several weeks with frequent stirring. The aerated soil was treated in the same way. At the end of this time lime was added to certain of the samples and the seeds were then planted. The proportions of fertilizers added are stated under "treatment" in the following table. Where more than one fertilizer was used, each was in the same proportion as when used alone. The amount of lime added is given in the third column. Five baskets of six plants each were used for each treatment. The experiment lasted from November 19 to December 8, 1904. The data are given in the following table. Only transpiration and weight are given. The cultures are arranged in order of transpiration figures.

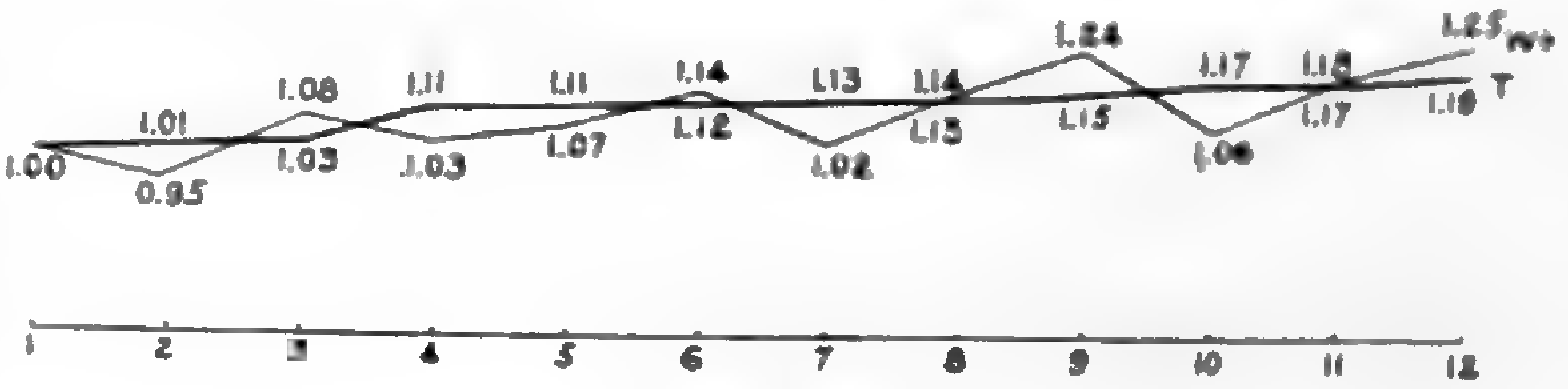

FIG. 10

DATA FOR SERIES VII

Treatment	Culture no.	P.p.m. lime added	Green weight of tops (*Wt*)	Total transpiration (*T*)
Cecil clay good added to poor. 10 per cent.	1	4000	7.30	313.8
Cecil clay poor, aerated	2	none	6.95	316.5
$NaNO_3$. 127 p. p. m.	3	2000	7.85	324.2
Lime. 1000 p. p. m.	4	none	7.50	337.5
$Ca_3(PO_4)_2$. 77 p. p. m.	5	2000	7.50[10]	348.4[10]
$NaNO_3+Ca_3(PO_4)_2$	6	3000	8.35	351.1
Stable manure. 7000 p. p. m.	7	2000	7.50	353.7
K_2SO_4. 130 p. p. m	8	2000	8.35	356.1
$NaNO_3+K_2SO_4+Ca_3(PO_4)_2$	9	3000	9.05	361.3
Cecil clay poor, natural	10	none	7.75	367.0
KNO_3. 151 p. p. m	11	4000	8.65	368.0
$NaNO_3+K_2SO_4$	12	3000	9.10	372.9

The curves are shown in *fig. 10.* That of transpiration is practically a straight line and is nearly horizontal. The weight curve varies on both sides of that of transpiration, leaving the latter as approximately the mean of the points of the former. No marked improvement of the soil by any of the treatments used is to be made out. All variations here are comparatively very slight.

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[10] Only 29 plants; calculated numbers for 30 plants are: *Wt*, 7.80; *T*, 349.2.

Series VIII.—This is a series similar to the last described, and carried out at the same time, but having as its basis another natural soil, Leonardtown loam poor.[11] For the treatments and data see the following table, in which the system of notation is the same as in the last. The cultures are again arranged by transpiration figures.

Curves for these data are given in *fig. 11*. They agree very well in all points with the last series discussed.

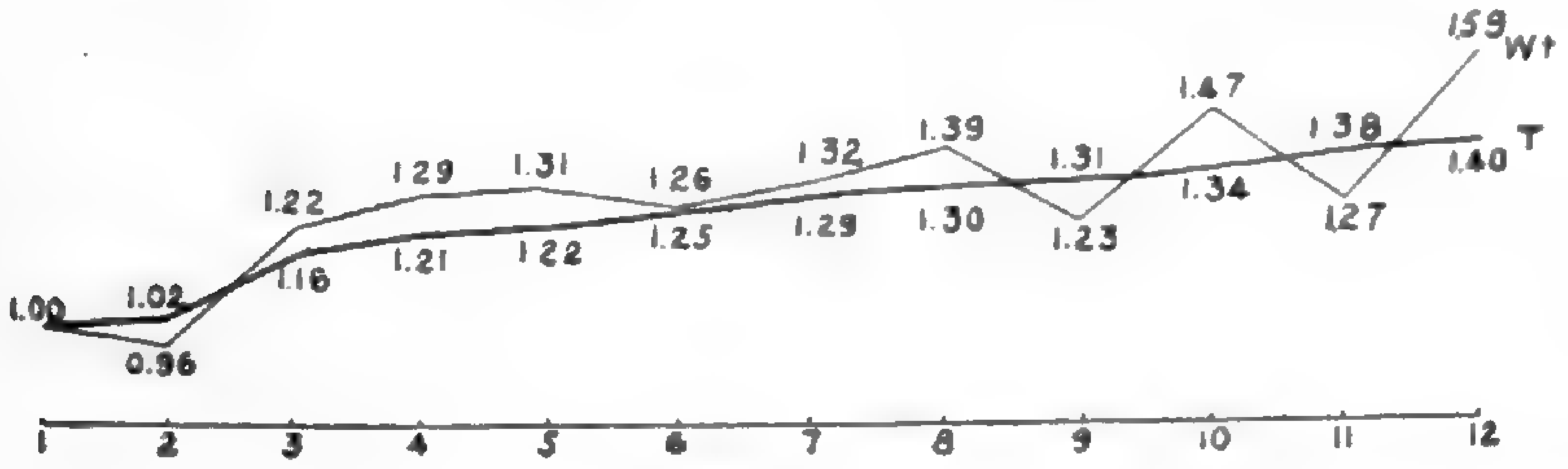

FIG. 11

Series IX.—This again is similar to Series VII, and was carried out at the same time, but is made from Leonardtown loam good,

DATA FOR SERIES VIII

Treatment	Culture no.	P.p.m. lime added	Green weight of tops (*Wt*)	Total transpiration (*T*)
Leonardtown loam poor, aerated	1	none	6.05	276.2
Leonardtown loam poor, natural	2	none	5.80	280.8
$Ca_3(PO_4)_2$. 77 p. p. m.	3	2000	7.40	320.4
$NaNO_3+Ca_3(PO_4)_2$	4	3000	7.80	333.0
K_2SO_4. 130 p. p. m	5	2000	7.90	337.3
10 per cent. Leonardtown loam, good added to poor	6	4000	7.60	347.5
$NaNO_3$. 127 p. p. m.	7	2000	8.00	356.4
KNO_3. 151 p. p. m.	8	4000	8.40	359.5
Lime. 1000 p. p. m.	9	none	7.45	362.0
$NaNO_3+K_2SO_4$	10	3000	8.90	371.1
Stable manure. 7000 p. p. m.	11	2000	7.70	428.0
$NaNO_3K_2SO_4+Ca_3(PO_4)_2$	12	3000	9.55	387.7

and sodium nitrate was added at the time of planting in place of lime, as in the last two series. The system of notation is the same as above and the cultures are arranged as in the two preceding series.

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[11] This soil was collected near Leonardtown, Md. It is a yellow silty loam, closely resembling loess, and is considered a good soil for general farming. It occupies large areas in Maryland and Virginia, and to some extent in Kentucky. The good and poor varieties of this soil are related in the same manner as those of Cecil clay.

DATA FOR SERIES IX

Treatment	Culture no.	P.p.m. $NaNO_3$ added	Green weight of tops (*Wt*)	Total transpiration (*T*)
10 per cent. Leonardtown loam poor added to good.	1	765	8.80	323.0
Leonardtown loam good, natural.	2	none	7.40[12]	352.8[12]
KNO_3. 151 p. p. m.	3	606[13]	10.10	375.6
$NaNO_3+K_2SO_4+Ca_3(PO_4)_2$.	4	382	11.00	384.6
$NaNO_3+K_2SO_4$.	5	none	10.50	398.6
Manure. 7000 p. p. m.	6	637	11.70	402.1
$Ca_3(PO_4)_2$. 77 p. p. m.	7	382	10.40	406.1[14]
Lime. 1000 p. p. m.	8	510	10.70[14]	410.0
$NaNO_3+K_2SO_4$.	9	none	10.20	424.1
K_2SO_4. 130 p. p. m.	10	255	10.05	426.9
Leonardtown loam good, aerated.	11	none	9.90	438.0
$NaNO_3$. 127 p. p. m.	12	none	10.60	438.4

The curves are given in *fig. 12*. With the exception of culture 2, and perhaps also of the last three cultures of the series, in which weight is low as compared to transpiration, these agree with the last two series discussed.

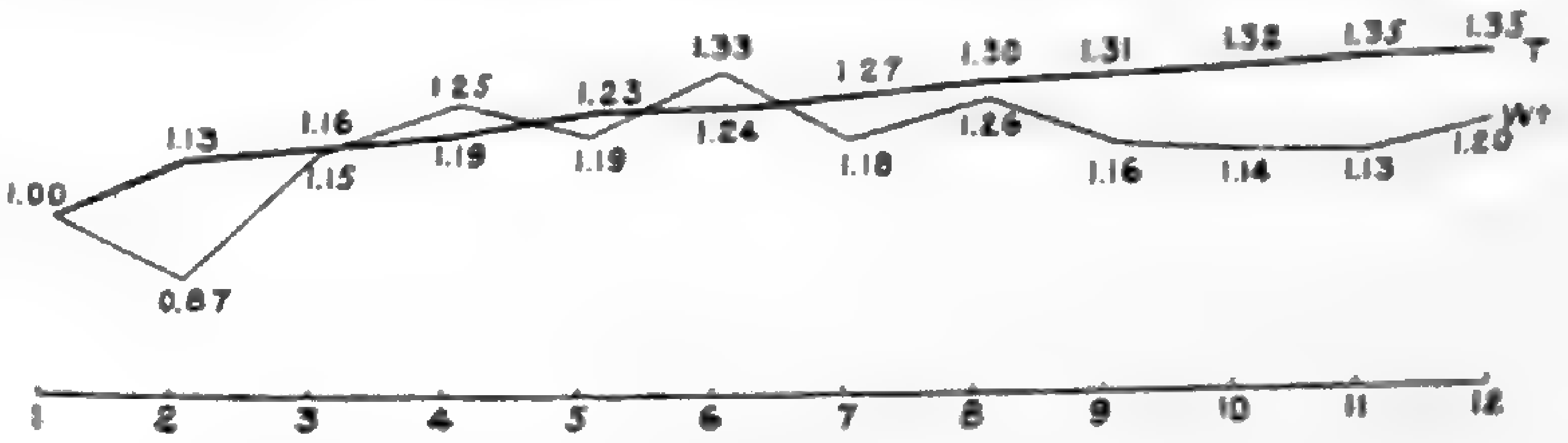

FIG. 12

Series X.—This consists of five different natural soils and a rich garden soil from the greenhouse. The experiment lasted thirty-four days, from November 11 to December 15, 1904. Weight of both leaves and tops as well as transpiration and leaf area were determined. A single basket of six plants was used for each soil. The data are given in the table. The arrangement is by transpiration figures.

DATA FOR SERIES X.

Soil	Basket no.	Total transpiration (*T*)	Leaf area (*A*)	Green weight leaves (*Wl*)	Green weight of tops (*Wt*)	$\frac{T}{A}$	$\frac{T}{Wt}$
Cecil clay poor.	1	68.8	48.1	0.70	0.86	1.43	80.1
Takoma soil.	2	70.6	48.8	0.73	0.73	0.86	82.1
Leonardtown loam poor.	3	90.1	60.6	0.97	1.21	1.49	74.5
Cecil clay good.	4	90.1	63.8	1.02	1.28	1.41	70.4
Leonardtown loam good.	5	127.9	74.8	1.24	1.54	1.71	83.1
Garden soil.	6	148.6	95.4	1.54	2.11	1.56	70.4

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[12] Only 29 plants; calculated numbers for 30 plants are: *Wt*, 7.65; *T*, 365.1.

[13] KNO_3 in place of $NaNO_3$.

[14] Only 29 plants; calculated numbers for 30 plants are: *Wt*, 11.10; *T*, 420.0.

The plants are shown in *fig. 13*, and the curves in *fig. 14*. Those for weight, transpiration, and leaf area approximate each other very well. With increasing fertility of the soil the transpiration increases somewhat more rapidly than the area, while the same function increases somewhat less rapidly than the weight of tops. Thus the curve of transpiration per unit area rises slightly, while that for transpiration per gram falls to about the same degree. The last two curves, however, both approximate horizontal straight lines.

FIG. 13

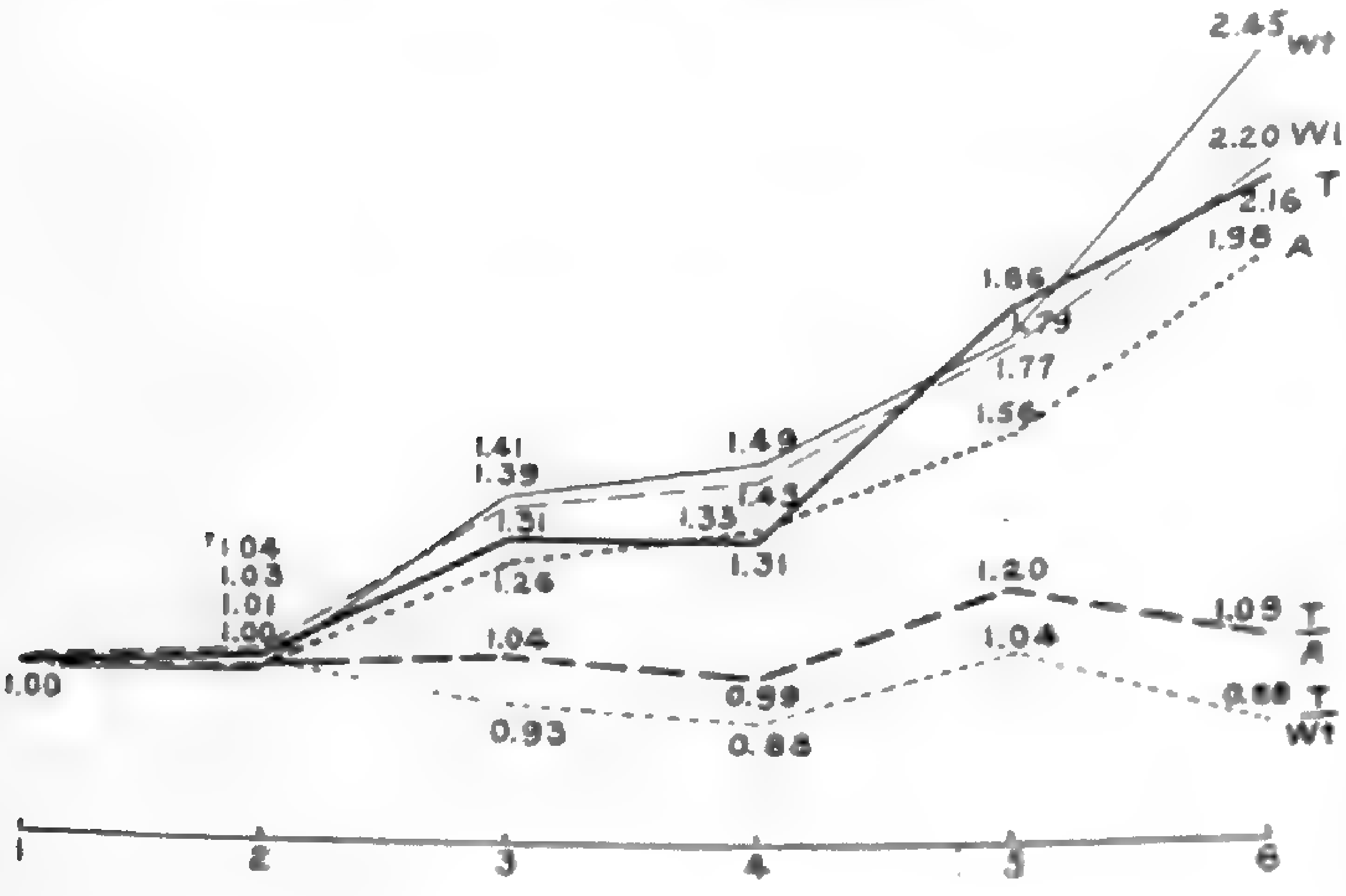

FIG. 14

Series XI.—This is a study of soil extracts made from the soils used in Series X. The plants were grown in bottles, as has been already stated. One bottle containing four plants was used for each culture. The experiment lasted from November 11 to December 1, 1904. The extract was changed every four days, and the transpiration was taken at the same intervals, beginning November 15. The plants were about three days old when placed in the bottles, the seeds having been germinated in sand. The data are given in the table.

A photograph of the series is given in *fig. 15*, and curves in *fig. 16*. It will be observed that the criteria other than transpiration dis-

DATA FOR SERIES XI.

Soil extract	Culture no.	Total transpiration (T)	Green weight leaves (Wl)	Green weight of tops (Wt)	$\frac{T}{A}$	$\frac{T}{Wt}$
Takoma soil	1	41.9	1.07	1.45	0.61	28.9
Cecil clay poor	2	54.9	1.09	1.44	0.75	38.1
Leonardtown loam poor	3	63.8	1.47	1.917	0.70	33.2
Cecil clay good	4	70.8	1.40	1.918	0.80	36.9
Leonardtown loam good	5	75.8	1.70	2.35	0.76	32.3
Garden soil	6	111.6	1.90	2.78	0.96	40.1

agree with the latter in the relation of cultures 3 and 4. By transpiration the soil of 4 is considerably better than that of 3, but by the other criteria it is a trifle poorer. Besides this discrepancy there appears a rather marked disagreement between the difference between 1 and 2 and that between 5 and 6. Comparing this set of curves with those of Series X, we find that the order of arrangement of the soil extracts (by transpiration) differs in one point from that of the soils themselves. By the soils, Cecil clay poor stands lower than Takoma soil, while by extracts this is reversed. However, by all four criteria these two are practically equivalent in the former series, and the same is true in the latter by all criteria but transpiration.

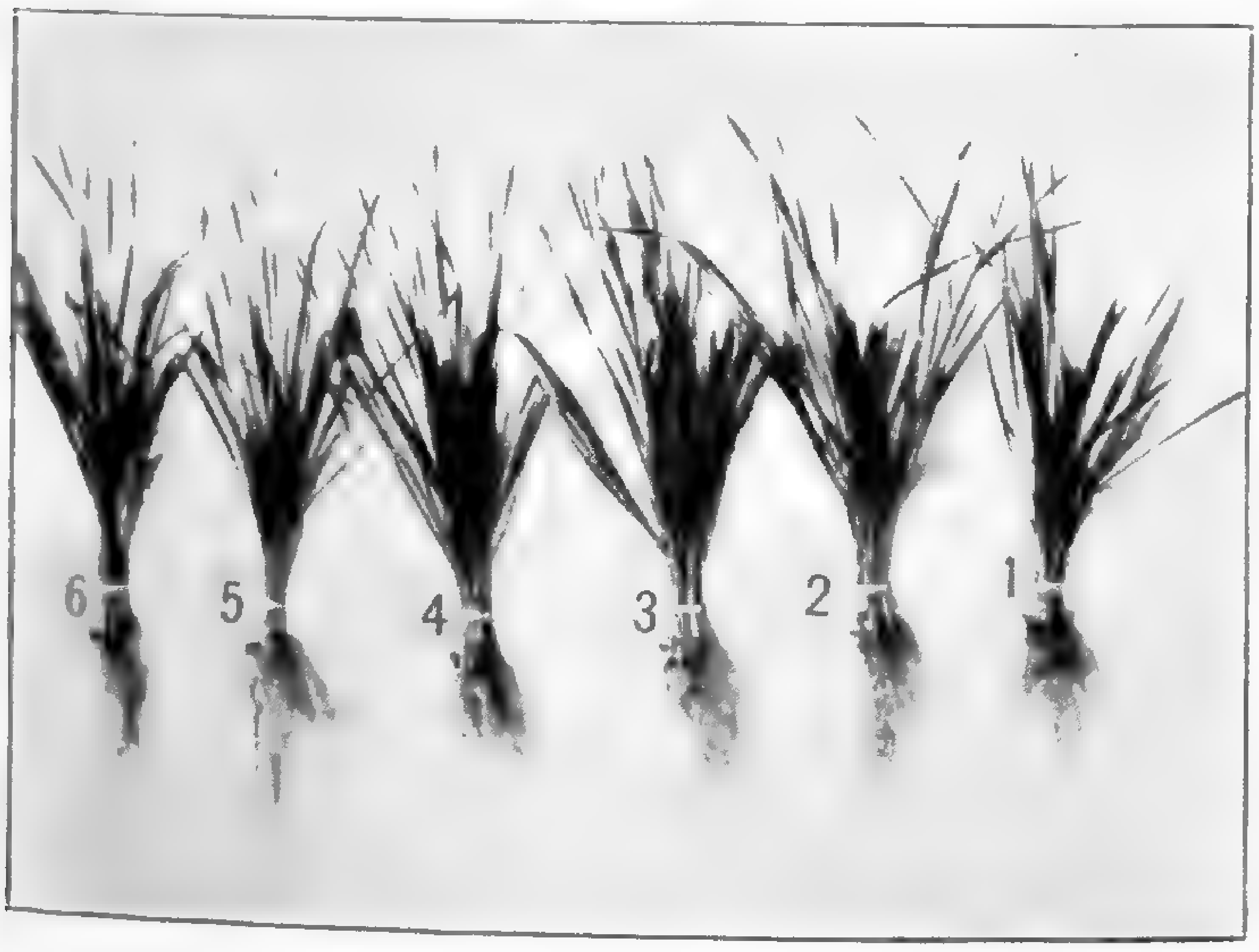

FIG. 15

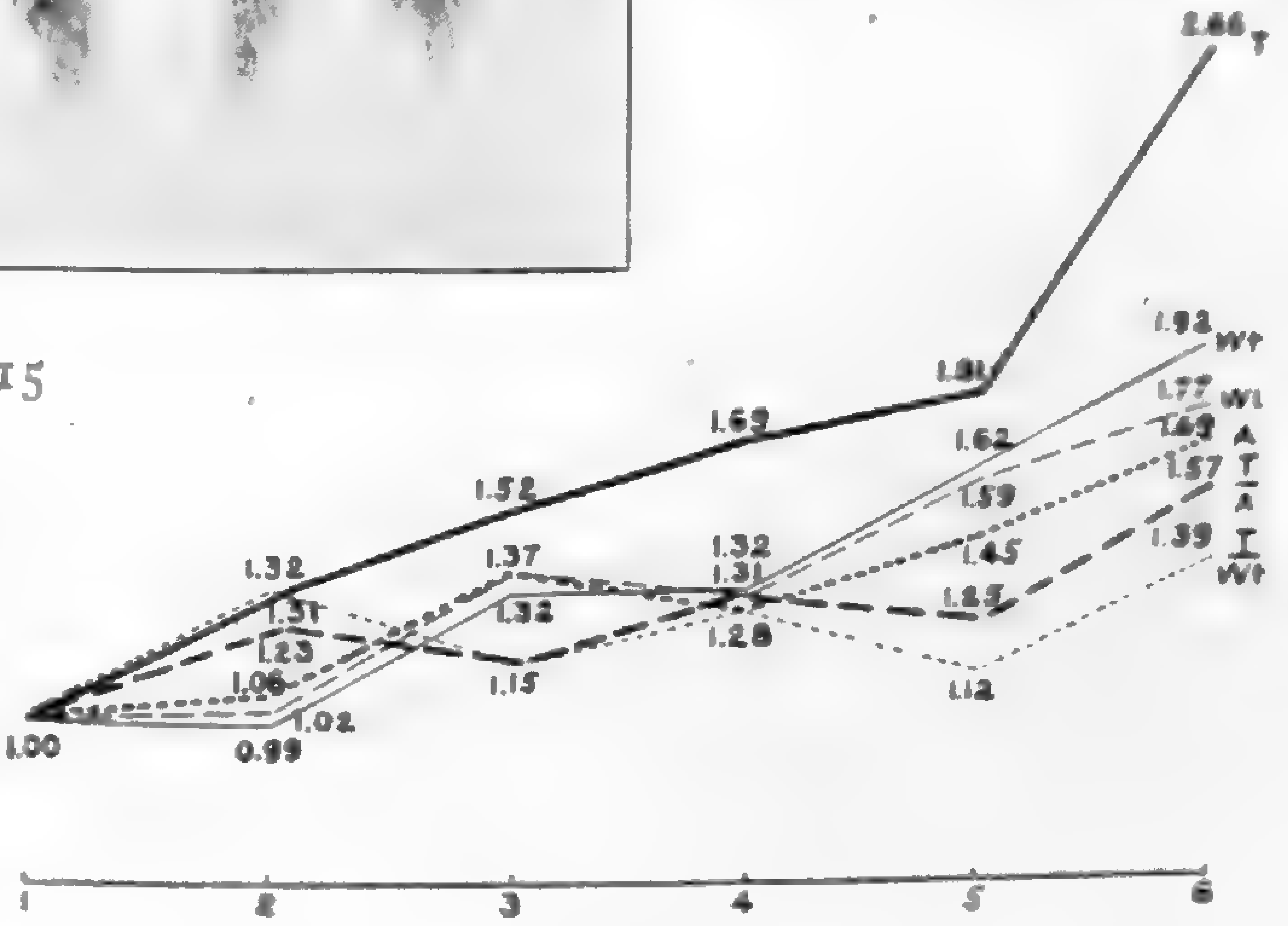

FIG. 16

Transpiration both per unit area and per gram of tops increases quite markedly with the increasing fertility of the extract.

Series XII.—This consists of duplicates of cultures 1, 2, 4, and 6 of Series XI. The cultures were carried on at the same time as were those of the former series. One bottle, containing four plants, was used for each culture. Leaf area was not determined. The curves are given in *fig. 17*.

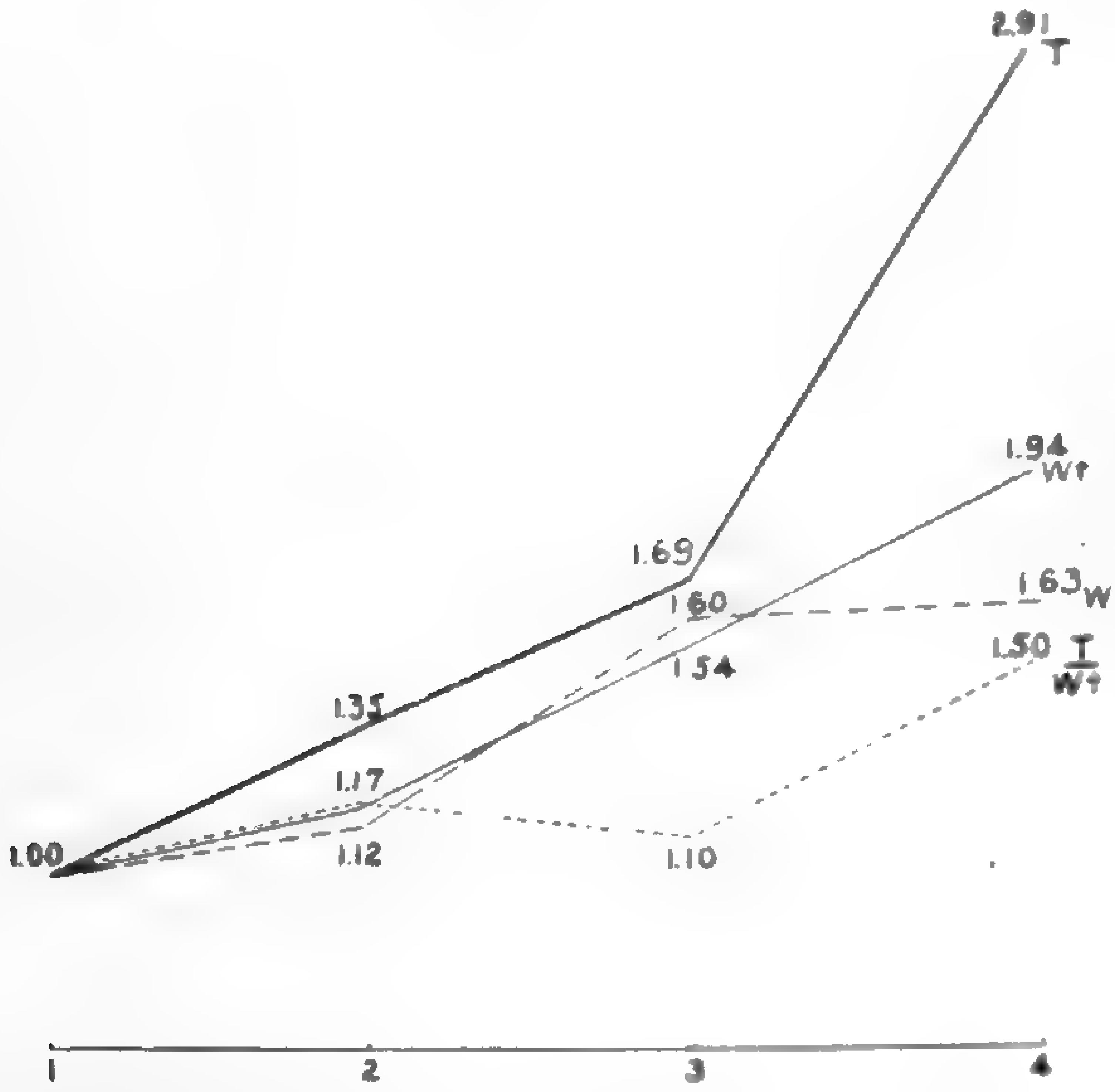

FIG. 17

From them it is seen that the greatest discrepancy between weight and transpiration in Series XI (that occurring in culture 4) does not appear here, and the discrepancy in culture 2 also disappears. The relatively high transpiration of the garden soil is again exhibited, but by both weight and transpiration the cultures fall in the same order, and this is the order obtained in the preceding series. Regarding the relation of Takoma soil to Cecil clay poor, it may be that the deleterious properties of the former are more pronounced in aqueous extract than in the soil itself.

FIG. 18

Series XIII.—This consists of five different nutrient solutions. No. 1 is a solution of the necessary salts which had already had wheat plants growing in it for twenty days. No. 2 is the same with one part per million pyrogallol added. No. 3 is the same but with ten times as much of the chemical. No. 4 is a nutrient solution exactly like no. 1 but freshly made. No. 5 is the used nutrient solution with manure extract added. The cultures lasted from October 11 to November 8, 1904. The transpiration was taken for 17 days, from October 22 to November 8.

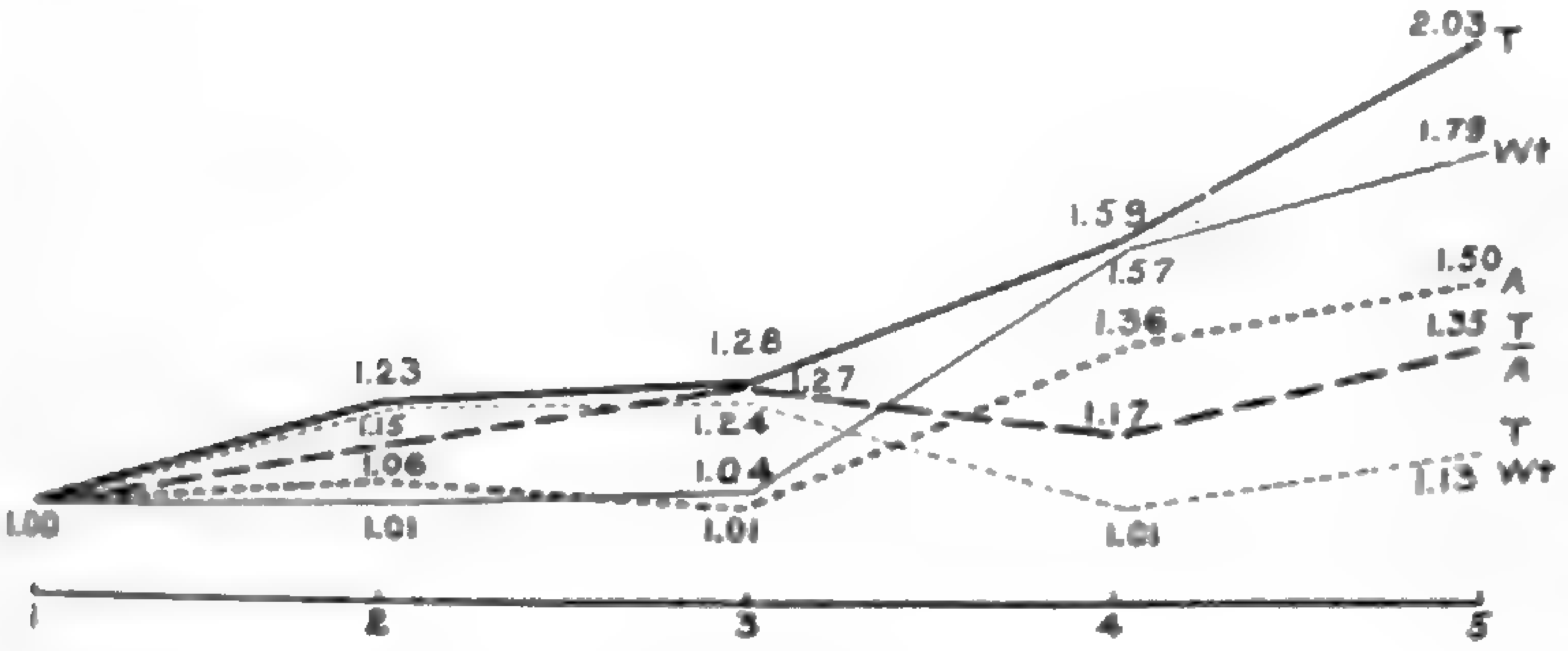

FIG. 19

A photograph of the series is shown in *fig. 18*, and curves are given in *fig. 19*. The first three cultures show practically the same weights and leaf areas, and nos. 2 and 3 show about equal transpirations. The transpiration numbers for nos. 2 and 3 are somewhat greater than that for no. 1. Nos. 3, 4, and 5 show about the same relation to each other by all three criteria, transpiration, weight, and area. In other words, the transpiration is surprisingly high in the two cultures containing pyrogallol. In some way this substance usually accelerates growth of roots, and this may explain the discrepancies above referred to. The question here brought up will be deferred to a future time.

FIG. 20

Series XIV.—This consists of soil extracts all made by the method described by WHITNEY and CAMERON (*loc. cit.*). No. 1 is an extract of the poor Takoma soil used in Series I, etc., but which had been used for the growth of wheat before for a period of twenty days. No. 2 is of the same extract freshly made with addition of one part per million pyrogallol. No. 3 is the same as the last without pyrogallol; and no. 4 is similar, but with addition of manure extract instead of the chemical. The period is the same as that for Series XIV.

The photograph for this series is given in *fig. 20*, and the curves in *fig. 21*. The three criteria arrange the cultures in the same order, although by transpiration the difference between nos. 2 and 3 is emphasized. Transpiration per unit area increases somewhat with the fertility of the solution; while that per gram is practically uniform throughout the series. The former of these ratios thus appears to vary in the opposite direction from that shown in certain of the soil series already described. It may be that the presence of a superabundance of water about the roots raises the transpiration per gram and per unit area above what it would be if the roots were in soil.

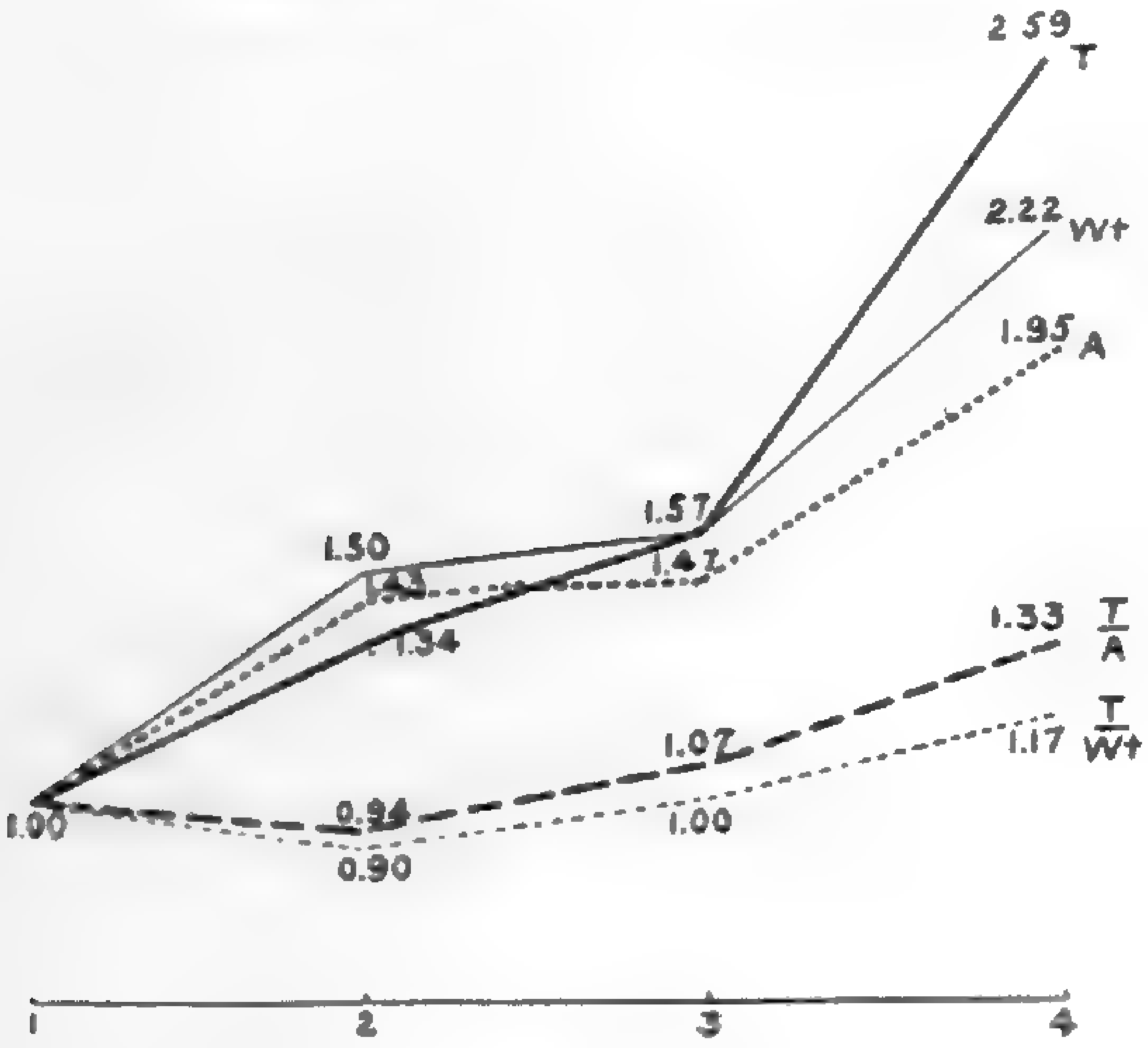

FIG. 21

CONCLUSION.

From the experiments which have been described the conclusion seems evident that total transpiration of wheat plants grown in various media is as good a criterion for comparing the relative growth in these media as is the weight of the plants. That these two criteria vary generally with the weight and area of the leaves gives the explanation for this conclusion. The facts are made clear that, for the types of media investigated at least, the amount of transpiration is practically a simple function of the leaf surface; and that this latter varies quite uniformly with the leaf weight, which in turn varies with the weight of the entire tops. Thus total transpiration appears to be a measure for the growth of the plant. With some series there seems to be a slight variation in the ratios of transpiration to weight and to area respectively, according to the nature of the medium; but these variations are so small when compared with those of their component terms, and lack uniformity in the different series to such a degree that they are practically negligible in the comparison of the cultures. It thus appears that the nature of the soil or solution in which the roots are grown has little or no influence on those structural and physiological properties of the leaves which control the amount of water lost per unit of leaf surface. The water loss per unit area of leaves is practically uniform throughout the different treatments; therefore the variations in total transpiration exhibited are due not to any difference in structure or activity of the leaves, but simply to the differences in extent of leaf surface developed.

In making use of this criterion of transpiration for the comparison of different nutrient media, it must be borne in mind that, as in all other biological experimentation, there will occur unexplained variations, and the truth must be attained by the summation of the results of a number of experiments. Many of the unexplained discrepancies of the experiments just described might not have occurred had the number of plants used been larger. The individual variation among wheat plants is found to be great, so that the larger the number of plants used the nearer would the result approach the true average.

Also, it must be remembered that if total transpiration is decreased by temperature, atmospheric conditions, etc., the different members of a series will approach each other in the amount of water lost; were transpiration checked completely, all the members would agree. It is thus necessary to have good conditions for evaporation from the leaves where such experiments are carried on, in order to magnify the differences in transpiration and keep them well above the limits of experimental error.

The method for comparison of plant growth here provisionally established for wheat is found also to hold for the grasses generally. This doubtless rests on the fact that the leaves of these plants are linear and of continuous basal growth. Whether or not it can be adapted to other groups of plants is not yet determined.

THE UNIVERSITY OF CHICAGO.

RUSTS ON COMPOSITAE FROM MEXICO.

J. C. ARTHUR.

THE following enumeration of two hundred collections of Mexican rusts on Compositae comprises part of Mr. E. W. D. HOLWAY'S material obtained on his several trips into Mexico, not heretofore published; together with two specimens collected by C. G. PRINGLE, communicated by Mr. HOLWAY; two by ROSE and PAINTER, communicated by Dr. J. N. ROSE; one by E. W. NELSON, communicated by Dr. W. G. FARLOW; and one by SELER, found in the phanerogamic herbarium of the N. Y. Botanical Garden. Of the fifty-four species in the list it has been found necessary to describe eighteen as new.

It is interesting to note that the genus Puccinia embraces three-fourths of all the species, and the genus Coleosporium one-half of the remaining number. Two new species are described under Dietelia, with some misgivings. Both of them are accompanied with spermogonia, and are devoid of a peridium. Whether these differences should constitute valid ground for separation into a new genus is problematical without further knowledge of their life histories and affinities. Cronartium, Pucciniosira, Uredo, and Æcidium with one species each, and Uromyces with two species are the remaining genera.

The present communication is another illustration of Mr. HOLWAY'S skill as a collector, and his service in making known the Mexican rust flora.

1. **COLEOSPORIUM VIGUIERAE** Diet. and Holw.

On *Viguiera helianthoides* HBK., Tehuacan, Nov. 18, 1903, no. 5355; *V. dentata* Spreng., City of Mexico, Oct. 14, 1898, no. 3055.

2. **COLEOSPORIUM VERBESINAE** Diet. and Holw.

On *Verbesina virgata* Cav., Oaxaca, Oct. 21, 1899, no. 3711; Cuernavaca, Oct. 30, 1903, no. 5298; Amecameca, Nov. 20, 1903, no. 5427: *V. montanoifolia* Rob. & Greenm., Patzcuaro, Oct. 19, 1898: *V. pinnatifida* Cav., Oct. 1896.

3. **COLEOSPORIUM ANCEPS** Diet. and Holw.

On *Verbesina sphaerocephala* A. Gr., Sayula, State of Jalisco, Oct. 7, 1903, no. 5124; Zapotlan, State of Jalisco, Oct. 10, 1903, no. 5145.

4. COLEOSPORIUM SOLIDAGINIS (Schw.) Thuem.

On *Aster pauciflorus* Nutt., City of Mexico, Oct. 10, 1898, no. 3071 a.

5. COLEOSPORIUM PARAPHYSATUM Diet. and Holw.

On *Liabum discolor* Benth. and Hook., Guadalajara, Sept. 28, 1903, no. 5062.

6. **Coleosporium Dahliae,** n. sp.—Uredosori hypophyllous, irregularly scattered, round, 0.5^{mm} across or less, soon naked, pulverulent; uredospores irregularly ellipsoid, 16–22 by 24–30μ, wall colorless, rather thin, 2μ, closely and strongly verrucose: teleutosori hypophyllous, irregularly scattered, sometimes confluent, roundish, about 0.5^{mm} across, waxy; teleutospores oblong, 18–21 by 45–70μ, rounded at both ends, early septate, bright orange-yellow fading to pale olive-yellow.

On *Dahlia variabilis* (W.) Desf., in city park, Guadalajara, Oct. 6, 1903, no. 5121.

7. **Coleosporium Steviae,** n. sp.—Uredosori hypophyllous, scattered unevenly and often thickly, round, 0.25–0.5^{mm} across, early naked, pulverulent; uredospores ellipsoid to globoid, somewhat angular, 18–23 by 26–35μ, wall colorless, rather thin, 1.5–2μ, finely verrucose: teleutosori hypophyllous, scattered, often confluent, irregularly orbicular, 0.25–0.5^{mm} across, waxy; teleutospores forming a single layer beneath the epidermis, cylindrical, 12–19 by 50–75μ, truncate or rounded at both ends.

On *Stevia trachelioides* (DC.) Hook., Nevada de Toluca, 3,000^{m} alt., Oct. 15, 1903, no. 5159 (type): *S. rhombifolia* HBK., Amecameca, Oct. 20, 1903, no. 5186; Rio Hondo, near City of Mexico, Oct. 4, 1899, no. 3565: *S. viscida* HBK., Santa Fé, near City of Mexico, Oct. 18, 1903, no. 5172: *S. reglensis* Benth., Santa Fé, near City of Mexico, Oct. 18, 1903, no. 5169: *S. monardaefolia* HBK., Cuernavaca, Sept. 26, 1898, no. 3014; Amecameca, Oct. 20, 1903, no. 5181: *S. salicifolia* Cav., Patzcuaro, Oct. 17, 1898, no. 3008; Toluca, Sept. 17, 1898, no. 3135, Sept. 4, 1903, no. 6778 (*Rose & Painter*); Pachuca, Oct. 27, 1903, no. 5248; Santa Fé, near City of Mexico, Oct. 18, 1903, no. 5176.

8. CRONARTIUM PRAELONGUM Wint.

On *Eupatorium* sp., Orizaba, Oct. 8, 1898, no. 3041.

9. **Dietelia Eupatorii,** n. sp.—Spermogonia amphigenous, numerous, crowded in small groups, punctiform, rather conspicuous, immersed, subepidermal, globoid, 100–150μ broad; ostiolar filaments becoming agglutinate: teleutosori hypophyllous and caulico-

lous, crowded in orbicular groups, often circinating about the spermogonia, on stems causing small swellings up to 1^{cm} long, on discolored spots, very small, 0.2–0.3^{mm} across, round, somewhat waxy; peridia wanting; spores ellipsoid, more or less angular from pressure, 20–25 by 24–36μ, wall golden-brown, smooth, medium thick, 1.5–2μ.

On *Eupatorium patzcuarense* HBK., Amecameca, Oct. 21, 1903, no. 5205 (type): *Eupatorium* sp., near City of Mexico, Oct. 9, 1898, no. 3033.

This and the following are the first species belonging to this genus reported from North America. They both differ from the type in the absence of a peridium, and in the presence of spermogonia. Like the type, however, they both have the sori separated from the tissues of the host by a filamentous layer of delicate, colorless hyphae. The form on Eupatorium is waxy, with smooth consolidated spores, like the type, the spores germinating in the sorus upon maturity. The form on Vernonia is not waxy, but pulverulent.

10. **Dietelia Vernoniae,** n. sp.—Spermogonia chiefly epiphyllous, numerous, crowded in orbicular groups, punctiform, golden-yellow becoming brown, prominent, subepidermal, depressed-globoid or somewhat conical, 130–145μ broad; central cavity large; ostiolar filaments becoming agglutinate: teleutosori hypophyllous, crowded opposite the spermogonia in annular groups of 2–7, or solitary, round, 0.5^{mm} across, soon naked, pulverulent, ruptured epidermis noticeable; peridia wanting; teleutospores ellipsoid or globoid, more or less angular and irregular from pressure, 22–27 by 30–37μ; wall very pale yellow, medium thick, 1.5–2μ, closely and strongly verrucose, except a small spot at the base, tubercles somewhat deciduous.

On *Vernonia* (probably *V. Deppiana* Less.), Jalapa, Mex., Oct. 2, 1898, no. 3111.

11. PUCCINIOSIRA BRICKELLIAE Diet. and Holw.

On *Brickellia secundiflora* A. Gr., Pachuca, Oct. 27, 1903, no. 5249: *Brickellia* sp., Guadalajara, Sept. 22, 1903, no. 5020; Zapotlan, State of Jalisco, Oct. 10, 1903, no. 5144; Amecameca, Nov. 20, 1903, no. 5428.

12. UREDO PARTHENII Speg.

On *Parthenium hysterophorus* L., San Andres Chalchicomula, near Mt. Orizaba, Oct. 8, 1898, no. 3228.

13. ÆCIDIUM CLIBADII Syd.

On *Clibadium arboreum* J. D. Smith, Jalapa, Oct. 2, 1898, no. 3114.

14. **Uromyces senecionicola,** n. sp.—Teleutosori hypophyllous,

thickly scattered, irregularly roundish, 0.5^{mm} or less across, long covered by the grayish epidermis; teleutospores obovoid, more or less angular, 20–25 by 24–36μ, obtuse or rounded at apex, narrowed at base, wall golden-brown, rather thin, 1–2μ, much thicker at apex, 3–6μ, concolorous; pedicel nearly colorless, thick, two-thirds length of spore or less.

On *Senecio Roldana* DC., Amecameca, Oct. 20, 1903, no. 5183 (type), Oct. 31, 1899, no. 3752: *Cacalia* sp., Patzcuaro, Oct. 20, 1898, no. 3182.

The morphological characters and gross appearance of this species closely resemble those of *Puccinia senecionicola,* except that the teleutospores are one-celled instead of two-celled. A very few uredospores were seen, which resembled those of *P. senecionicola* closely, except that they were quite colorless, which may have been due to weathering, or to their origin in teleutosori as an obsolescent form of spore. A single group of hypophyllous aecidia was also found, accompanied by epiphyllous spermogonia, but too old for securing accurate characterization.

15. UROMYCES CUCULLATUS Syd.

On *Zexmenia* sp., Iguala, Oct. 4, 1900 (*C. G. Pringle*): *Perymenium Berlandieri* DC., Amecameca, Oct. 31, 1899, no. 3753: *P. verbesinoides* DC., Cuernavaca, Sept. 30, 1898, no. 3116: *P. Mendezii* DC., Pachuca, Oct. 5, 1899, no. 3578, Oct. 28, 1903, no. 5257: *P. discolor* Schrad., Oaxaca, Nov. 10, 1903, no. 5362, Nov. 14, 1903, no. 5417.

16. **Puccinia senecionicola,** n. sp.—Uredosori amphigenous, somewhat gregarious or solitary, round, small, tardily naked, pulverulent, cinnamon-brown, ruptured epidermis noticeable; uredospores globoid, 24–27 by 25–32μ, wall cinnamon-brown, thin, sparsely and strongly echinulate, pores 2, opposite in the equator: teleutosori hypophyllous, thickly scattered and somewhat confluent, punctiform or bullate, long covered by the epidermis; teleutospores oblong or oblong-clavate, 16–27 by 42–60μ, obtuse, truncate or even rounded at apex, and often oblique, more or less narrowed at base, slightly or not constricted at septum, wall golden-brown, sometimes darker above, rather thin, little to much thickened at apex, 3–12μ, concolorous; pedicel short, nearly colorless.

On *Senecio angulifolius* DC., Amecameca, Oct. 20, 1903, no. 5189 (type), Oct. 31, 1899, no. 3762; Pachuca, Oct. 6, 1899, no. 3586, Oct. 28, 1903, no. 5254; Oaxaca, Oct. 22, 1899, no. 3714; Nevada de Toluca, 10,500^{ft} alt., Oct. 15, 1903, no. 5162: *S. sinuatus* HBK., Pachuca, Oct. 28, 1903, no. 5252: *Cacalia Pringlei* Wats., Zapotlan, State of Jalisco, Oct. 9, 1903, no. 5143: *C. ampullacea*

Greenm., Pachuca, Oct. 5, 1899, no. 3572, Oct. 27, 1903, no. 5244: *C. sinuata* Cerv., Patzcuaro, Oct. 16, 1898, no. 3196: *C. amplifolia* DC., Oaxaca, Oct. 23, 1899, no. 3725: *C. obtusiloba* Rob. & Greenm., Cuernavaca, Sept. 30, 1899, no. 3538, Oct. 30, 1903, no. 5299; Patzcuaro, Oct. 17, 1898, no. 3171: *Cacalia* sp., Guadalajara, Sept. 14, 1899, no. 3417; Uruapan, Oct. 11, 1899, nos. 3617, 3618.

17. PUCCINIA TITHONIAE Diet. and Holw.

On *Tithonia tubaeformis* A. Gr., Acambora, Oct. 21, 1899, no. 3143; near Tula, Sept. 20, 1898, no. 3197: *T. speciosa* Hook., Sept. 28, 1898, no. 3119.

18. **Puccinia globulifera,** n. sp.—Uredosori hypophyllous, small, round, scattered, pulverulent, cinnamon-brown; uredospores globose, small, 15–18µ in diameter, wall medium thick, 2µ, cinnamon-brown, evenly and strongly echinulate, pores 2, opposite in the equator: teleutosori amphigenous, small, round, scattered, somewhat pulverulent, blackish; teleutospores oblong-globose, 22–25 by 24–32µ, semiopaque, rounded at both ends, not constricted at the septum, wall dark chocolate-brown, 3µ thick, closely and evenly aculeate with strong conical points; pedicel colorless except near the spore, slender, firm, 5–6µ thick, twice the length of the spore or longer, place of insertion indefinite, often at the septum.

On *Otopappus epalaceus Pringlei* Greenm., Iguala, Nov. 3, 1903, no. 5313.

This species is widely different from *P. Otopappi* Syd., which has smooth teleutospores of the common obovate-ellipsoid form.

19. PUCCINIA ASTERIS Duby.

On *Aster pauciflorus* Nutt., City of Mexico, Oct. 10, 1898, no. 3071.

20. **Puccinia Gymnolomiae,** n. sp.—Uredosori hypophyllous, scattered, small, early naked, pulverulent, bright cinnamon-brown; uredospores globoid or obovate-globoid, 20–24 by 21–27µ, wall golden yellow, rather thin, 1–2µ, closely and strongly echinulate, pores 2, opposite, in the equator or often much lower: teleutosori hypophyllous, scattered, small, somewhat pulverulent, chestnut-brown; teleutospores elliptical, 26–30 by 36–45µ, rounded at both ends, which are strongly introverted and concave when dry, much constricted at the septum, wall chestnut-brown, smooth, evenly thick, 3–4µ, apex slightly thicker with a very low semiyhaline umbo; pedicel colorless, about once length of spore.

On *Gymnolomia subflexuosa* Benth. & Hook., Oaxaca, Oct. 17, 1899, no. 3645 (type): *G. patens brachypoda* Rob. & Greenm., Jalapa, Oct. 2, 1898, no. 3113.

This species does not include the rusts on species of Gymnolomia occurring in the United States throughout the Rocky Mountain region, which belong to *Puccinia Helianthi* Schw.

21. PUCCINIA ENCELIAE Diet. and Holw.

On *Encelia adenophora* Greenm., Etzatlan, State of Jalisco, Oct. 2, 1903, no. 5092; Oaxaca, Nov. 10, 1903, no. 5360: *Encelia* sp., Guadalajara, Oct. 3, 1903, no. 5102.

22. **Puccinia Caleae,** n. sp.—Spermogonia epiphyllous, crowded, in small groups opposite the aecidia, punctiform, inconspicuous, globoid, 100–130µ broad: aecidia hypophyllous, in circular groups, peridia cylindrical, lacerate; aecidiospores globoid, 18–24 by 20–27µ, wall pale yellowish, thin, closely and prominently verrucose: uredosori amphigenous, in small groups or scattered, small, early naked, pulverulent, cinnamon-brown; uredospores globoid, or obovate-globoid, 20–24 by 24–30µ, wall dark cinnamon-brown, medium thick, 1.5–2.5µ, sparsely and strongly echinulate, pores 2, opposite and near the equator: teleutosori chiefly epiphyllous, scattered, 1–1.5^{mm} across, early naked, somewhat pulverulent, blackish; teleutospores obovate-oblong or ellipsoid, 20–30 by 40–54µ, obtuse above, narrowed below, sometimes rounded at both ends, slightly or not constricted at septum, wall dark chestnut-brown, smooth, thick, 3–3.5µ, apex unthickened, or with a more or less prominent and paler umbo, sometimes with a similar umbo on the lower cell next the septum; pedicel colorless, firm, once to twice length of spore.

On *Calea axillaris urticaefolia* Rob. & Greenm., Sayula, State of Jalisco, Oct. 8, 1903, no. 5126 (type): *C. Zacatechichi rugosa* Rob. & Greenm., Cuernavaca, Oct. 30, 1903, no. 5301: *C. hypoleuca* Rob. & Greenm., Oaxaca, Nov. 10, 1903, nos. 5364, 5384: *Calea* sp., Etzatlan, State of Jalisco, Oct. 2. 1903, no. 5097.

23. **Puccinia Axiniphylli,** n. sp.—Uredosori not seen; uredospores in the teleutosori ellipsoid or globoid, 16–24 by 21–26µ, wall yellowish, thin, 1–1.5µ, sparsely and strongly echinulate, pores probably 3 and equatorial, very indistinct: teleutosori hypophyllous, irregularly gregarious, or scattered, somewhat confluent, small, tardily and imperfectly naked, dull chestnut-brown; teleutospores oblong or obovate-oblong, irregular, large, 24–30 by 45–60µ, obtuse or obliquely truncate above, somewhat narrowed below, slightly or

not constricted at the septum, wall smooth, cinnamon-brown, or partly darker, rather thin, 1.5–2.5μ, much thickened above, 7–12μ; pedicel tinted, firm, 7–12μ broad, half length of spore or shorter.

On *Axiniphyllum tomentosum* Benth., Oaxaca, Oct. 21, 1899, no. 3710; Etla, State of Oaxaca, Nov. 13, 1903, no. 5393.

24. **Puccinia Noccae**, n. sp.—Uredorosi amphigenous, small, scattered, pulverulent, cinnamon-brown; uredospores globoid, 18–24 by 20–28μ, wall pale brown, rather thin, 1.5–2μ, evenly echinulate, pores 3, in the lower hemisphere, often close to the base: teleutosori amphigenous, small, scattered, blackish, somewhat pulverulent; teleutospores broadly oblong or elliptical, 26–31 by 32–42μ, rounded at both ends, or obtuse at apex, not constricted at septum, wall smooth, dark chestnut-brown, thick, 3–4μ, thicker at apex, 10–12μ, a broad semihyaline umbo at apex, often a similar one on the lower cell; pedicel colorless, firm, once to once and a half length of spore.

On *Nocca decipiens* Kuntze, Sayula, State of Jalisco, Oct. 7, 1903, no. 5122 (type): *N. rigida* Cav., Cuernavaca, Oct. 29, 1903, no. 5262: *N. suaveolens* (HBK.) Cass., Oaxaca, Oct. 23, 1899, no. 3724.

25. **Puccinia jaliscana,** n. sp.—Uredorosi hypophyllous, small, round, pale yellowish, soon naked, somewhat pulverulent; uredospores globoid or oblong-globoid, 18–24 by 21–27μ, pale brownish or nearly colorless, wall rather thin, 1.5–2μ, minutely echinulate-verrucose, pores 6–8, scattered: teleutosori chiefly hypophyllous, small, round, early naked, blackish, somewhat pulverulent; teleutospores elliptical, 20–24 by 30–39μ, rounded at both ends, slightly constricted at septum, semiopaque, wall chocolate-brown, prominently verrucose, thick, 2.3–3μ, slightly thicker at apex, 4–6μ; pedicel colorless, once or once and a half length of spore.

On *Porophyllum Holwayanum* Greenm., Sayula, State of Jalisco, Oct. 8, 1903, no. 5130.

26. PUCCINIA POROPHYLLI Henn.

On *Porophyllum macrocephalum* DC., Cardenas, Oct. 22, 1898, no. 3152; Yautepec, Oct. 24, 1903, no. 5238: *Porophyllum* sp., Guadalajara, Sept. 15, 1899, no. 3431; Chapala, Sept. 17, 1899, no. 3439 bis.

27. PUCCINIA TAGETICOLA Diet. and Holw.

On *Tagetes tenuifolia* Cav., Sept. 12, 1899, no. 3403; Etla, State of Oaxaca, Nov. 16, 1903, no. 5425: *T. filifolia* Lag., Cuernavaca, Sept. 26, 1898, no. 3031;

Guadalajara, Sept. 28, 1903, no. 5028: *T. lucida* Cav., Patzcuaro, Oct. 19, 1898, no. 3233; Cuernavaca, Oct. 29, 1903, no. 5264: *T. micrantha* Cav., San Angel, City of Mexico, Oct. 1, 1900 (*C. G. Pringle*): *Tagetes* sp., Guadalajara, Sept. 15, 1899, no. 3423; Oaxaca, Oct. 20, 1899, no. 3685; City of Mexico, Oct. 19, 1903, no. 5179.

28. PUCCINIA ZEXMENIAE Diet. and Holw.

On *Zexmenia podocephala* A. Gr., Patzcuaro, Oct. 20, 1898, no. 3215, Oct. 13, 1899, no. 3626; Chapala, Sept. 20, 1899, no. 3468: *Z. fasciculata* A. Gr., Patzcuaro, Oct. 18, 1898, no. 3101; Cuernavaca, Sept. 30, 1899, no. 3530: *Z. ceanothifolia* Schz. Bip., Guadalajara, Sept. 28, 1903, no. 5058; Cuernavaca. Oct. 29, 1903, no. 5268: *Z. helianthoides* A. Gr., Cuernavaca, Sept. 30, 1899, no, 3531: *Z. elegans* Schz. Bip., Patzcuaro, Oct. 13, 1899, no. 3632: *Z. crocea* A. Gr., Cuernavaca, Sept. 25, 1898, no. 3016; Cuautla, State of Morelos, Oct. 23, 1903, no. 5232: *Z. aurea* B. & H., Rio Hondo, near City of Mexico, Oct. 4, 1899, no. 3566: *Zexmenia* sp., Chapala, Oct. 5, 1903, no. 5116.

A number of these collections have well developed aecidia with the other spores, and no. 3016 shows only aecidia. The teleutospores are quite variable in size and roughness of surface.

29. PUCCINIA OPACA Diet. and Holw.

On *Zexmenia* sp., Guadalajara, Sept. 29, 1903, no. 5069; Patzcuaro, Oct. 16, 1898, no. 3002.

One of these collections, no. 5069, shows aecidia in good condition. The aecidia are deep-seated in the tissues, appear hemispherical on the surface, and open by a small orifice; the peridial cells are loosely united, and fall away readily; the aecidiospores are somewhat smaller than those in *Puccinia Zexmeniae*, and have a thicker wall.

30. **Puccinia Diaziana,** n. sp.—Teleutosori hypophyllous, in open groups, 3–8^{mm} across, on pale spots, often annular, small, 0.25^{mm} or less in diameter, round, pulvinate, chestnut-brown or lighter; teleutospores linear-oblong or oblong-fusiform, 15–21 by 38–54μ, usually narrowed and obtuse at each end, slightly constricted at septum, wall cinnamon-brown, paler below, smooth, thin, 1–1.5μ, much thickened at apex, 5–8μ; pedicel slightly tinted, thick, half length of spore.

On *Ximensia encelioides* Cav. (*Verbesina encelioides* A. Gr.), City of Porfirio Diaz, State of Coahuila, Oct. 10, 1900.

This species belongs to the LEPTOPUCCINIA section, as the spores germinate freely in the sorus, centrifugally as they mature. It differs from most species of this section inhabiting composite hosts by having the sori well separated from one another, instead of crowded in a compact group.

31. **Puccinia semiinsculpta,** n. sp.—Uredosori amphigenous, scattered, round, small, 0.2–0.3$^{\mathrm{mm}}$ across, cinnamon-brown, soon naked, pulverulent; uredospores broadly elliptical or globoid, 17–25 by 22–28μ, wall 2μ thick, echinulate, pores indistinct, probably 3 and equatorial: teleutosori amphigenous, or often only epiphyllous, scattered, round, small, 0.2–0.5$^{\mathrm{mm}}$ across, often confluent, soon naked, pulverulent, chocolate-brown, or compact and cinereous from germination; teleutospores broadly elliptical or elliptical-obovate, 25–36 by 40–50μ, round at both ends, or narrowed below, slightly or not constricted at septum, wall finely to coarsely reticulate-verrucose, thick, 4–6μ, slightly or not thickened at apex, 5–9μ, concolorous, often thinner below; pedicel colorless, 4–7μ thick, once to twice length of spore, more or less minutely rough.

On *Vernonia Alamani* DC., Amecameca, Oct. 31, 1899, no. 3754 (type); Patzcuaro, Oct. 17, 1898, no. 3105, Oct. 10, 1899, no. 3602, Oct. 13, 1899, no. 3631; Oaxaca, Nov. 11, 1903, no. 5379; Amecameca, Oct. 20, 1903, no. 5190: *Vernonia* sp., Chapala, Sept. 19, 1899, no. 3459; Cuernavaca, Sept. 30, 1899, no. 3540; Oaxaca, Oct. 18, 1899, no. 3668.

The different collections vary in appearance. In some of the collections most or all of the sori are dark and pulverulent, in others they are compact and pale from germination, while in others its two forms are variously intermixed. The spores from germinating sori are thinner-walled, lighter-colored, and more obovate. The extreme forms are quite unlike, but all gradations occur, even on the same leaf. The uredosori are quite inconspicuous.

32. **Puccinia egregia,** n. sp.—Uredospores from the teleutosori globoid, 23–26 by 24–28μ, wall golden-yellow, rather thin, echinulate, pores 3, equatorial: teleutosori amphigenous, scattered, pulvinate, chocolate-brown; teleutospores ellipsoid, 27–30 by 35–46μ, rounded at both ends, slightly or not constricted at septum, wall thick, 4–6μ, slightly or not thickened at apex, coarsely and prominently verrucose, with conical and well separated papillae; pedicel colorless, 5–6μ thick, twice length of spore.

On *Vernonia uniflora* Schz. Bip., Oaxaca, Dec. 29, 1895, no. 1739 (*Seler*).

This specimen was obtained in looking over the phanerogamic herbarium at the New York Botanical Garden. It is a very marked species. The host was determined by VOLKENS, as recorded on the label.

33. PUCCINIA ELECTRAE Diet. and Holw.

On *Electra Galeottii* A. Gr., Oaxaca, Nov. 11, 1903, no. 5387, Nov. 13, 1903, no. 5394.

34. **Puccinia Zaluzaniae,** n. sp.—Uredosori chiefly epiphyllous, scattered, round, small, soon naked, ruptured epidermis evident; uredospores obovate, 16–21 by 23–27μ, wall golden-brown, rather thin, 1.5–2μ, sparsely and finely echinulate, pores 2, opposite in the equator: teleutosori chiefly epiphyllous, scattered, very small or punctiform, confluent, somewhat pulverulent, blackish; teleutospores semiopaque, ellipsoid, 21–27 by 39–45μ, obtuse or rounded at both ends, slightly or not constricted at septum, wall dark chocolate-brown, minutely rugose, medium thick, 1.5–2.5μ, thicker at apex; pedicel colorless except next the spore, tapering downward, lowest third noticeably roughened, twice length of spore.

On *Zaluzania asperrima* Schz. Bip., Tehuacan, Nov. 7, 1903, no. 5347.

This species is much like *Puccinia Electrae*, but has smaller and less roughened spores, which form smaller sori.

35. PUCCINIA CIRSII Lasch.

On *Carduus lomatolepis* (Hemsl.), City of Mexico, Oct. 14, 1898, no. 3047: *C. orizabensis* (Klatt.), Toluca, Sept. 19, 1898, no. 3133: *Carduus* sp., Patzcuaro, Oct. 17, 1898, no. 3102; Uruapan, Oct. 11, 1899, no. 3616; Etla, State of Oaxaca, Oct. 23, 1899, no. 3730.

36. **Puccinia concinna,** n. sp.—Uredospores in the teleutosori globoid, 19–22 by 24–28μ, wall thin, 1μ, minutely echinulate, pores 4, approximately equatorial: teleutosori chiefly hypophyllous, scattered, roundish, 0.5–1$^{\mathrm{mm}}$ across, pulvinate, blackish; teleutospores oblong or ellipsoid, 24–30 by 37–50μ, rounded or obtuse at apex, rounded below, slightly or not constricted at septum, wall chocolate-brown, smooth, thick, 3–3.5μ, thicker above, 6–10μ, concolorous; pedicel colorless, except next the spore, delicate, once to thrice length of spore, often deciduous.

On *Conoclinium Greggii* (A. Gr.) Small (*Eupatorium Greggii* A. Gr.), Sierre Madre, Sept. 29, 1899, *E. W. Nelson*, comm. W. G. FARLOW.

This species is much like the South American *P. Eupatorii* Diet., but differs in having thinner-walled uredospores, with twice as many pores, and much thicker-walled teleutospores. The sorus of the North American form is also larger and earlier naked.

37. PUCCINIA INANIPES Diet. and Holw.

On *Eupatorium brevipes* DC., Oaxaca, Nov. 10, 1903, no. 5375: *E. hirsutum* DC., Cuernavaca, Oct. 30, 1903, no. 5274: *Eupatorium* sp., Sayula, State of Jalisco, Oct. 8, 1903, no. 5128.

38. PUCCINIA ESPINOSARA Diet. and Holw.

On *Eupatorium espinosarum* A. Gr., Oaxaca, Nov. 10, 1903, no. 5366: *E. Smithii* Rob., Oaxaca, Nov. 10, 1903, no. 5365.

39. PUCCINIA CONOCLINII Seym.

On *Eupatorium Neaeanum* DC., Etla, State of Oaxaca, Nov. 13, 1903, no. 5410.

40. **Puccinia rosea** (D. and H.), n. n.

On *Eupatorium deltoideum* Jacq., Amecameca, Oct. 20, 1903, no. 5202; Oaxaca, Oct. 21, 1899, no. 1119: *E. tubiflorum* Benth., Patzcuaro, Oct. 17, 1898, no. 3007, Oct. 19, 1898, no. 3232, Oct. 10, 1899, no. 3600: *E. glabratum* HBK., Pachuca, Oct. 28, 1903, no. 5255; Amecameca, Oct. 22, 1903, no. 5204: *E. trinervium* Schz. Bip., Oaxaca, Nov. 14, 1903, no. 5418: *E. Gonzalezii* Rob., Etla, State of Oaxaca, Nov. 13, 1903, no. 5403: *Eupatorium* sp., Cuernavaca, Sept. 26, 1898, no. 3013; Patzcuaro, Oct. 17, 1898, no. 3100: *Stevia rhombifolia* HBK., Jalapa, Oct. 2, 1898, no. 3107; Pachuca, Oct. 5, 1899, no. 3581, also Sept. 1, 1903, no. 6724 (*Rose & Painter*): *Ageratum corymbosum* Zacc., Yautepec, Oct. 23, 1903, no. 5235; Cuernavaca, Sept. 28, 1899, no. 3509: *A. strictum* Cuernavaca, Sept. 30, 1899, no. 3533.

The uredospores and teleutospores of this species closely resemble those of *Puccinia Conoclinii*, but are noticeably larger.

41. PUCCINIA DESMANTHODII Diet. and Holw.

On *Desmanthodium fruticosum* Greenm., Oct. 9, 1903, no. 5130: *D. ovatum* Benth., Etla, State of Oaxaca, Nov. 13, 1903, no. 5402.

42. **Puccinia paupercula,** n. sp.—Teleutosori hypophyllous, crowded in orbicular groups, 1–4^{mm} across, minute, punctiform, confluent, soon naked, compact, chocolate-brown, usually cinereous by germination; teleutospores oblong or lance-oblong, 15–17 by 39–50μ, acute or obtuse at apex, obtuse or narrowed at base, slightly or not constricted at septum, wall smooth, rather thin, thicker at apex, 7–9 μ; pedicel colored like the spore, firm, one half length of spore or less.

On *Elephantopus spicatus* Juss., Veracruz, Oct. 5, 1898, no. 3074.

This species differs from *Puccinia Elephantopodis* P. Henn., from Argentine, by the position and arrangement of the sori, as well as in the shape and size of the spores.

43. PUCCINIA ABRUPTA Diet. and Holw.

On *Viguiera excelsa* Benth. & Hook., City of Mexico, Oct. 18, 1903, no. 5174; Amecameca, Oct. 20, 1903, no. 5197: *V. tenuis* A. Gr., Guadalajara, Sept. 30, 1903, no. 5079: *V. helianthoides* HBK., Santa Fé, near City of Mexico, Oct. 18, 1903, no. 5173; Tehuacan, Nov. 8, 1903, no. 5358: *V. buddleiformis* Benth. & Hook. f., Patzcuaro, Oct. 20. 1898, no. 3217, Oct. 13, 1899, no. 3630; Rio Hondo near City of Mexico, Oct. 4, 1899, no. 3563; Morelia, Oct. 14, 1899, no. 3634: *Viguiera* sp., Guadalajara, Sept. 29, 1903, no. 5070.

The teleutospores on each species of host differ a little from all the others. It would be possible to make as many species of rusts as there are species of Viguiera, but the differences are of a character that can very plausibly be ascribed to the influence of the host, and it seems more in keeping with the present conception of species, therefore, to list these slight variations, whose limits are yet undetermined, under a single name. The specimens cited, therefore, include what have been separated as *Puccinia abrupta* D. & H. and P. *subglobosa* D. & H. An examination of the type material of *P. Viguierae* Peck, discloses the fact that the host was incorrectly determined by the collector. The rust is clearly not one of the forms on Viguiera, but is doubtless *P. Helianthi* Schw.

44. PUCCINIA NANOMITRA Syd.

On *Viguiera eriophora* Greenm., Oaxaca, Oct. 21, 1899, no. 3689: *V. dentata* Spreng., Oaxaca, Oct. 25, 1899, no. 3744.

45. PUCCINIA IOSTEPHANES Diet. and Holw.

On *Iostephane heterophylla* Benth., Cuernavaca, Oct. 30, 1903, no. 5291.

46. PUCCINIA COGNATA Syd.

On *Verbesina tetraptera* A. Gr., City of Mexico, Oct. 11, 1898, no. 3061; Rio Hondo, near City of Mexico, Oct. 4, 1899, no. 3564; Patzcuaro, Oct. 13, 1899, no. 3627; Oaxaca, Oct. 21, 1899, no. 3706: *V. pinnatifida* Cav., Cuernavaca, Nov. 1, 1903, no. 5307: *V. sphaerocephala* A. Gr., Zapotlan, State of Jalisco Oct. 9, 1903, no. 5141: *V. montanoifolia* Rob. & Greenm., Patzcuaro, Oct. 16, 1898, no. 3000, Oct. 10, 1899, nos. 3605, 3606; Morelia, Oct. 8, 1899, no. 3592.

The collection on *V. sphaerocephala* is without teleutospores, and is referred here with some slight doubt, as the uredospores of several related species are much alike. In deciding upon the boundaries of this species it has not been possible to agree with SYDOW in his *Monographia Uredinearum*. The Schweinitzian species, which is founded upon a South Carolina collection, probably on *Verbesina occidentalis*, although the specific determination was not made at the time, appears to be confined to southeastern United States, and is not yet reported on any other host than *V. occidentalis*. The species named by LONG *Puccinia similis*, and changed by SYDOW to *P. cognata*, occurs from Texas southward, upon a variety of hosts. It may be identical with the South American *P. Spegazziniana* DeT., but the exact proof is not at hand. The form on *P. montanoifolia* has slightly smaller and paler spores, but otherwise the same. No. 3606 is accompanied by an abundance of aecidia.

47. PUCCINIA FEROX Diet. and Holw.

On *Verbesina diversifolia* DC., Oaxaca, Oct. 21, 1899, no. 3692; Etla, Oaxaca, Nov. 14, 1903, no. 5396.

48. PUCCINIA AFFINIS Syd.

On *Verbesina trilobata* Rob. & Greenm., Oaxaca, Nov. 15, 1903, no. 5420: *Verbesina* sp., Etzatlan, State of Jalisco, Oct. 2, 1903, no. 5093.

49. PUCCINIA TUBERCULANS E. and E.

On *Aplopappus spinulosus* DC., Aguas Calientes, Sept. 12, 1899, no. 3404: *Bigelovia veneta* A. Gr., Pachuca, Oct. 27, 1903, no. 5250, Oct. 5, 1899, no. 3584.

50. PUCCINIA PRAEMORSA Diet. and Holw.

On *Brickellia veronicaefolia* A. Gr., Tehuacan, Nov. 7, 1903, no. 5343.

51. PUCCINIA DECORA Diet.

On *Brickellia megalodonta* Greenm., Guadalajara, Sept. 22, 1903, no. 5022.

52. PUCCINIA INVESTITA Schw.

On *Gnaphalium semiamplexicaule* DC., Santa Fé, near City of Mexico, Oct. 13, 1903, no. 5175; Amecameca, Oct. 20, 1903, no. 5191: *G. leptophyllum* DC., Nevada de Toluca, Oct. 15, 1903, no. 5155: *G. oxyphyllum* DC., Amecameca, Oct. 20, 1903, no. 5194: *Gnaphalium* sp., Oaxaca, Nov. 11, 1903, no. 5381.

53. PUCCINIA EVADENS Harkn.

On *Baccharis glutinosa* Pers., Etla, State of Oaxaca, Nov. 13, 1903, no. 5409: *B. pteronicoides* DC., Patzcuaro, Oct. 14, 1898, no. 3099: *Baccharis* sp., City of Mexico, Sept. 20, 1896.

54. PUCCINIA BACCHARIDIS-MULTIFLORAE Diet. and Holw.

On *Baccharis multiflora* HBK., Santa Fé, near City of Mexico, Oct. 18, 1903, no. 5166; Amecameca, Nov. 20, 1903, no. 5430: *B. elegans* HBK., Oaxaca, Nov. 11, 1903, no. 5382.

PURDUE UNIVERSITY,
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A MORPHOLOGICAL STUDY OF ULMUS AMERICANA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXVIII.

CHARLES H. SHATTUCK.

(WITH PLATES VII-IX)

A STUDY of this species was suggested by the interesting results of recent investigations in this region of the Archichlamydeae; notably those of KARSTEN (**12**), Miss BENSON (**1**), ZINGER (**22**), and NAWASCHIN (**16**).

METHODS.

Collections were made from February 13 to May 1, 1903, and repeated during the same period for 1904. During the first year collections were made on alternate days throughout the more rapid period of growth, and at intervals of ten days at other times. During the second year the same plan was followed except that collections were made every day during the period of fertilization and embryo growth.

The ovules are covered with a dense growth of hair which prevents sinking in the killing fluid; but after immersion in 95 per cent. alcohol they sink at once. A 2 per cent. solution of chromo-acetic acid was found to give the best results as a killing agent for all but the oldest stages; these requiring a somewhat stronger solution.

The material was imbedded in paraffin and the sections were cut from 2 to 10μ in thickness. A preparation of Le Page's glue and glycerin was used for fixing sections to the slide (glue 40 parts, water 10 parts, glycerin 50 parts). The albumen and several other fixatives were first tried, but all failed to fix the sections to the slide. The glue mixture is as perfectly transparent on the slide as Mayer's albumen fixative, is more easily prepared, is a much stronger adhesive, will keep indefinitely, and is not so easily coagulated by heat.

The most satisfactory combination for staining the ovules was found to be safranin and gentian violet. The addition of orange G to the above brought out the pollen tubes best, as they hold the gentian violet after it is drawn from the nucellus and integuments. The male cells stained best in orange G. Haidenhain's iron-haematoxylin gave good results, as did also gentian violet.

FLOWERS.

The earliest stages in the development of the flower were not studied. The first collecting was done on February 13, when the ovule was found to contain a clearly defined megaspore, and the anthers to be in the pollen mother cell stage. By March 25 the trees were in full bloom.

The method by which self-pollination is prevented, at least to a large extent, is of interest. When the flower bud first opens, the two-parted stigma is found protruding beyond the anthers and is ready for pollination (*fig. 1*). About two of the more centrally placed flowers in each cluster are somewhat earlier than the others in lengthening their flower stalks and filaments and in opening their anthers (*fig. 2*). The first flower to open its anthers has an excellent opportunity to pollinate the entire cluster. At the same time this flower may be prevented from self-pollination only by the pollen from some earlier flower having reached its exposed stigma before its own anthers were opened. In many instances the stigmas of flowers whose anthers were not yet open were found covered with pollen grains, some of which had developed tubes. As the time required for the pollen tube to complete its growth is from one to three days, it is quite evident that these early tubes will have completed the act of fertilization in each flower before its own pollen grains have an opportunity to begin the development of tubes.

MICROSPORANGIUM.

On February 13 the microsporangia were well formed. Most of the sporogenous cells of the four chambers were in the spore mother cell stage, in which they had evidently passed the winter (*fig. 3*).

It is of interest to note that at this stage it is impossible to distinguish any definitely organized tapetum, the cells all having the same size and shape, and giving the same reaction to stains. Sporangia of the same date were found in which the mother cells had passed into the synapsis stage (*fig. 4*); the nucleolus staining red and the chromatin mass violet. Many of the cells which were functioning as tapetum contained two or three nuclei and abundance of food material which stains deeply.

The tapetum consists generally of a single layer; and is derived from the original sporogenous mass. This is clearly shown by the fact that the two layers of cells within the endothecium never contribute to the formation of tapetum, but break down early while the endothecium itself enlarges (*fig. 5*). That the tapetum is derived from the original sporogenous mass is further shown by its extension inward, sometimes to the depth of several layers (*fig. 4*), more or less intermingled with the cells which are functioning as spore-forming tissue. Bower (**2**) has shown that in Equisetum from one-fourth to one-third of the sporogenous cells disorganize and do not form spores. He says "their function is that of a diffused tapetum and there can be no doubt that their substance contributes to the nutrition of the survivors." This contribution seems to be very evident in Ulmus.

Wylie (**21**) has shown in Elodea that there is a regular contribution to the tapetum from the sporogenous mass; Webb (**20**) shows in Astilbe that the tapetum has the same origin as the spore mother cells; Land (**14**) notes that in Ephedra it is often impossible to distinguish the tapetal cells from adjacent mother cells, mentioning that the tapetum seems to be potentially sporogenous tissue which has become sterile by virtue of its position; and Coulter (**6**) states that in Ranunculus it seemed as if the whole tapetum were cut off from the periphery of the sporogenous mass. The tapetum in Ulmus is surely composed of sterilized sporogenous cells.

On February 15 the pollen mother cells are just beginning to pass from their winter stage, for on the same slide mother cells were found in the resting stage (*fig. 3*), in synapsis (*fig. 4*), in the first mitosis (*fig. 6*), and in the second mitosis (*fig. 7*). Ten days later the tetrads were well formed (*fig. 5*); also there were many cells containing four free nuclei, evidently just preparing to form microspores (*fig. 8*).

The tapetum begins to break down about March 1, and by March 12 is entirely absorbed. At this time the tetrads are uninucleate (*fig. 9*). The two inner layers of the sporangium wall also rapidly break down and disappear. At the same time the endothecium enlarges; its cells take on a cork-like appearance and do not stain well; later the irregular thickening bands appear in its cells (*fig. 5*).

The filaments do not begin to elongate until March 20, when they extend quite rapidly, the microsporangium being fully mature March 26.

MEGASPORANGIUM.

On February 13 the megasporangium consisted of the nucellus containing a single hypodermal archesporial cell and a single integument. The archesporial cell divides by a periclinal wall, and the outer daughter cell also divides by a periclinal wall, giving rise to two parietal layers of cells (*fig. 23*); one of these occasionally again divides. The megasporangium evidently passes the winter in the megaspore mother cell stage, thus being identical in this particular with the microsporangium.

By February 15 the mother cell begins to enlarge. It accomplishes this chiefly by elongation, the long embryo sac pushing its somewhat pointed lower extremity deep into the tissue of the nucellus (*fig. 24*). The second integument appears February 25. By March 15 the first integument has closed over the top of the nucellus (*fig. 27*), whose crown cells have already begun to enlarge and divide preparatory to forming the long beak-like or archegonium-like necks shown in figures of more mature stages. These archegonium-like necks strongly resemble those figured by Miss LYON (**15**) for *Euphorbia corollata.* They differ however from those of Euphorbia in that they do not project through or beyond the integuments, but press against them. Possibly the rapid anticlinal divisions of the cells of the inner integument cause the elevation, thus forming a dome-like cavity into which the beak-like tip of the nucellus grows (*figs. 27–35*). The integuments are fully developed by March 25. A third integument was clearly made out in a number of instances (*fig. 27*), which is probably due to the splitting of the outer integument.

MALE GAMETOPHYTE.

The mother cells were found in the first and second mitosis on February 15 (*figs. 6–7*). About February 25 there appears a distinct though delicate wall about each of the four young spores, which are still enclosed by the wall of the mother cell (*fig. 9*). The wall of the mother-cell gradually breaks down and by March 1 the microspores are rounding off; many of them have formed their tube and generative nuclei. These are at first very much alike, but the tube nucleus soon becomes larger and stains more deeply (*fig. 10*). At this time the two coats can be clearly distinguished, the exine having acquired an uneven, reticulate surface and showing five very distinct openings (*figs. 10–11*) through which the intine can be seen.

The division of the generative nucleus was observed March 23, or before the dehiscence of the sporangia (*fig. 12*). At this time the tube nucleus shows signs of disintegration which is completed by March 26. The tube nucleus was often found disintegrating when the pollen tube was just starting, and was never found to leave the pollen grain, and in my judgment it never does so in *Ulmus americana.* Perhaps this is due to the fact that the pollen tube is not more than 3^{mm} in length.

It was definitely determined that the male structures are cells, and not merely nuclei, the delicate limiting membranes being clearly made out. During a large part of their existence in the pollen grain these lenticular cells are attached to each other by their adjoining ends in such a manner as to make them appear in longitudinal section as if astride of the tube nucleus (*fig. 13*). WYLIE (**21**) has shown that in Elodea the male cells are attached in a similar manner.

FEMALE GAMETOPHYTE.

The mother cell does not form the usual tetrad, but functions directly as a megaspore (*fig. 23*). This condition is well known in many angiosperms. While no instance of more than one megaspore was found, the fact that there are frequently two embryo sacs in the older stages at once suggests the possibility that the megaspore mother cell in Ulmus may yet be found like that of Juglans, a closely allied form, to vary in the number of megaspores it forms, or possibly to form occasionally two mother cells. This would account for the double embryo sacs (*figs. 55–56*).

In the early part of February the megaspore shows only slight differentiation, being but little larger than the adjacent cells (*fig. 23*). The nucleus however is quite large, deeply staining, and begins to show signs of preparation for division.

The actual mitosis resulting in the binucleate embryo sac was not observed, but binucleate sacs were found March 11 (*fig. 25*), in which the spindle fibers between the nuclei had not yet disappeared. By March 16 these nuclei had again divided, showing a great variation in the arrangement of the resulting four nuclei (*figs. 26, 27, 60*). On March 17 the third mitosis (*fig. 28*) shows one nucleus dividing parallel to the main axis and three at right angles to it. *Figs. 29-31* are even more perplexing than the foregoing, showing that rapid divisions have occurred in various planes.

After reaching the eight-nucleate stage there are, in a majority of cases, no further nuclear divisions; the egg apparatus begins to organize, the antipodals take their proper place, and the polar nuclei move toward each other preparatory to fusion (*fig. 30*). However, in very many cases, there is further nuclear division without any indication of polarity, the nuclei being distributed promiscuously throughout the cytoplasm of the sac and all apparently alike (*figs. 31-55*).

Mitotic figures were not found in the sac after the eight-nucleate stage was reached, but many sacs were examined containing as high as twelve (occasionally more) free nuclei very evenly distributed and very similar in appearance. Later a number of embryo sacs were found having more than eight nuclei and showing polarity. In these four nuclei were in the micropylar and eight or more in the antipodal end of the sac (*fig. 32*). *Fig. 54* shows the only observed exception to the above rule. (These numbers include also the nuclei which are to function as polars at a later date.)

The antipodals, excepting two or three, soon disintegrate. The remaining ones enlarge rapidly, sometimes rivaling the egg in their prominenee (*figs. 53-54*). They seem, however, to be of the passive type common among Archichlamydeae.

The embryo sac of *Ulmus americana*, therefore, shows a condition intermediate between the regular eight-nucleate angiosperm type and the sixteen-nucleate sac of the Peperomia described by CAMPBELL (**3**) and JOHNSON (**11**).

The fusion of the eight nuclei to form the endosperm nucleus in Peperomia has its parallel in the fusion of several nuclei in Ulmus for the same purpose. NAWASCHIN (**16**) has reported an instance of three polar nuclei fusing in Ulmus and I have frequently observed three or four nuclei in contact and evidently preparing to fuse (*figs. 58–59*). Several cases were found where a well formed egg appeared in the antipodal end of the sac (*figs. 36, 50, 54, 56*). Notwithstanding the fact that in each of these cases the structures seemed to be normal eggs in every particular, I hesitated to adopt this interpretation until later, when embryos were discovered in the antipodal ends of two sacs, and in each of which a larger and older embryo appeared in the micropylar end (*figs. 51–52*). These antipodal embryos are wholly within the sac and I do not think they were produced apogamously.

In 1895 CHAMBERLAIN (**5**) found in *Aster novae-angliae* what he termed an antipodal oosphere, calling attention to its cytological resemblances to the ordinary oosphere, and stating that "we need only fertilization and the formation of an embryo to completely establish its right to the name."

Lately Miss OPPERMANN (**17**) has found an antipodal egg in *Aster undulatus*, with the sperm lying against the cytoplasm of the egg, thus proving that fertilization does actually occur.

TRETJAKOW (**19**) has found the antipodal embryo which, since Miss OPPERMANN's discovery we are justified in concluding comes from a fertilized antipodal egg, thus making the history complete and establishing beyond a reasonable doubt the right to call this structure an egg. As the conditions mentioned above were all found in Ulmus, I feel justified in calling these antipodal structures eggs. There are two well formed synergids which enlarge nearly to the size of the egg. One of these usually disappears about the time the pollen tube enters the sac. The other generally persists until after the first division of the egg.

The polar nuclei were never found actually fusing, though they were often found in close contact (*fig. 33*), in which condition they seem to remain for some time.

WYLIE (**21**) has shown that in Elodea the actual presence of the pollen tube in the ovule is necessary in order to stimulate fusion. GUIGNARD (**10**) has arrived at the same conclusion in regard to Capsella. I find that the polar nuclei of *Ulmus americana* behave in the same manner, fusion occurring at least before fertilization.

FERTILIZATION.

The most interesting feature in connection with fertilization is the behavior of the pollen tubes. These begin to project through the openings in the exine about March 26, usually presenting a single tube for each pollen grain (*fig. 15*). While this is the general rule, it is by no means always the case, as many pollen grains were found developing from two to five tubes (*figs. 18–19*). In *fig. 18* all the tubes seem to have had an equal stimulus to growth, but such is not the case in *fig. 19*. In this instance the largest tube was in contact with the stigmatic hair, which fact doubtless accounted for its greater size. Eventually one of these tubes gains the ascendency over the others which are drawn back into the microspore as it gradually shrivels and the tube elongates (*fig. 17*). This figure also shows the peculiar method of the young tube on coming in contact with the stigmatic hair, down which it almost invariably travels to reach the stigma.

It was noted frequently that the tube when meeting the hair nearly at right angles would direct its course towards the distal end instead of towards the stigmatic end, as might be expected. After reaching the end of the hair the tube would often form a cyst-like enlargement before proceeding downward to the stigmatic tissue.

The behavior of the pollen tubes within the tissue has been so accurately described by NAWASCHIN (**16**) for *Ulmus montana* and *Ulmus pedunculata* that it will not be necessary to dwell upon their behavior in *Ulmus americana*. Suffice it to say, the same branching and apparently aimless wandering through the funiculus, integuments, and occasionally the nucellus which he describes was noted. In a few cases these tubes were found anastomosing about the micropylar end, as shown in *fig. 22*. The tube, after pressing its way through the micropyle, enters the nucellus near the tip of the beak (*fig. 35*) and passes directly to the upper end of the embryo sac. The only cases where I observed branching were those of belated tubes entering the ovule after fertilization (*figs. 21–22*). Such tubes seem to have a general tendency to push toward the antipodal end of the sac. In fact there is some indication that they occasionally reach the chalaza.

The pollen tube is not easily disintegrated after fertilization, and is found intact, though staining feebly, until the embryo has from sixteen to twenty-four cells. Two tubes passing down the same micropyle were occasionally noted (*fig. 20*).

The male cells lose their cytoplasm on entering the pollen tube, and during their journey to the embryo sac are simply elongated nuclei (*figs. 16, 33*). They were found side by side in the tube soon after leaving the pollen grain and were still somewhat elongated and very close together on entering the embryo sac, where the tube enlarges in a very irregular cyst-like manner (*fig. 33*). After entering the sac the nuclei become spherical and begin to gather a small amount of cytoplasm around them. The first to enter the sac generally fuses with the fused polars (*fig. 34*), the second fusing with the egg. Fertilization occurs from March 29 to April 1.

ENDOSPERM.

The endosperm begins to form soon after the male nucleus fuses with the fusion nucleus (*fig. 34*). This almost always occurs before fertilization, but instances were noted where fertilization probably occurs first (*fig. 37*). This variation was noted by LAND (**13**) in Erigeron, where he found sometimes the egg and at other times the endosperm nucleus dividing first. COULTER and CHAMBERLAIN (**8**) also call attention to the fact that after fertilization the egg seems to rest for a period, while free endosperm nuclei are being formed. While this may be true in a majority of cases in Ulmus (*figs. 35, 36*), many instances were found which seem to be at variance with it (*fig. 37*).

The formation of endosperm generally proceeds rapidly and takes place by free nuclear divisions, the nuclei being scattered through the cytoplasm of the sac. These nuclei, especially in the early stages, are enormous in size and multinucleolate (*figs. 35, 36, 56*), the nucleoli being so large as to be mistaken often for nuclei in the act of fusing, as mentioned by STRASBURGER (**18**) for *Corydalis cava*. The endosperm nuclei were often found to be in simultaneous division throughout the sac (*fig. 50*), and in no instance was a rudimentary cell-plate noted. As the development of endosperm progresses, the cytoplasm becomes more and more vacuolate, the nuclei take a parietal position and become smaller; yet throughout its existence the endosperm is characterized by large multinucleolate nuclei.

EMBRYO.

The first division of the fertilized egg is by a transverse wall (*figs. 36–38*). The terminal cell again divides, usually transversely (*fig. 39*), while the micropylar cell becomes vesicular although not enlarging very much.

After a proembryo of three or sometimes four cells has been formed, the end cell is usually the first to divide by a vertical wall (*fig. 40*). However, many exceptions to this rule were found, *fig. 42* showing the second as well as the terminal cell forming a vertical wall; while *fig. 43* shows the second cell dividing first. *Figs. 44* and *45* show anomalous forms of embryos in which no definite order of division can be discovered.

From the regular octant stage the development of the embryo is quite rapid and usually regular, the apical octants being the first to divide by periclinal walls, thus differentiating the dermatogen of the cotyledonary region (*fig. 46*). Almost immediately that of the hypocotyledonary region is formed in the same way (*fig. 47*). *Fig. 48* shows early development of plerome, of periblem of the root, and the differentiation of the dermatogen of the root tip. A further study of the development of the embryo revealed nothing worthy of mention.

POLYEMBRYONY.

The discovery of pollen tubes near the chalazal region, as well as perfectly formed eggs in the antipodal end of the embryo sac, led me to suspect that antipodal embryos might be discovered associated with normally placed embryos. In several cases antipodal embryos were noted (*figs. 51, 52*), and in one case an extra-micropylar embryo (*fig. 49*). It is also likely that pseudo-polyembryony may result from the presence of two embryo sacs, as well-formed and probably fertilized eggs were observed in such cases (*fig. 56*).

SUMMARY.

1. The microsporangia are in the mother cell stage in the early part of February and probably pass the winter in this stage, forming tetrads at the first breaking of winter weather.

2. The tapetum is formed from the peripheral layer of sporogenous tissue.

3. The pollen grains leave the tetrad stage March 16 to 18 and generally show tube and generative nuclei at this time. By March 23 the male cells appear, while the dehiscence of the sporangium occurs from March 25 to 27.

4. The single megaspore begins to germinate February 15, resulting in eight to sixteen and occasionally more free nuclei.

5. In many instances the pollen grains thrust tubes through the openings in the exine in from two to five directions before coming in contact with the stigma, but only the one gaining such contact develops.

6. The pollen tube generally enters through the micropyle, though it has been found piercing the nucellus at various places and even making its way down the funiculus; it may also branch profusely, but this seems to occur only in the cases of belated tubes.

7. The male cells leave the pollen grain as soon as the tube is 1^{mm} in length, remaining close to its tip, and were always found side by side; they appear in their early existence to be fastened together by their adjoining ends.

8. The tube nucleus does not leave the pollen grain.

9. Double fertilization was observed, taking place March 28 to 31, the first male cell fusing with the endosperm nucleus.

10. The endosperm nucleus generally divides before the fertilized egg, forming large, multinucleolate nuclei.

11. The embryo is of the massive type, the suspensor cell enlarging but little.

12. An antipodal egg is not uncommon.

13. Two embryos are occasionally found in the same sac.

14. Two embryo sacs are sometimes formed in a single nucellus with an egg apparatus in each.

15. Chalazogamy was not certainly found, but from indications it may occur.

I am indebted to Professor JOHN M. COULTER and to Dr. CHARLES J. CHAMBERLAIN for efficient direction and assistance.

WASHBURN COLLEGE, TOPEKA, KANSAS.

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EXPLANATION OF PLATES VII–IX.

All figures were made with an Abbé camera lucida and reduced one-half in reproduction. Figures with a magnification greater than 600 diameters were made with a Zeiss apochromatic objective 2^{mm}, ap. 1.30, and Zeiss compensating oculars 4, 8, and 12. All others with Spencer 5^{mm} and 16^{mm} objectives and oculars 4 and 8.

The abbreviations employed in describing fhe figures are as follows: *fl*, flower; *pt*, pollen tube; *po*, polar nuclei; *e*, egg; *en*, endosperm nucleus; *ed*, endothecium; *s*, stigma; *sy*, synergids; *smc*, spore mother cells; *f*, fusion nucleus; *at*, antipodals; *m*, male cell; *mm*, megaspore; *o*, ovule; *oi*, outer integument; *ii*, inner integument; *tn*, tube nuclei; *t*, tapetum; *gn*, generative nucleus; *cr*, crown cells; *n*, nucellus; *sh*, stigmatic hair.

FIG. 1. Young flower showing stigma protruding and ready for fertilization. ×12.

FIG. 2. Flower cluster showing filaments and flower stalks in the center as first to elongate. ×5.

FIG. 3. Winter stages of microsporangium showing mother cells. ×600.

FIG. 4. Later stage showing the organization of tapetum from peripheral mother cells; other mother cells in synapsis. ×600.

FIG. 5. Section of microsporangium showing enlargement of endothecium, the breaking down of the tapetum, and the two inner layers of cells of the sporangium walls; also tetrads dissociating. ×600.

FIG. 6. Microspore mother cell in first mitosis. ×1260.

FIG. 7. Second mitosis of microspore mother cell. ×1260.

FIG. 8. Four-nucleate mother cell preparing to form tetrads. ×1060.

FIG. 9. Tetrads within the mother cell. ×1000.

FIG. 10. Microspore showing tube and generative nuclei and openings in the exine. ×1260.

FIG. 11. Portion of the exine showing holes through which pollen tubes emerge. ×1200.

FIG. 12. Division of generative nucleus to form male cells. ×1260.

FIG. 13. Male cells attached by their adjoined ends; tube nucleus disintegrating. ×1260.

FIG. 14. Male cells free and encircling disintegrating tube nucleus. ×1260.

FIG. 15. Pollen tube as it usually appears. ×1260.

FIG. 16. Male nuclei in pollen tube. ×1260.

FIG. 17. Disintegrating microspore showing cyst formed at end of stigmatic hair. ×1260.

FIG. 18. Microspore showing five tubes emerging; all equal in size. ×1260.

FIG. 19. Microspore showing five emerging tubes; one in contact with the stigmatic hair. ×1260.

FIG. 20. Two pollen tubes entering the same micropyle. ×450.

FIG. 21. Branching pollen tubes. ×200.

FIG. 22. Anastomosing pollen tubes. ×200.

FIG. 23. Megaspore mother cell showing nucellus and first integument. ×1200.

FIG. 24. Later stage of megaspore. ×1260.

FIG. 25. Binucleate stage of the embryo sac. ×1260.

FIG. 26. Normal four-nucleate stage of embryo sac. ×700.

FIG. 27. Frequent form of the four-nucleate stage of embryo sac; also a third integument. ×400.

FIG. 28. Mitosis of the four-nucleate sac. ×900.

FIG. 29. Eight-nucleate sac; unusual mitosis in antipodal end. ×1200.

FIG. 30. Usual eight-nucleate sac with the egg apparatus organizing and the polars approaching each others preparatory to fusion. ×900.

FIG. 31. Embryo sac showing more than eight nuclei, but no sign of polarity. ×600.

FIG. 32. Multinucleate embryo sac showing polarity. ×900.

FIG. 33. Eight-nucleate sac showing fusion of polars and entrance of pollen tube bearing the two male cells. ×1450.

FIG. 34. Embryo sac showing one male cell in the act of fusing with the fusion nucleus, and the other near egg. ×1450.

FIG. 35. First integuments; nucellus showing beak and bearing pollen tube; embryo sac showing first division of fertilized egg and multinucleolate nuclei of endosperm. ×500.

FIG. 36. Embryo sac showing two-celled embryo unusually large; multinucleolate nuclei of rapidly forming endosperm; also an antipodal egg. ×810.

FIG. 37. Embryo sac showing two-celled embryo, and the beginning of the formation of endosperm tissue. ×1200.

FIG. 38. Ordinary type of two-celled embryo. ×500.

FIG. 39. Three-celled embryo. ×500.

FIG. 40. Four-celled embryo showing first vertical wall. ×500.

FIG. 41. Four-celled embryo showing usual method of formation of second vertical wall. ×500.

FIG. 42. Three-celled embryo; both end cells dividing at once. ×500.

FIG. 43. Three-celled embryo showing second cell dividing before the end cell. ×500.

FIG. 44. Anomalous form of embryo. ×500.

FIG. 45. Anomalous form of embryo. ×500.

FIG. 46. Later embryo showing the periblem in the cotyledonary region; also mitosis in the hypocotyledonary region. ×400.

FIG. 47. Embryo showing periblem in hypocotyledonary region. ×400.

FIG. 48. Advanced embryo showing early development of periblem and dermatogen of root tip. ×400.

FIG. 49. Two embryos in the micropylar end of sac. ×500.

FIG. 50. Well-formed embryo in micropylar end of sac; endosperm in simultaneous mitosis; egg-like formation in chalazal end. ×400.

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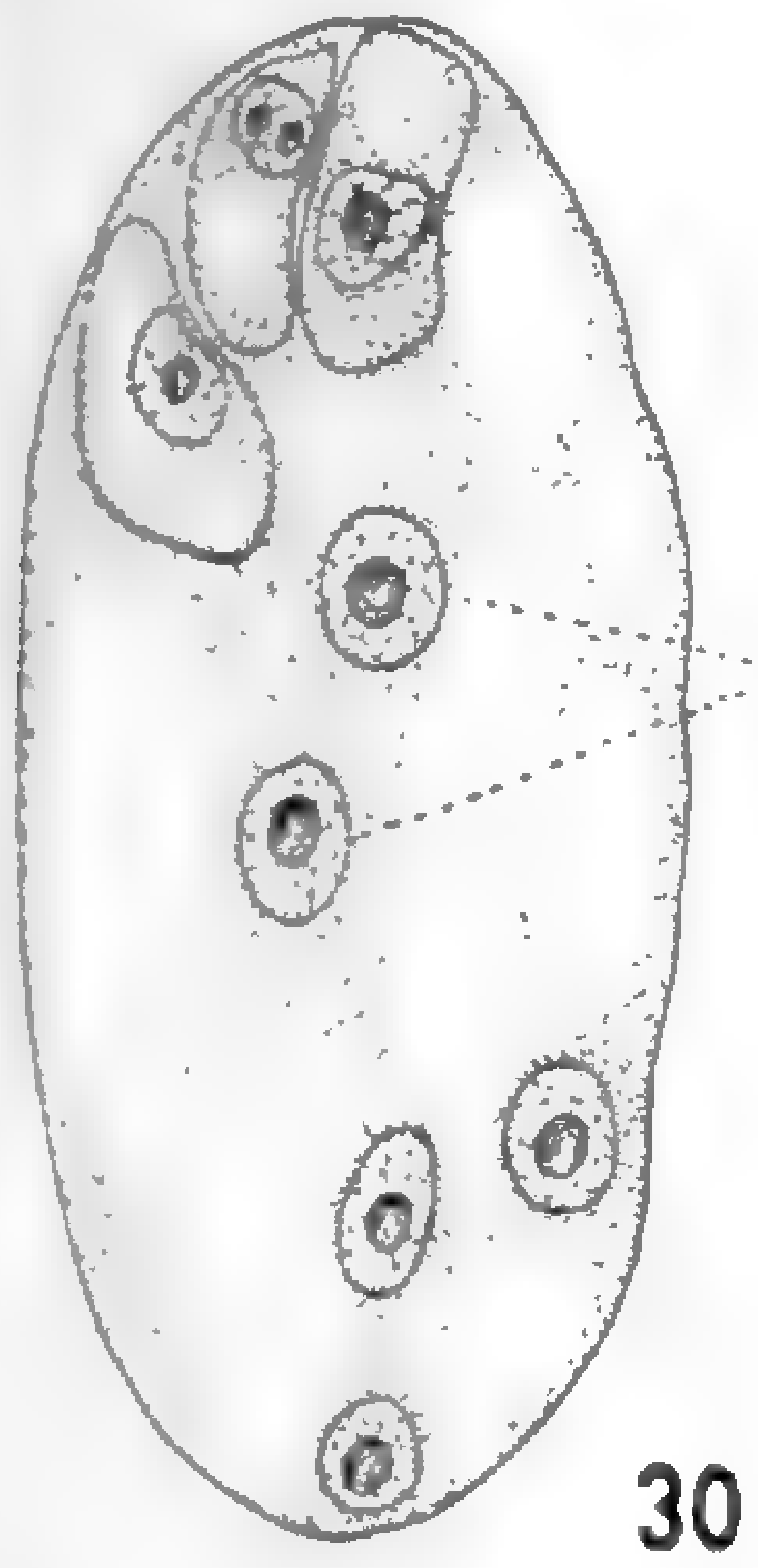

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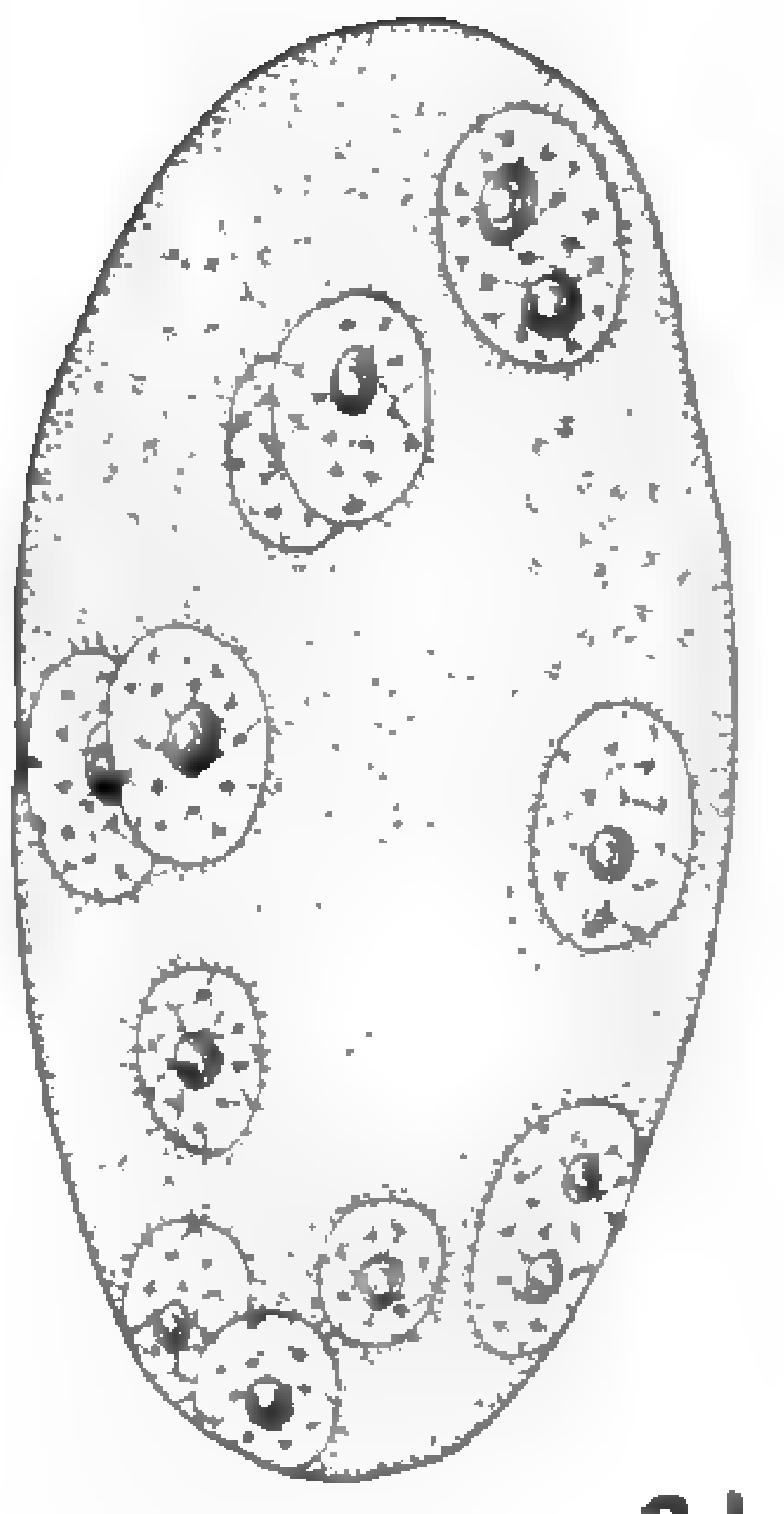

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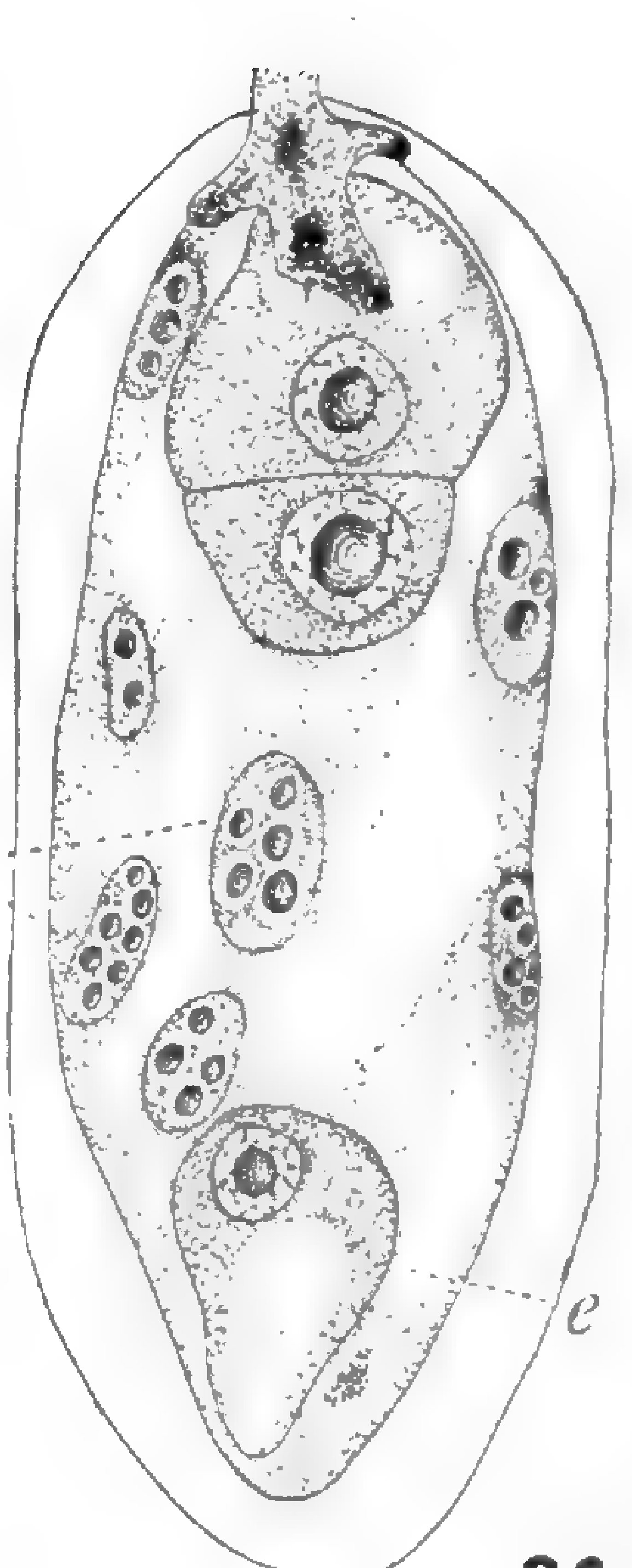

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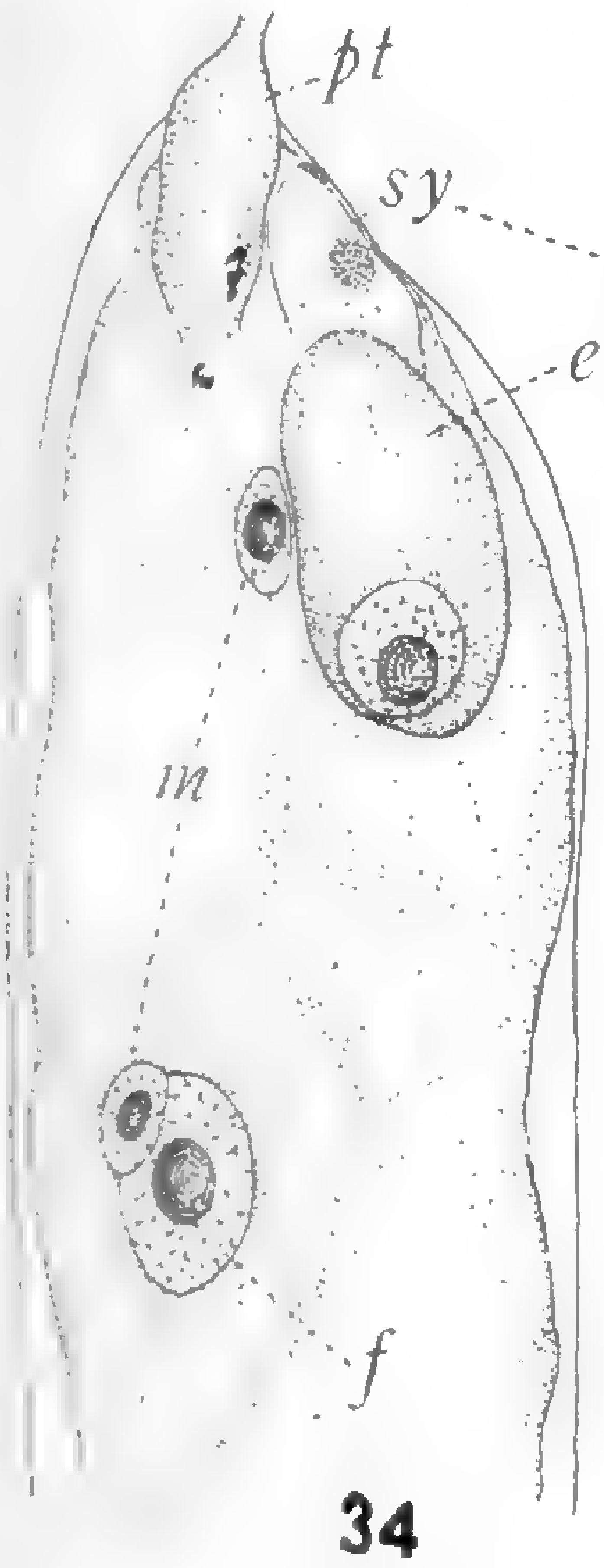

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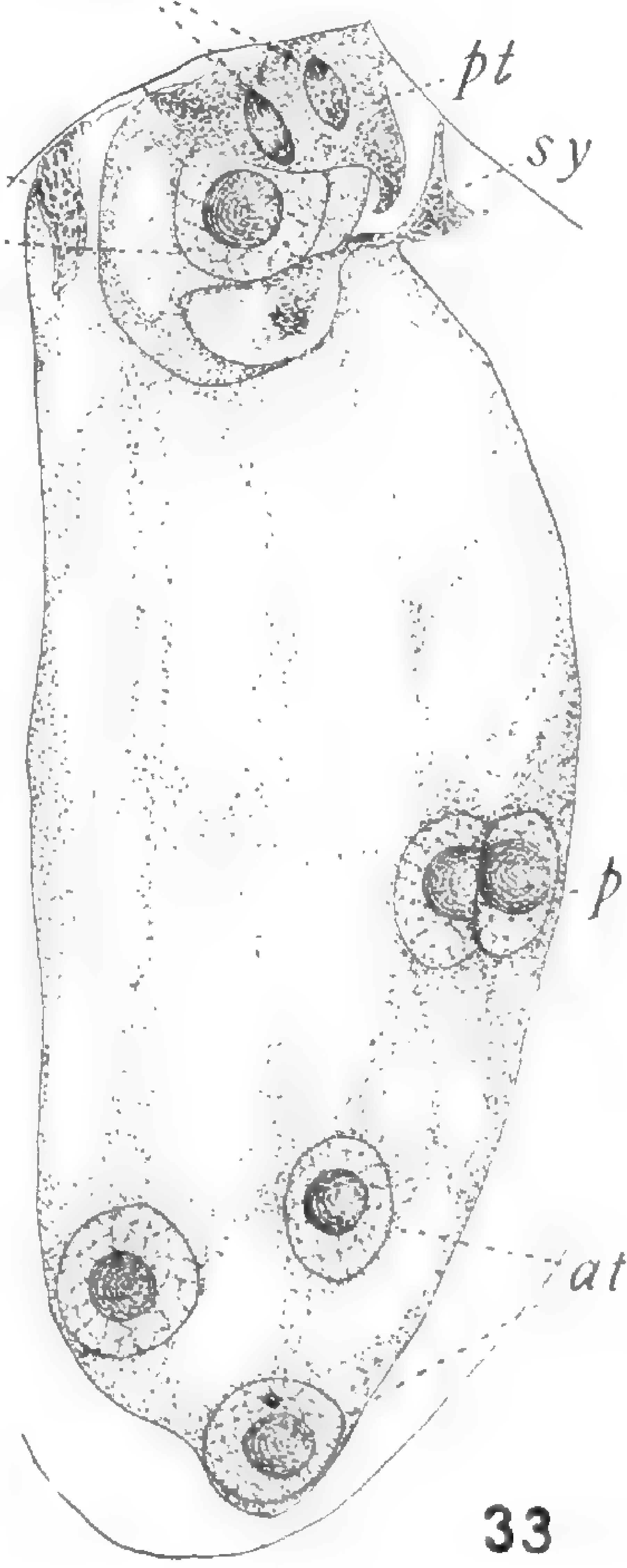

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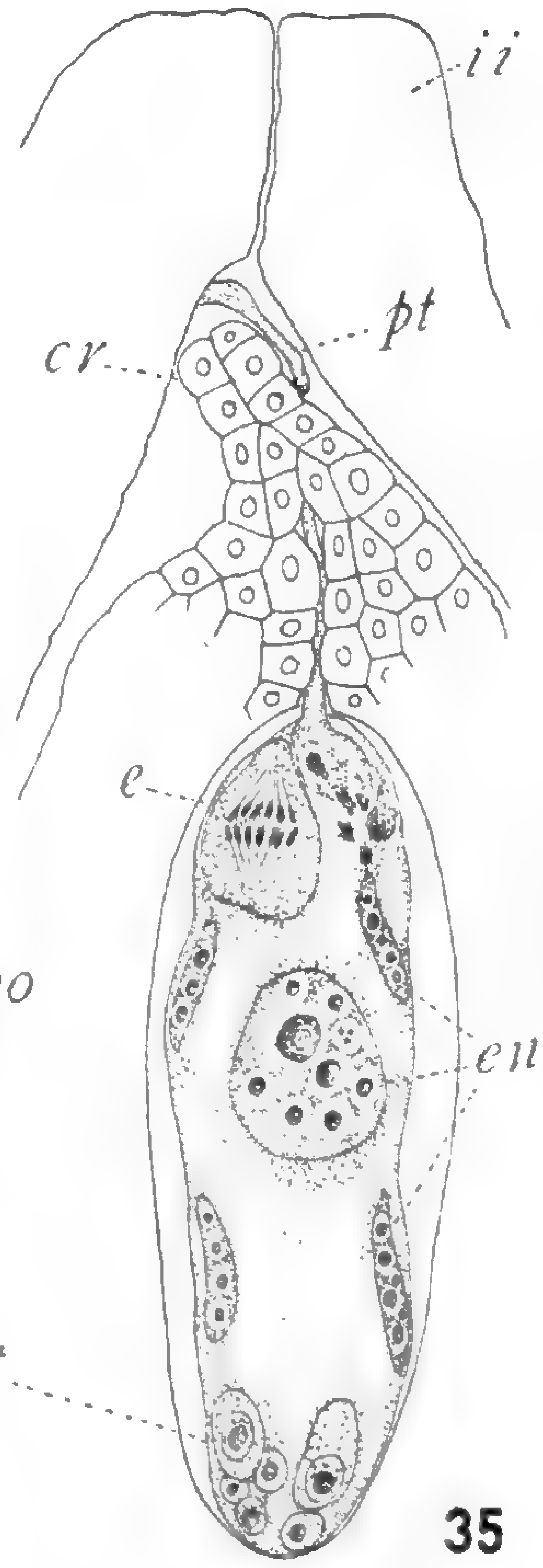

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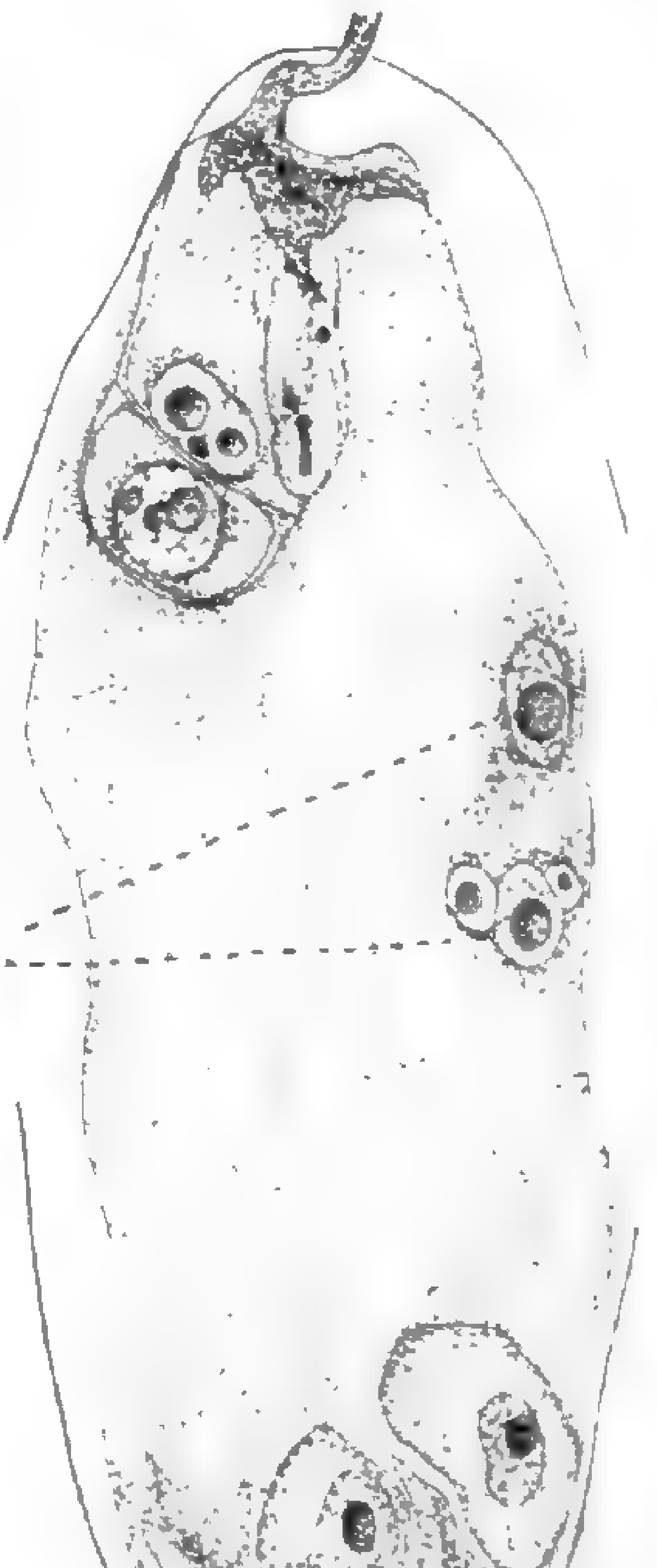

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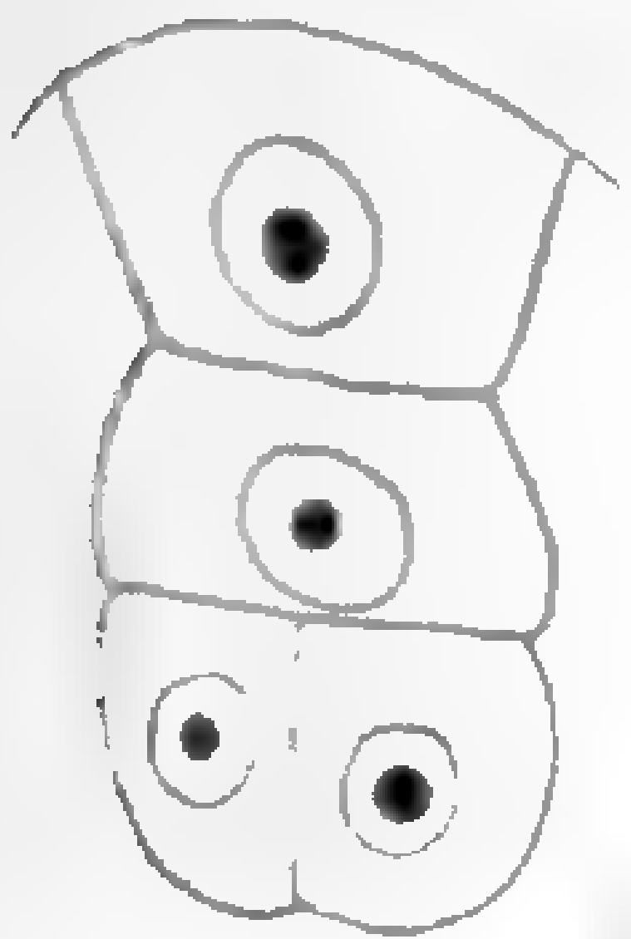

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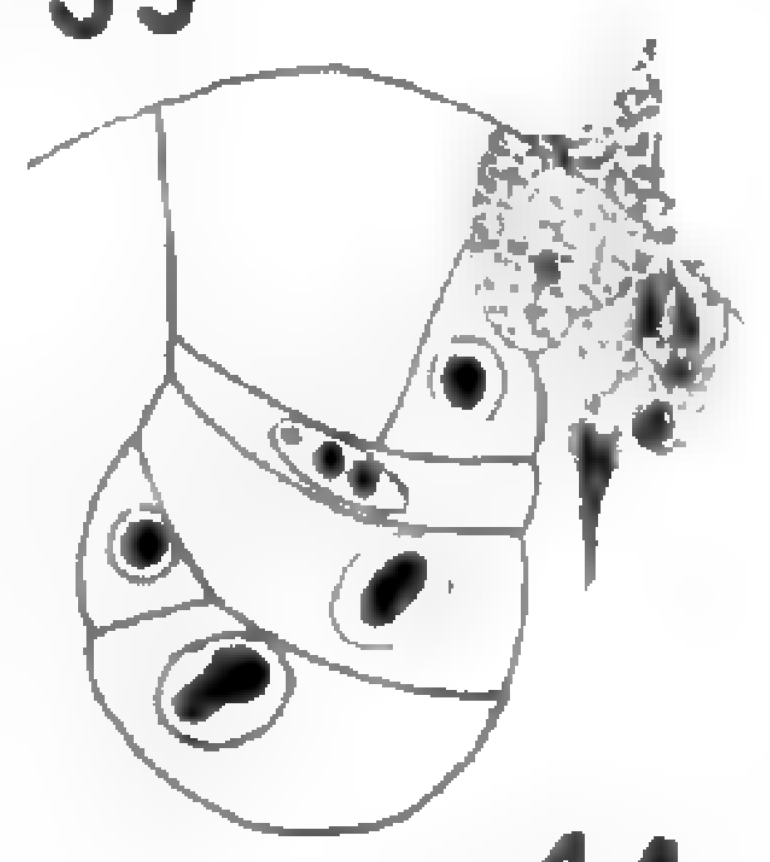

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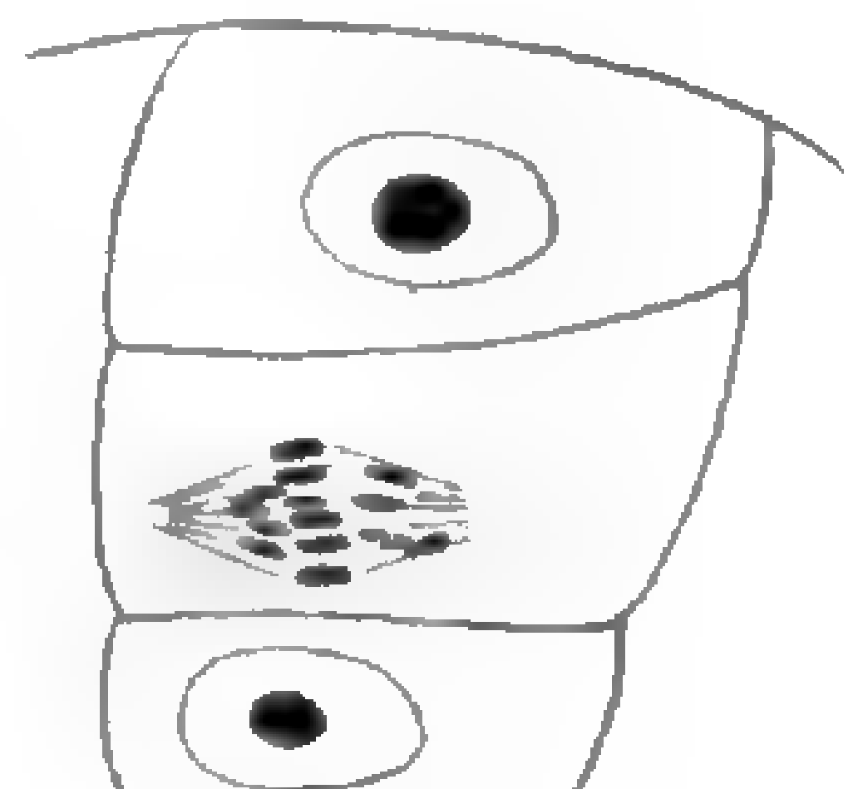

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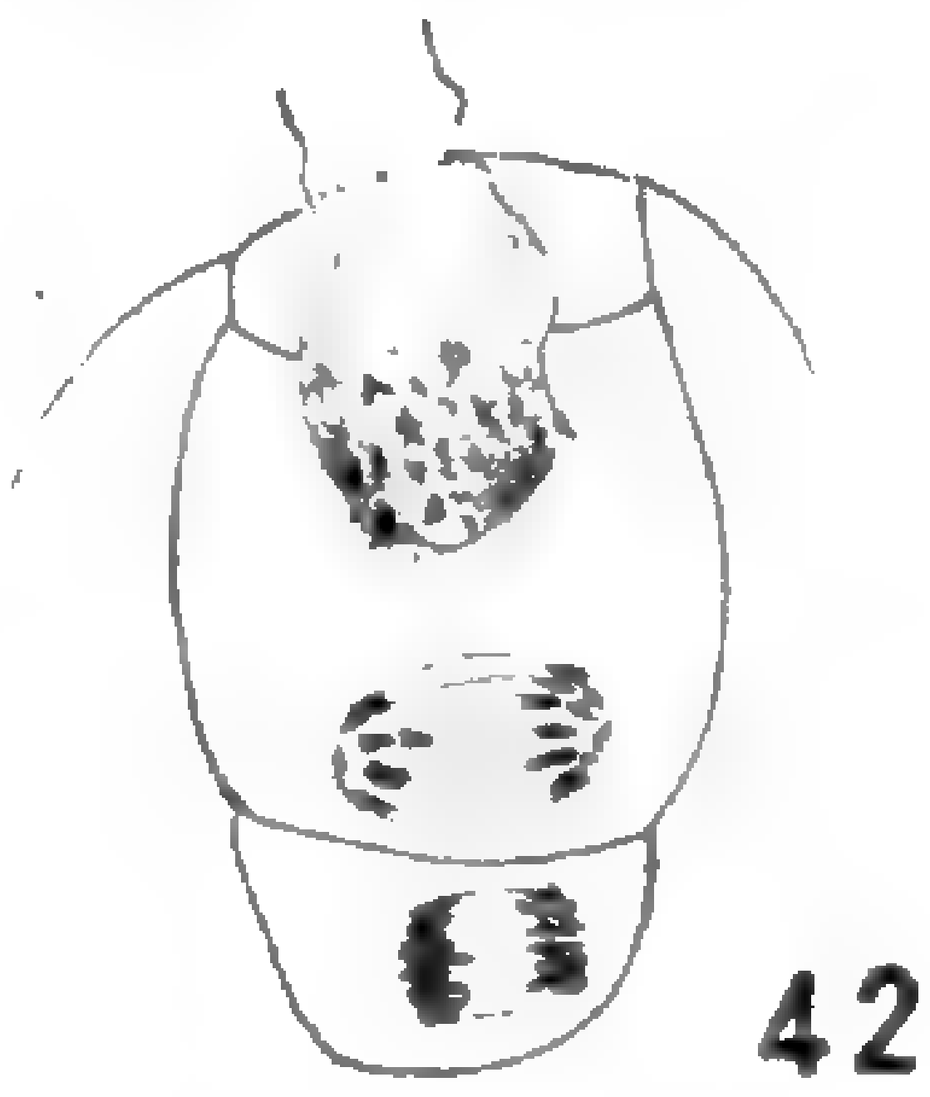

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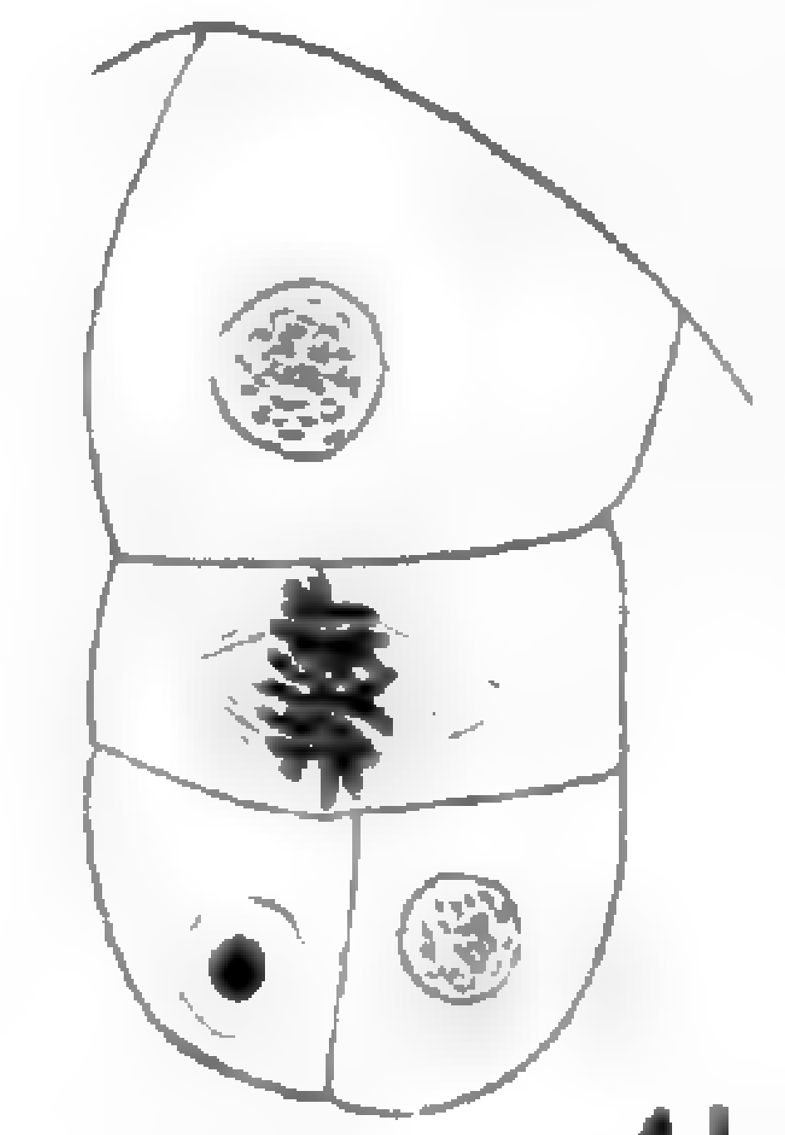

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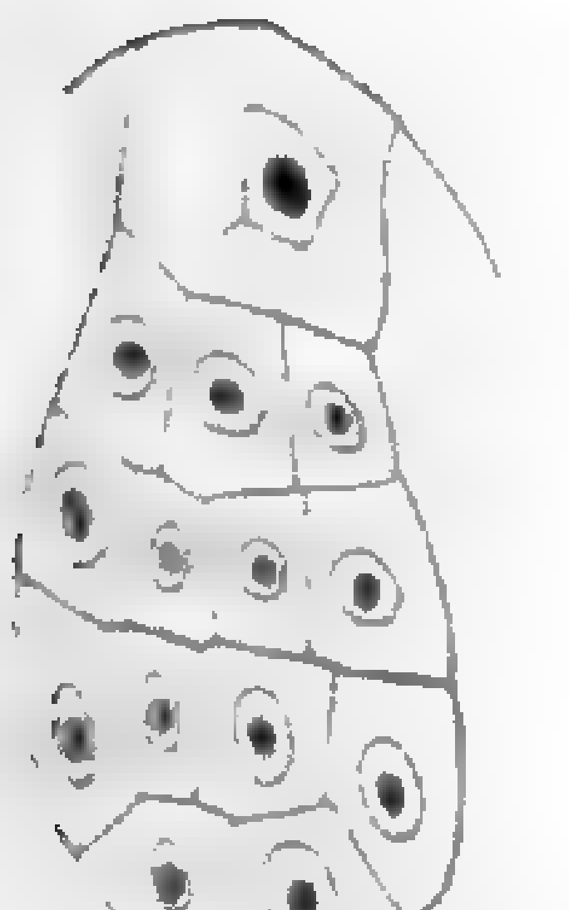

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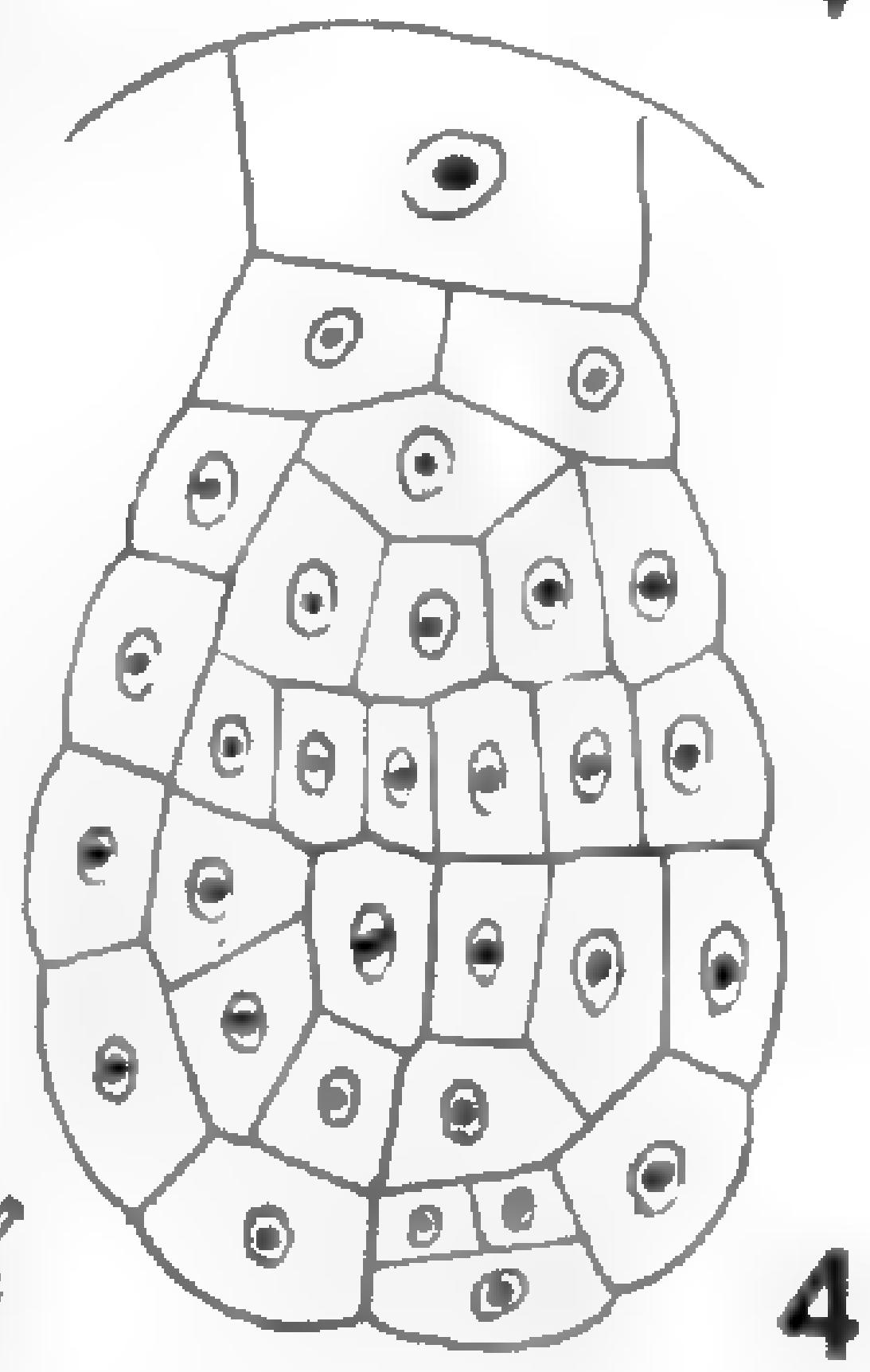

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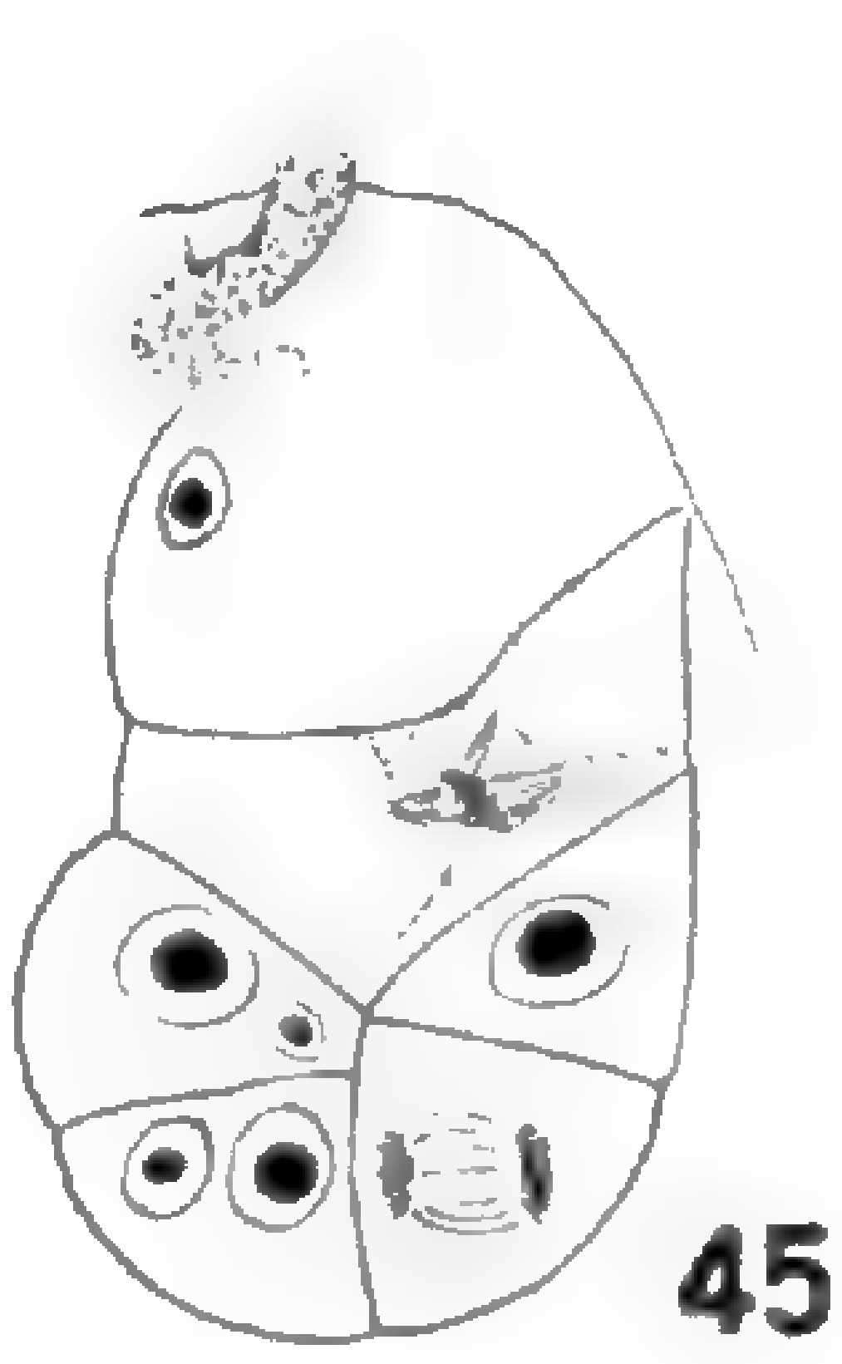

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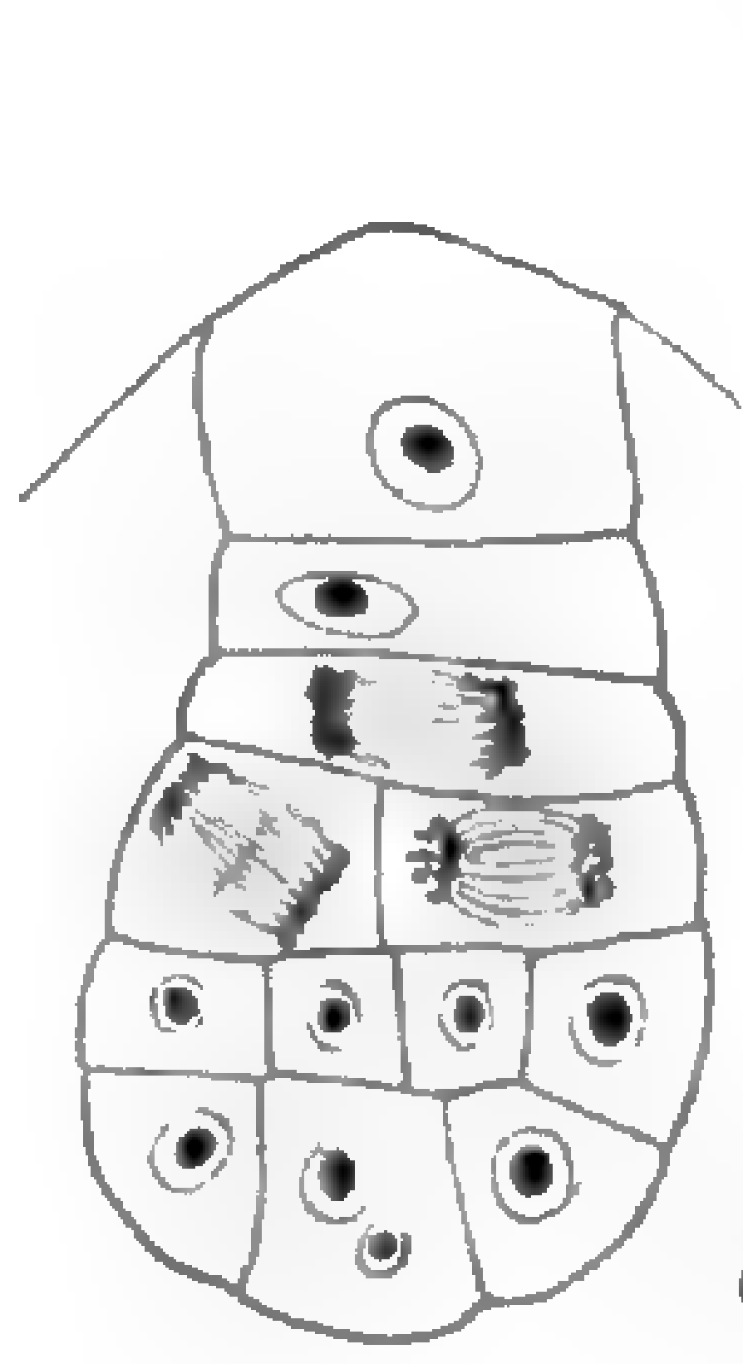

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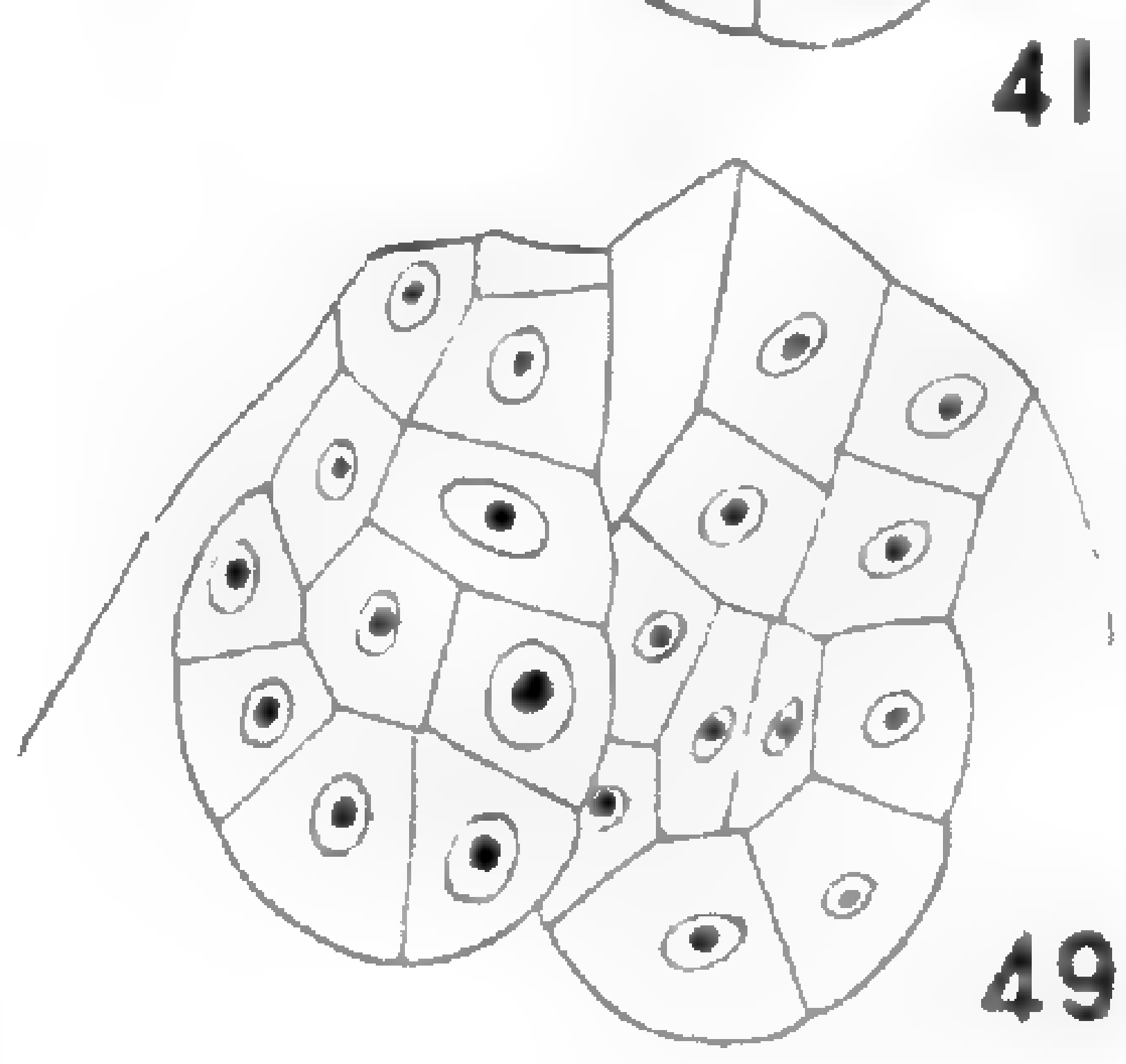

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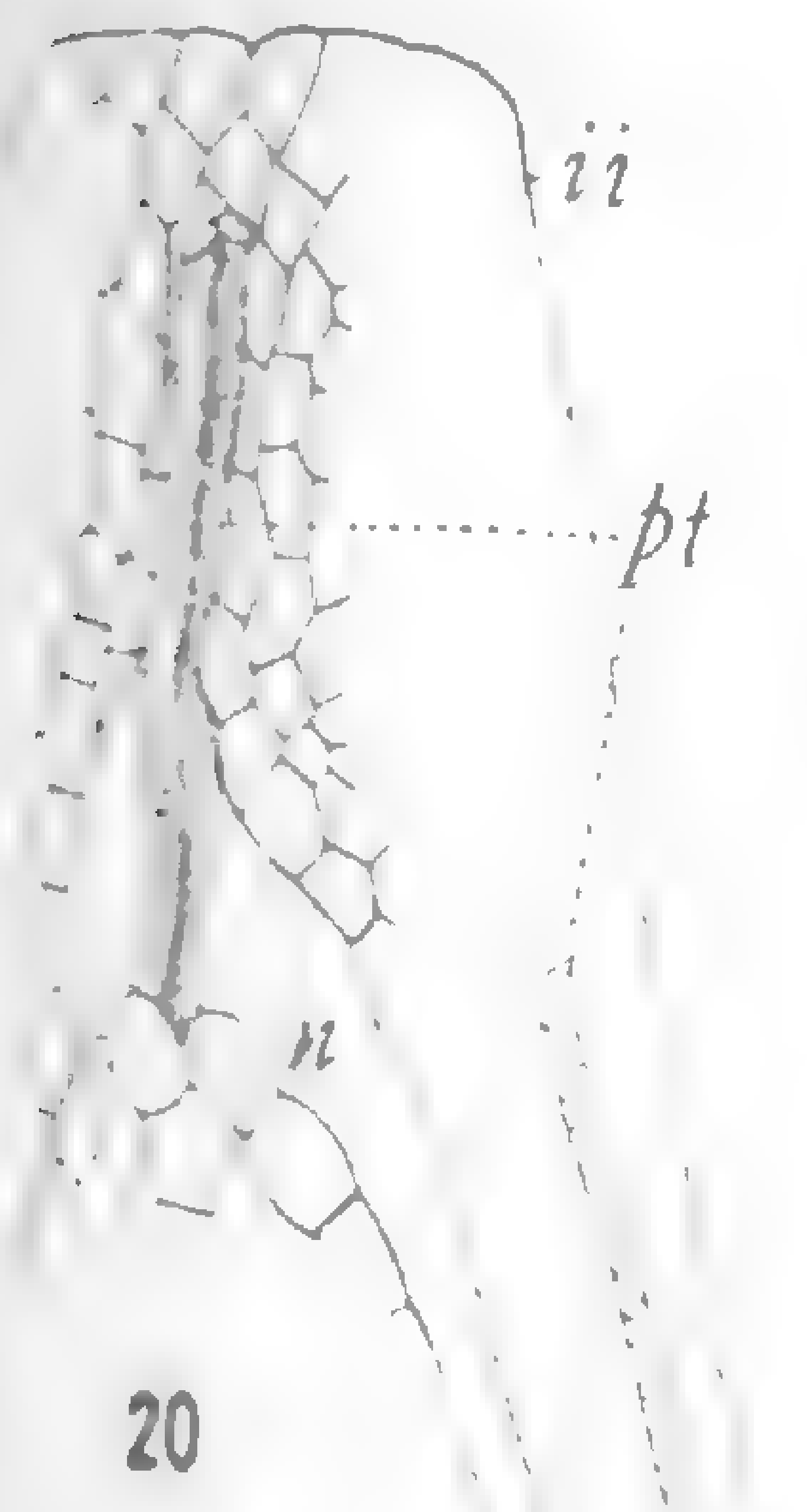

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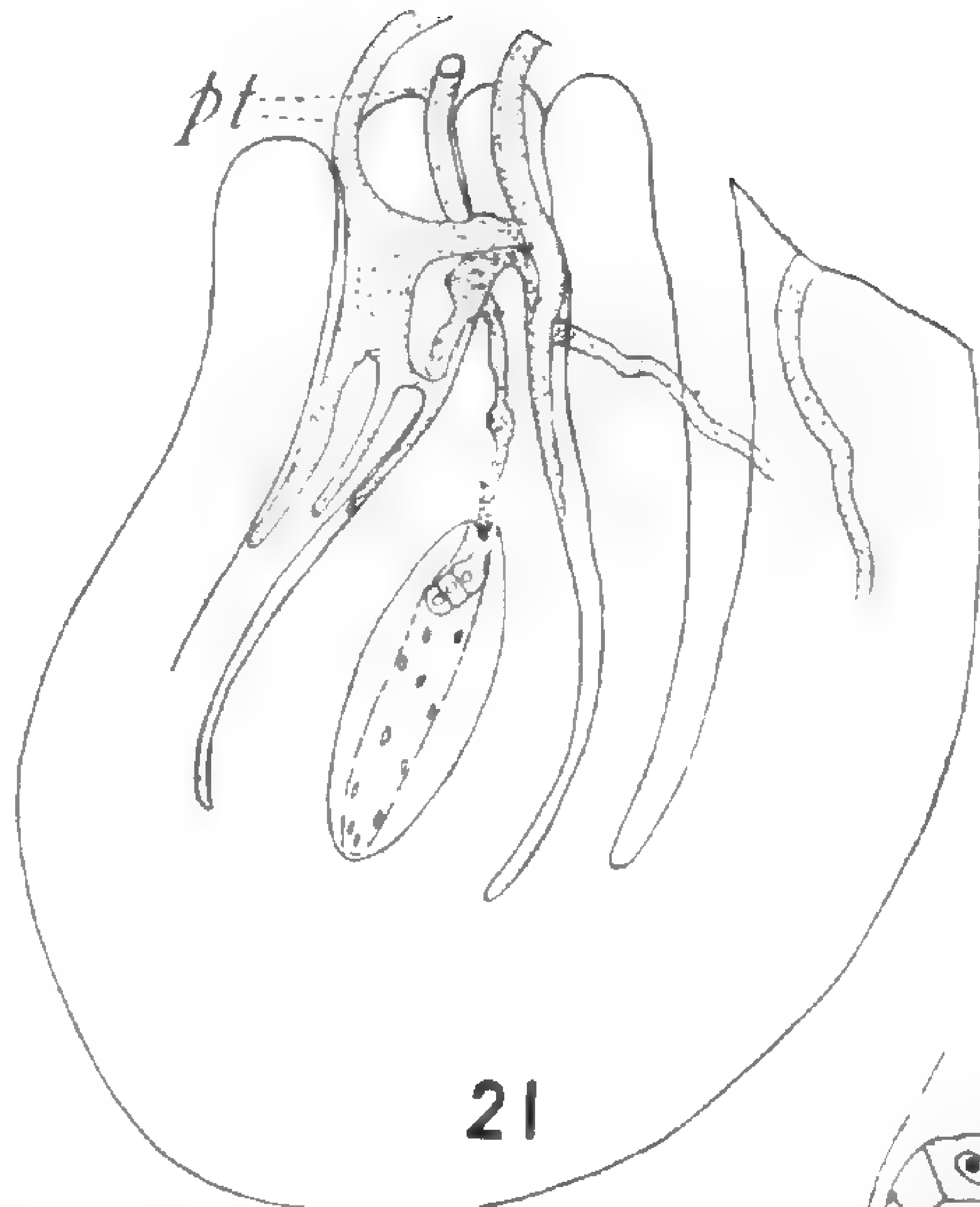

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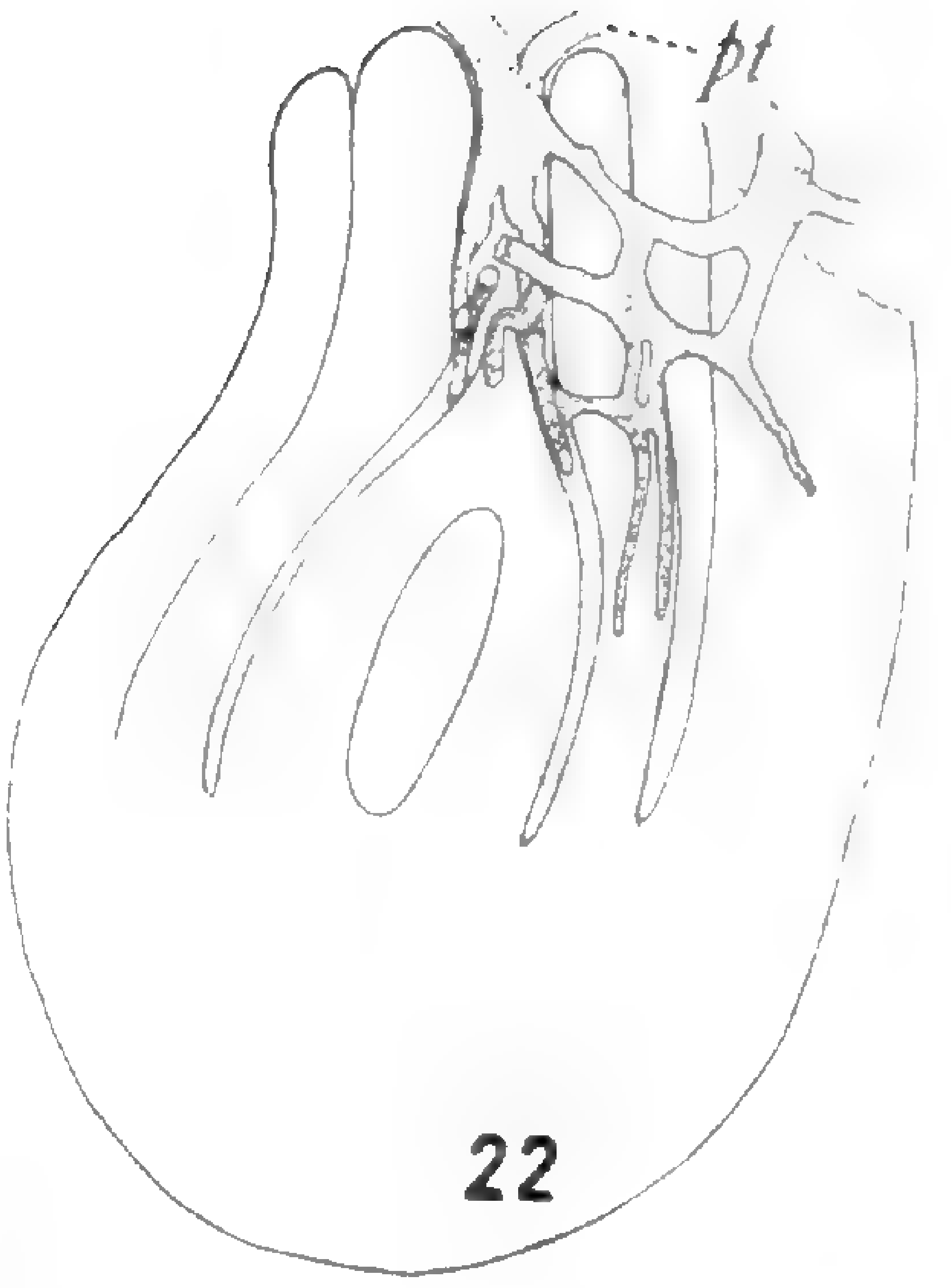

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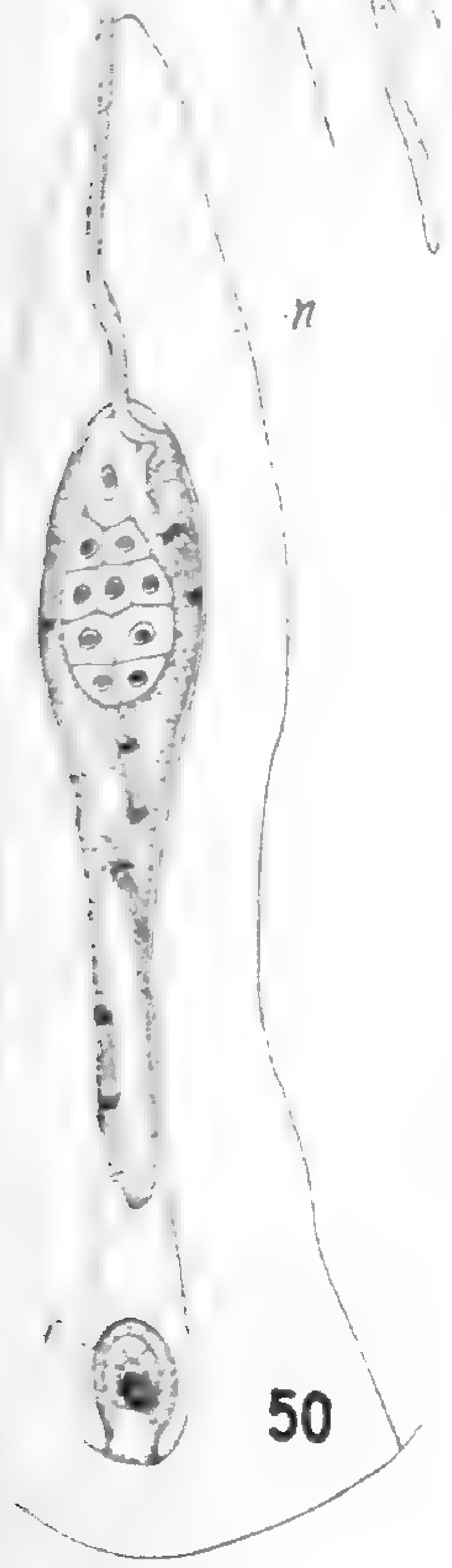

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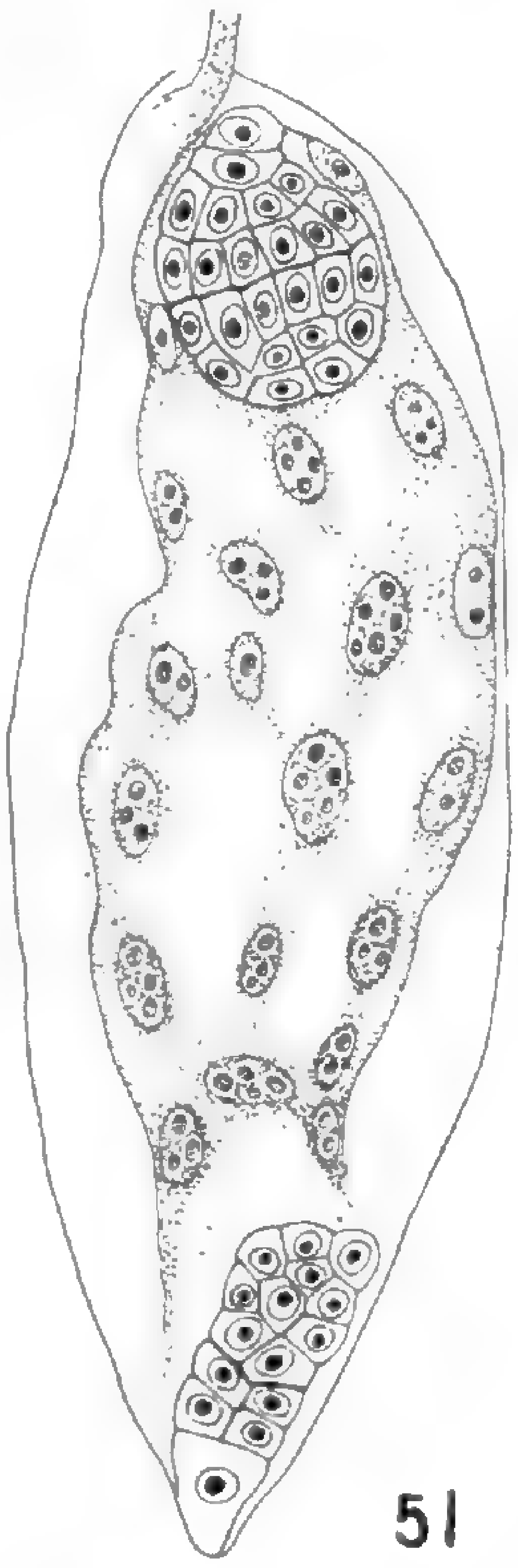

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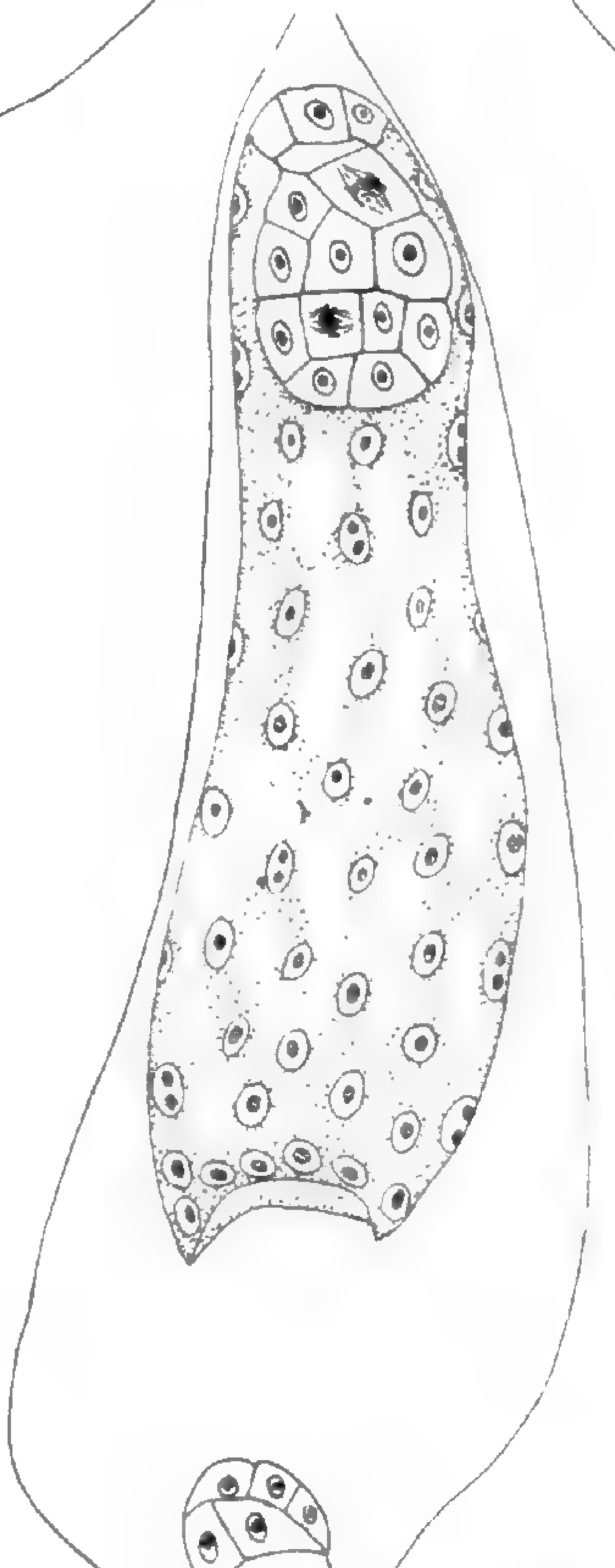

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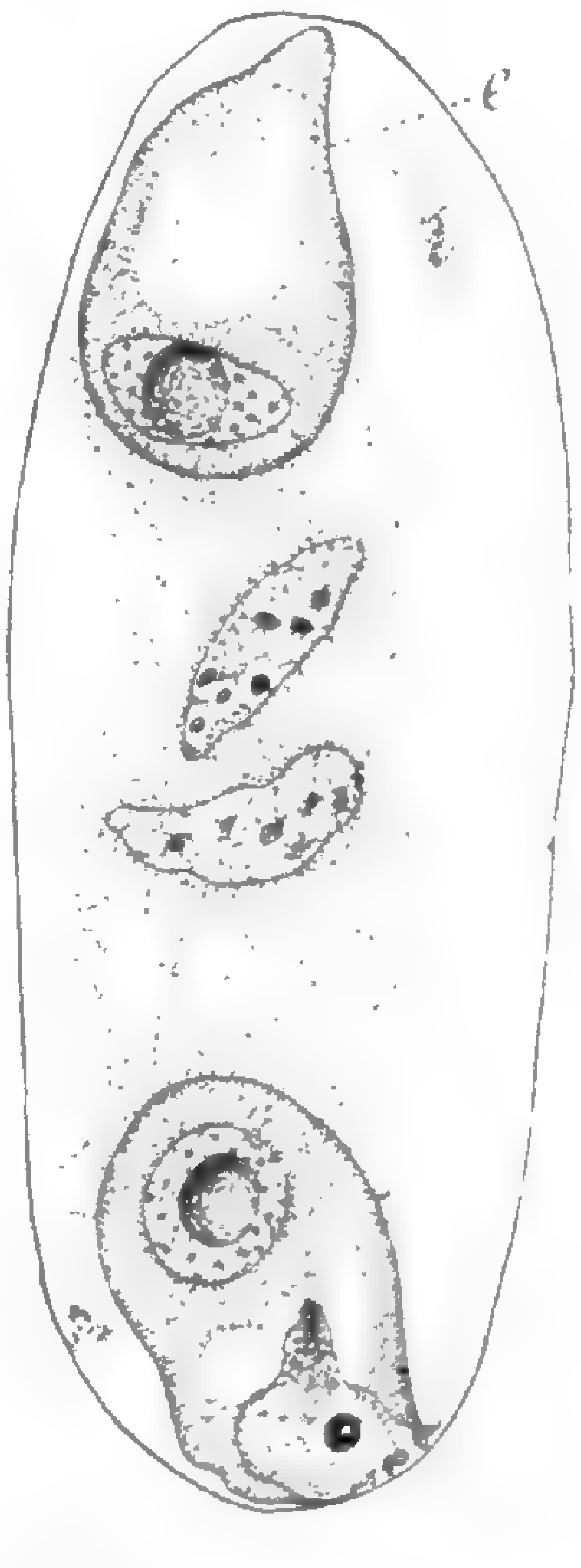

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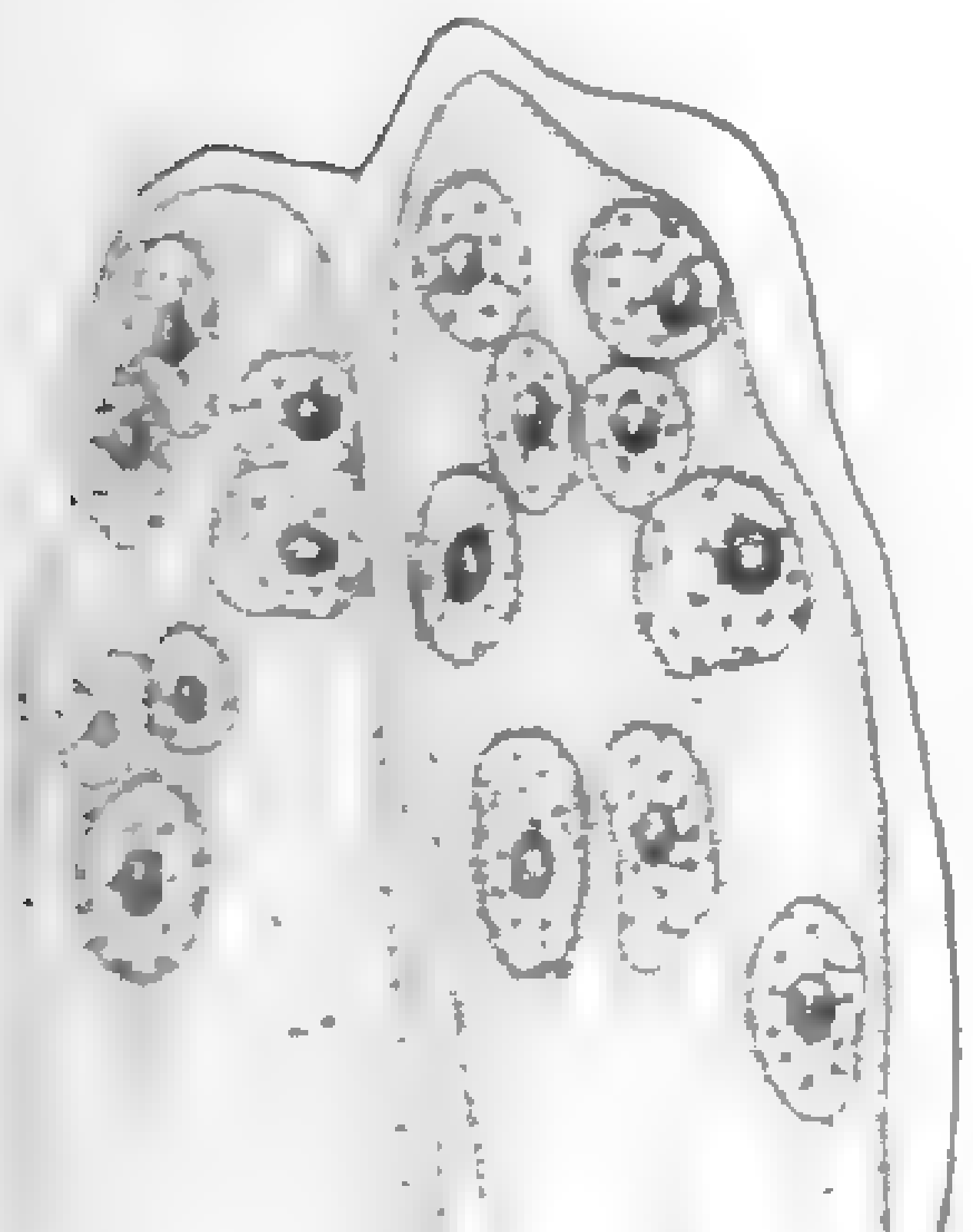

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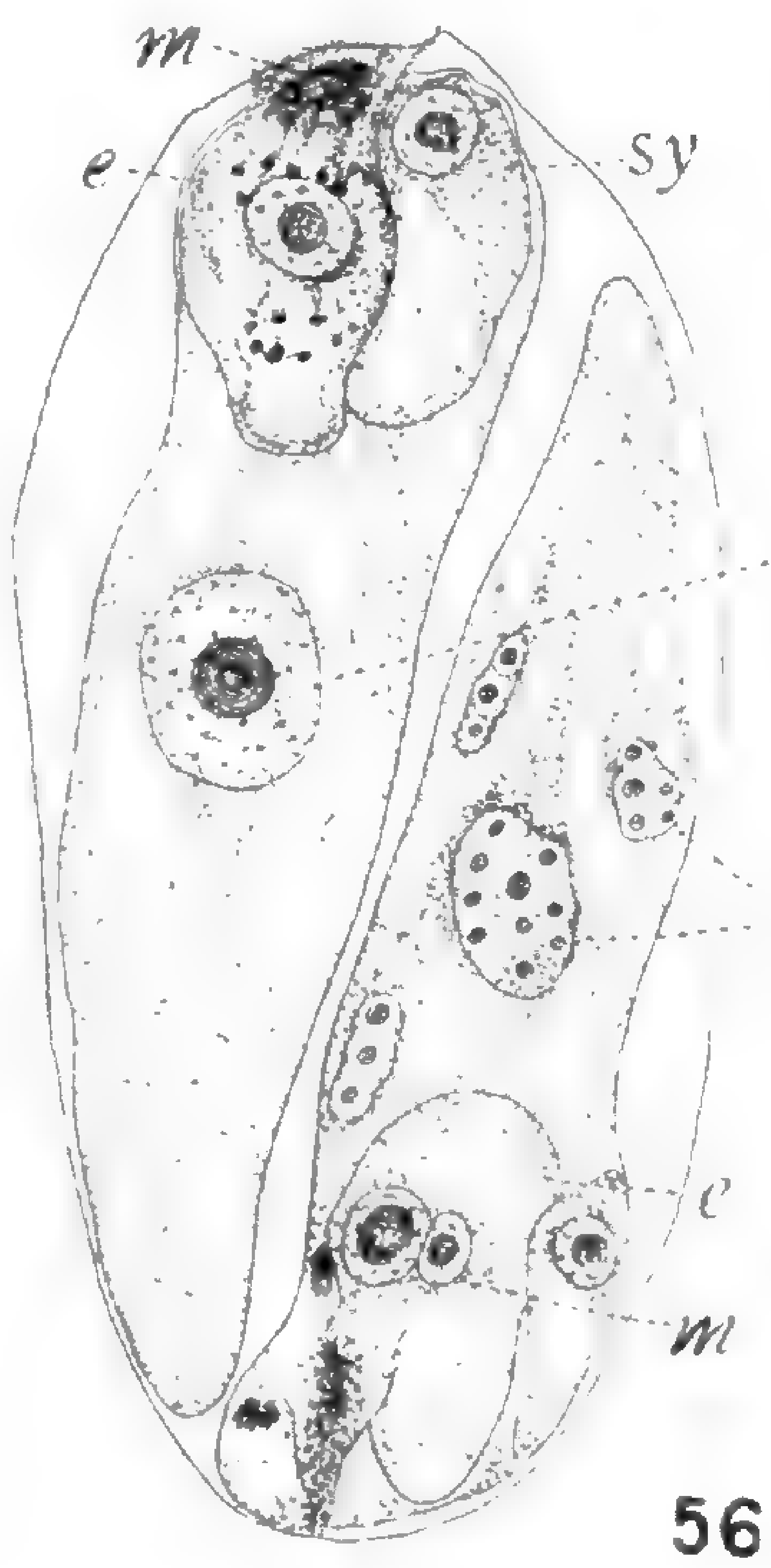

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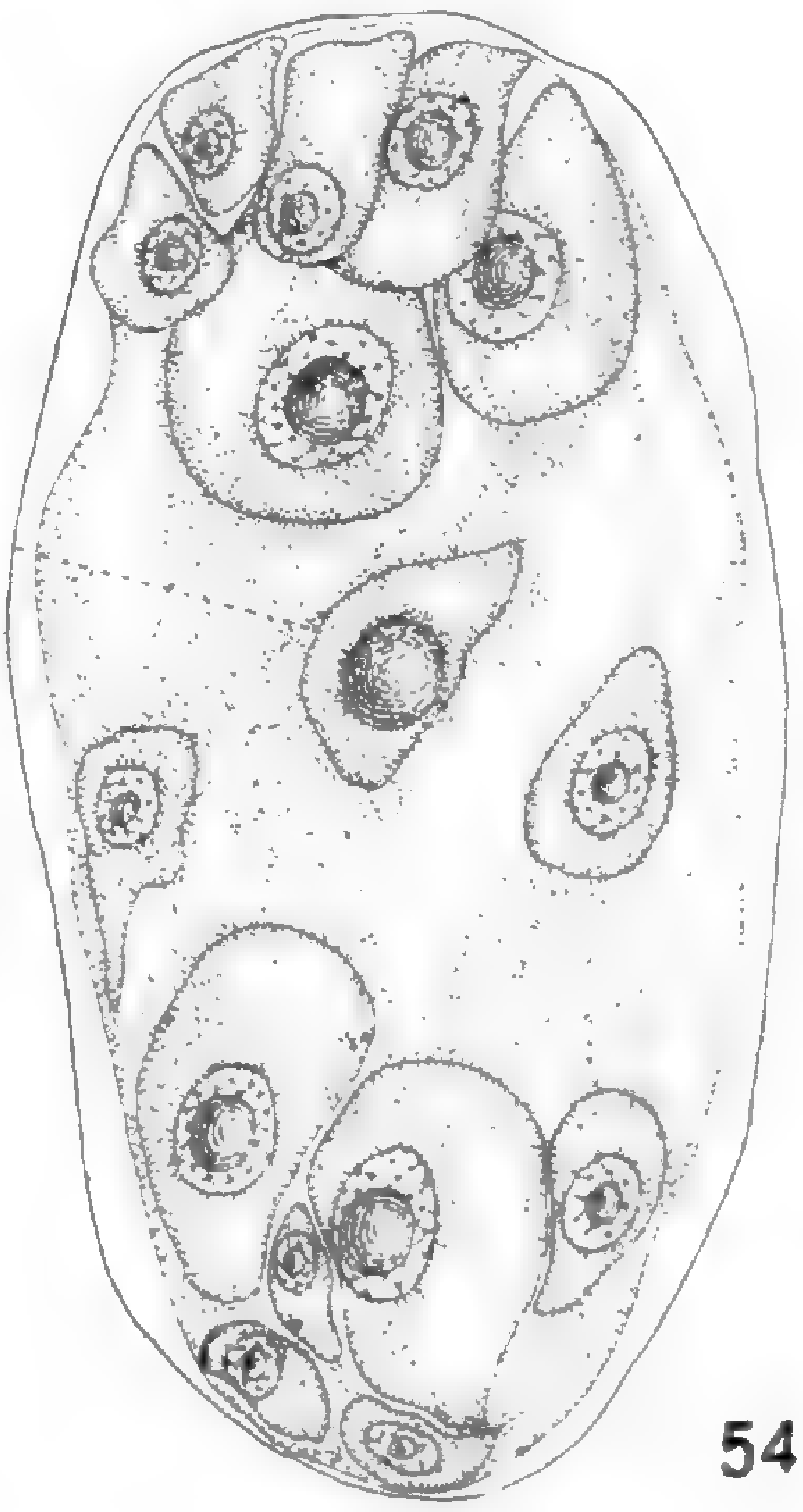

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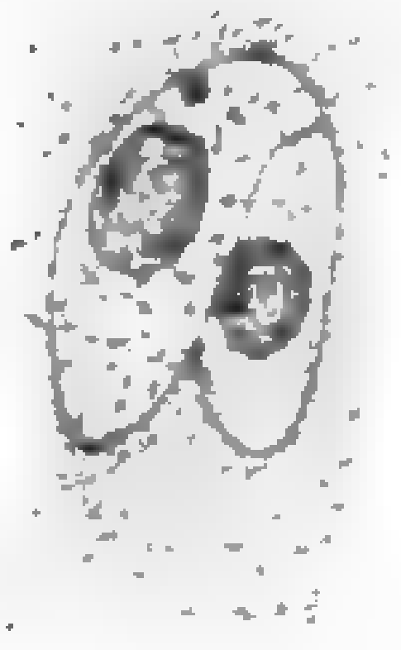

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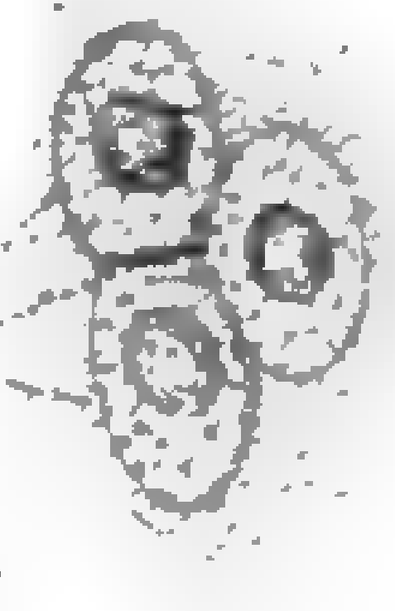

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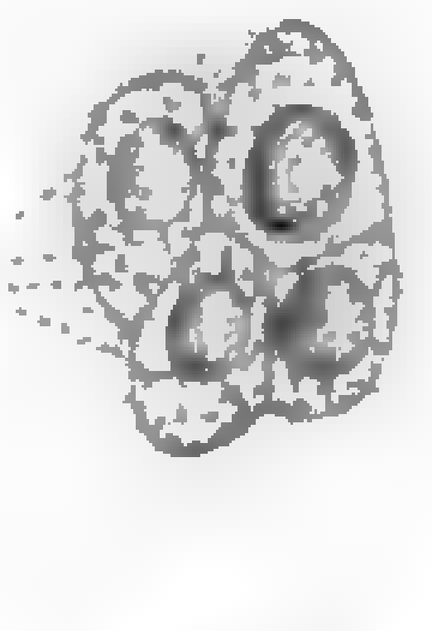

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FIG. 51. Embryo sac showing two embryos nearly the same age. ×500.

FIG. 52. Embryo sac showing two embryos; one much older. ×800.

FIG. 53. Embryo sac showing unusually large antipodal. ×810.

FIG. 54. Large embryo sac showing fifteen nuclei, the central one probably the fusion nucleus; a large egg-like antipodal. ×1200.

FIG. 55. Double embryo sac showing in one sac nine, and in the other twelve nuclei; no egg apparatus organized. ×1200.

FIG. 56. Double embryo sac showing egg apparatus organized in the opposite ends. ×1000.

FIG. 57. Fusion of two polars. ×1000.

FIG. 58. Fusion of three polars. ×1000.

FIG. 59. Fusion of four polars. ×1000.

FIG. 60. Second mitosis of the binucleate sac. ×400

BRIEFER ARTICLES.

PRECURSORY LEAF SERRATIONS OF ULMUS.

(WITH TWO FIGURES)

IT is a commonly accepted fact that embryonic plant tissue is mostly devoid of intercellular air spaces, and that gas interchange is accomplished from cell to cell by means of water which contains the necessary gases in solution. Such tissues are generally small in bulk, so that the most deeply lying cells are not widely distant from the outside atmosphere. Intercellular air spaces develop as the embryonic tissue increases in size, until at maturity an intricate system of passages, connecting with the atmosphere through stomata, insures proper aeration.

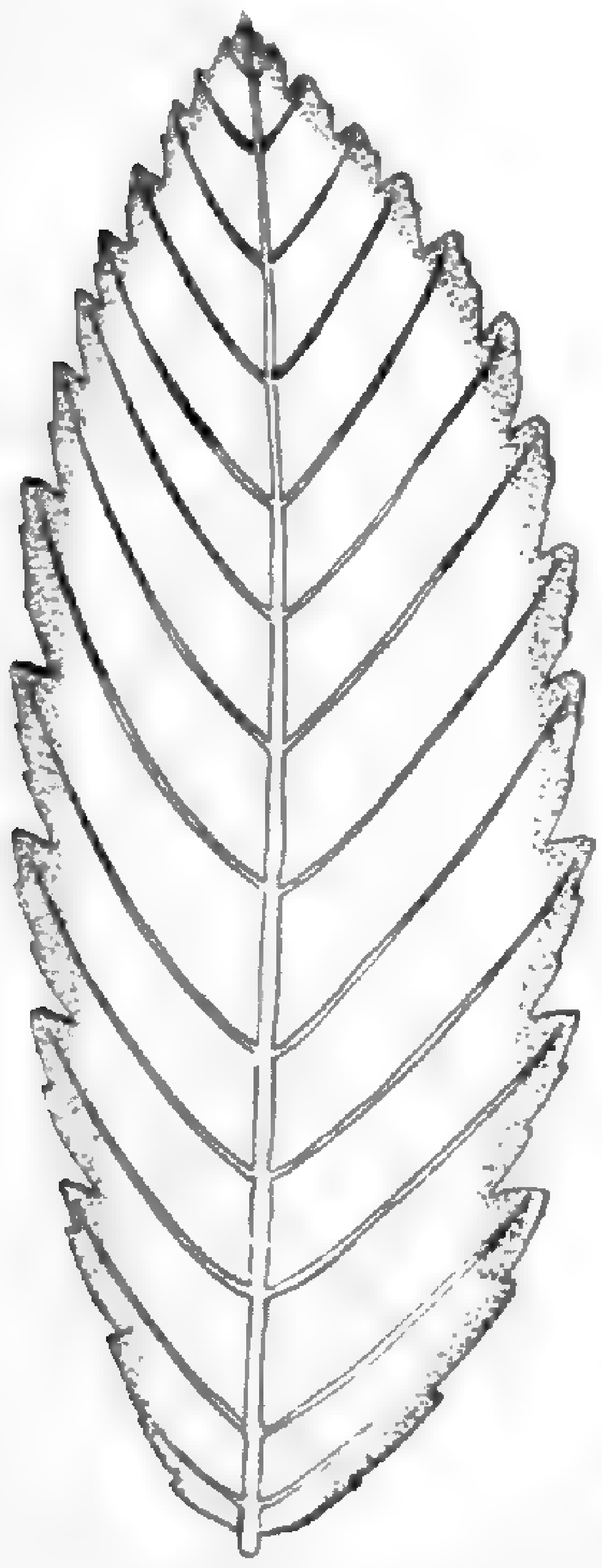

FIG. 1.—Young leaf of *Ulmus alata;* shaded regions are those in which spongy parenchyma has developed.

Leaves in which air spaces are prominently developed to assist the process of photosynthesis form no exception to the rule. Tissues of young leaves are compact, and form air passages during their growth after emergence from the bud scales. While wide observation is perhaps lacking to support the view that the air spaces arise uniformly over the entire leaf, it is generally accepted as true.

RACIBORSKI[1] has shown, however, that the leaves of certain lianas have a part which develops air spaces and stomata and hence becomes functional in advance of the main portion of the leaf. Such an organ he calls a *Vorläuferspitze*, and it consists of a slender, pointed prolongation of the blade, from which it is partially separated by a slight constriction. It appears that the purpose of the organ is to begin the process of photosynthesis as early as possible, which would help to accelerate the development of the main portion of the leaf.

While no such well-differentiated leaf organ is reported from plants living in temperate latitudes, it seems certain that spongy parenchyma does not always develop simultaneously over all parts of the leaf. An exception

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[1] RACIBORSKI, M., Ueber die Vorläuferspitze. Flora **87**: 1–37. 1900.

is to be found in Ulmus, the serrations of whose leaves become functional when the latter are still very small, or about the time they are emerging from the bud scales. It is not necessary to cut sections to observe this phenomenon, for the leaf margins are of a deep green color, which contrasts strongly with the pale yellowish-green of the remaining portion (*fig. 1*). The serrations appear slightly swollen as though the leaf were thicker in this region than elsewhere. The color contrast remains for a considerable time, or until the leaf has nearly reached its full size.

It requires but a section of a young Ulmus leaf to prove that the serrations really have fully developed spongy parenchyma and functional stomata, while adjacent and other portions of the leaf consist of compact tissue. In *fig. 2* it will be seen that in the right or marginal portion of the section the air spaces are such as would be found in any ordinary mature mesophytic leaf; while on the left of the section, which lies toward the midrib, there will be seen regular rows of cells compactly arranged and evidently in embryonic condition. It will also be noticed that the marginal portion is thicker, in consequence of the development of air spaces.

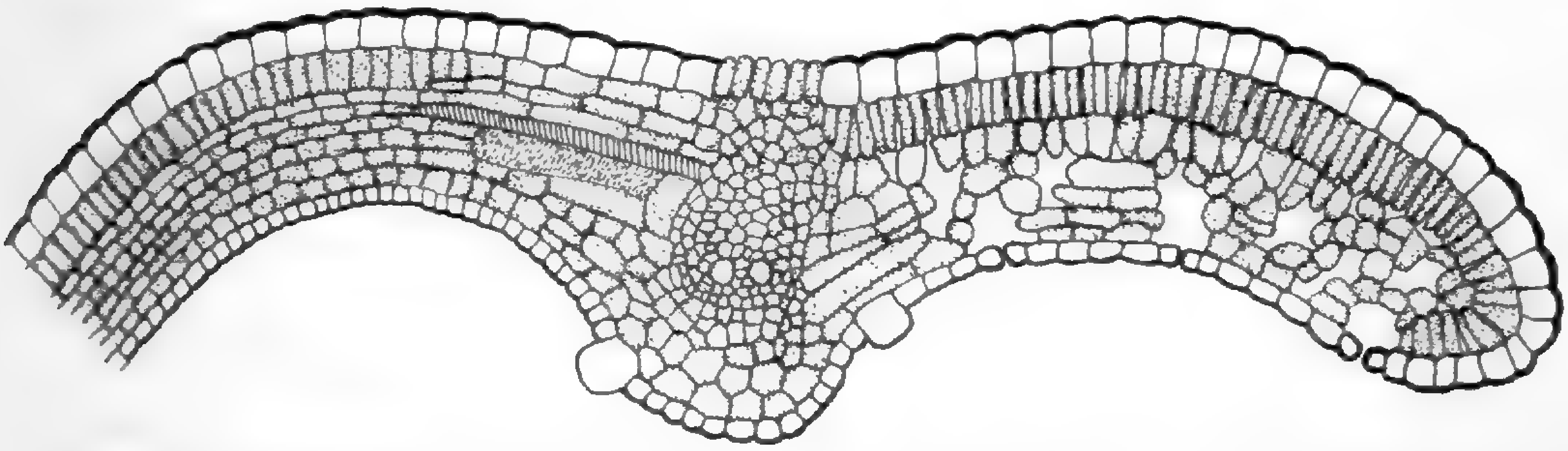

FIG. 2.—Cross-section of a leaf at the margin; the spongy parenchyma on the right is readily distinguishable from the compact embryonic tissue on the left.

It is probable that other instances of precursory leaf serrations will be found, in fact one other was found by the writer, but it was not so well marked a case as that of Ulmus.—FREDERICK H. BILLINGS, *Louisiana State University, Baton Rouge, La.*

THE EFFECT OF DIFFERENT SOILS ON THE DEVELOPMENT OF THE CARNATION RUST.

VARIOUS ideas are held in regard to the rusting of plants, especially the small grains, and to a limited extent asparagus, carnations, and chrysanthemums. The conditions which favor the rusting of such plants as the carnation and the chrysanthemum, plants grown in the greenhouse for the most part, are probably better understood than those which favor the rusting of field crops. However, the conditions that would tend to bring about infection in one place would probably bring it about in the other. Observations made in the field cannot in general be as reliable as those made in the greenhouse, where the conditions of temperature and humidity, important factors in bringing about infection, are to a greater extent under the control of the observer. Observations made in the greenhouse may be duplicated from time to time more readily than can be done in the field.

An example of the rusting of wheat, cited by ROBERTS,[2] seems to indicate that an excess of nitrogen in the soil favors rusting. The many field observations made by STONE and SMITH,[3] on the other hand, indicate that the physical condition of the soil is an important factor in the abundance and distribution of the asparagus rust, the rust being more abundant on asparagus grown in light soils with a low water retentivity, and less abundant on asparagus grown in heavier soils containing more organic matter and with a higher water retentivity.

What are the conditions that produce an abundance of rust, whether in the field or in the greenhouse? Are they excessive food supply in the form of available nitrogen, the physical condition of the soil, favorable conditions for bringing about infection, or some other causes? There cannot be a general distribution or abundance of a rust without a previous general infection; and there must have been a previous development of rust spores with which to bring about such an infection and distribution. There must have been sufficient food furnished by the host so that the rust could mature its spores for distribution and infection. Of course, certain conditions of temperature and moisture are always necessary before germination of the spores and infection can take place.

Some results obtained by the writer, in cooperation with the United States Department of Agriculture, have already been published in *Science*.[4] The present results obtained for the carnation rust, when different kinds of soils were used, are a continuation of the same line of investigation. From previous inoculations of Asparagus, Allium, Dianthus, and Gypsophila, with the asparagus and carnation rusts, the results obtained seemed to indicate that the conditions that were favorable for the development of the host were also favorable for the development of the rust.

A considerable number of inoculations were made on different species of Asparagus and Dianthus. The plants were of different ages and grown in the greenhouse, where they were under control in so far as infection was concerned. The results show that the plants that were making a vigorous growth were more susceptible to artificial infection—inoculation—

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[2] ROBERTS, I. P., The fertility of the land. p. 155. 1897.

[3] STONE, G. E. and SMITH, R. E., Ann. Rept. Hatch Expt. Sta. **14**:1902

[4] SHELDON, JOHN L., Science, N. S. **16**:397. 1902.

than those that were making little or no apparent growth. A few slowly growing plants were repeatedly inoculated without success until the plants were given extra care and stimulated so that they began to grow more vigorously. Some carnations, grown in small pots, were each inoculated five or six times at intervals of about twenty days, without any of the inoculations being effective. These plants grew very slowly, were slender and produced only one, or at most two, small blossoms.

Certain varieties of carnations are known to be more susceptible to the rust than others; among these are Uncle John and Daybreak. Other varieties are practically immune. The green-leaved varieties are considered by carnation growers to be more susceptible than the more glaucous-leaved ones. The writer has noticed that there was a difference in the period of incubation of the rust when both green- and glaucous-leaved species of Dianthus were inoculated at the same time.

A lack of susceptibility to inoculation, similar to that noted for Asparagus and Dianthus, occurred when seedling onions were inoculated with the asparagus rust. The inoculations were begun as soon as the seedlings appeared above ground, and were repeated at intervals until the seedlings were two months old, when almost every inoculation was successful.

From the results obtained, not only with the rusts referred to, but with other fungi, it would seem that plants, like animals, are not equally susceptible to infection and inoculation at all times. The negative results obtained by other investigators, as well as by the writer, may be attributed in some instances probably to a lack of susceptibility of the host at the time the inoculation was made and not to a failure of the spores to germinate or to the way the inoculation was made. At some other period the same plant might have been susceptible. The state of growth of a plant seems to have much to do with the success or failure following an inoculation, as well as conditions of temperature and moisture which favor the germination of the spores.

It was determined in some of the earlier inoculations that the season, temperature, and sunshine exerted a marked influence on the period of incubation of the asparagus and carnation rusts. It was also thought that the soil made some difference; for when twenty to thirty plants were grown in the same soil, as in a box or large flowerpot, the period of incubation of the rust for each of the plants inoculated at the same time varied only a few hours in most instances, while those that were of the same age and grown in different soils showed more variation.

As a means for testing whether a difference in soils would bring about a difference in the period of incubation of a rust, a stock plant, a green-leaved pink which was known to be very susceptible to the carnation rust, was selected. Sets of cuttings were taken from the stock plant and rooted in river sand. After the cuttings were well rooted, they were transplanted to pots containing the soils to be tested. Each of the soils was carefully mixed before it was put into the pots, so that all would be as uniform in composition as possible. The five soils used ranged from one that was principally sand with a very small amount of organic matter to those containing less sand and more organic matter and clay.

After the plants were potted, they were arranged in sets of five or seven in large saucers, and placed so far as it was possible under the same conditions of light, heat, etc. When the plants had become established and made a growth of a few inches, each set was inoculated. Of the 170 plants inoculated, only three failed to show rust sori in sixteen to twenty-one days, the majority showing sori in seventeen to nineteen days.

The leaves were carefully examined with a hand lens twice a day after yellow spots began to show on them, indicating that infection had taken place. When the uredospores were observed to be breaking through the epidermis of a leaf, a record was entered for that plant. This record was afterward used in making comparisons with the composition of the soils. The Bureau of Soils of the United States Department of Agriculture made a mechanical analysis of the soils and determined the percentage of organic matter and nitrogen.

Rather than depend upon his own judgment, which was liable to have been somewhat biased on account of having watched the development of the pinks and the rust, the writer averaged those of several other persons with respect to vigor, growth, and color of the plants.

The results of the investigation are summarized in part below; the details will be published later. Whether similar results can be obtained by using a different host and parasite remains to be determined.

1. The intensity of color was directly proportional to the amount of clay in the different soils.

2. The growth of the host was directly proportional to the amount of organic matter, nitrogen, and silt in the different soils.

3. The period of incubation of the carnation rust, while not uniform in every instance, was in general inversely proportional to the amount of organic matter, nitrogen, and silt in the different soils, and to the growth of the host; it was directly proportional to the amount of gravel and sand in the different soils; that is, the more gravel and sand there were in a soil, the longer it was before the uredospores broke through the epidermis after an inoculation had been made; and the more organic matter, nitrogen, and

silt there were in a soil, the less time it was before the uredospores broke through the epidermis after an inoculation had been made.

4. Those soils that were favorable for the development of the host were also favorable for the development of the rust; namely those containing the most organic matter combined with silt and clay and a small amount of sand—soils with a high water retentivity, soils rich in nitrogen.

If then the conditions favorable for bringing about distribution and infection were the same for the different soils, the rust should in time be more abundant on those plants grown in a heavy loam where the period of incubation of the rust was least, than on those grown in a light sandy soil, agreeing with the observations made by ROBERTS (*l. c.*) on the wheat rust, rather than those made by STONE and SMITH (*l. c.*) on the asparagus rust. There is a possibility that while the asparagus rust may not have developed so rapidly on the asparagus grown in light soils with a low water retentivity, the greater abundance was due to conditions which were more favorable for bringing about infection. Whether the humidity is greater over sandy soils than over a heavy loam, the writer cannot say from personal observations. Perhaps some one has already determined this factor, which is so important in bringing about the infection of cultivated crops with various parasitic fungi.—JOHN L. SHELDON, *Agricultural Experiment Station, Morgantown, W. Va.*

CURRENT LITERATURE.

BOOK REVIEWS.

German instruction in botany.

IT IS INTERESTING to compare the latest German book on botanical instruction with our own. Dr. KIENITZ-GERLOFF,[1] professor of botany in the Agricultural school at Weilburg, has briefly described the present condition of botanical teaching in Prussia; has discussed at some length the principles, pedagogical and botanical, on which a proper course should be laid out; and has devoted the greater part of his book to the outlining of such a course as meets his views.

The first section of the book may be passed over with the remark that "nature study" finds a place in the primary schools, but it is nature study directed to a somewhat definite end; for pupils are taught something of the structure and life of plants, and are even "made familiar with the use of the lens and microscope." This study is extended in the intermediate grades, and in the *Gymnasien* and *Realschulen* becomes a two to six-hour course weekly in natural sciences, continued for six years. Of this botany has a reasonable share. In the *Landwirthschaftschulen* (not technical schools) zoology and botany have four hours weekly for two years and two hours a week for a third, and applied biology has the same time.

In the second section the author with rather elaborate pedagogic philosophy develops his theory that the normal course of instruction in botany should be planned broadly on the lines that its historical development has followed. In the practical application of this theory he divides the course into four parts: (1) preparatory, (2) morphology and taxonomy, (3) physiology and anatomy, (4) cryptogams and reproduction.

In the preparatory course, no formal morphological distinctions are made, but the endeavor is to awaken interest, and to train in observation and induction by using the common and useful flowering plants. Incidentally, of course, a good deal of morphology is learned.

The second course, by using plants of the larger orders and families, and by comparisons, is for training in external morphology, and at the same time to give fundamental conceptions of taxonomy. The mere determination of names is made wholly incidental, and the memorizing of terms and definitions is rightly condemned. In both these courses actual examples of lessons (stenographically reported) are given.

The third course is given *in extenso* in the form of questions and a statement

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[1] KIENITZ-GERLOFF, F., Methodik des botanischen Unterrichts. 8vo. pp. viii+290. *figs. 114*. Berlin: Otto Salle. 1904. *M*6.50.

of the way in which pupils are to answer them, accompanied by many illustrations; so that this part of the book might almost be used as a guide for elementary plant physiology and anatomy.

The fourth course begins with a somewhat detailed presentation of the bacteria, after which the book breaks off suddenly with a recommendation that pupils study a list of fourteen cryptogams, closing with the sexual reproduction of the phanerogams and a synopsis of the whole system.

There is much good advice and suggestion in Dr. KIENITZ-GERLOFF's book, but like all such books it plans a course which is far beyond the possibility of execution in the time allowed. Naturally it demands a well-prepared teacher, and when once a school has that factor, the problem is practically solved. To such this book will be helpful if it does not suggest overcrowding. (And to everybody it would have been more helpful had a good index been provided.)

It is interesting to see that the ideals as to the content and method of botanical instruction in the higher schools in Germany and America are so nearly identical. But we fear Germany will long outstrip us in the practical application of these ideals unless superintendents are more alive to the necessity for the thorough training in botany of those to whom they commit such teaching.—C. R. B.

MINOR NOTICES.

POND[2] has been studying the relation of aquatic plants to the substratum. After an introduction and a historical résumé of the subject, he gives the details of a series of carefully conducted experiments on the growth of aquatic plants under different soil conditions. The plants experimented on were *Vallisneria spiralis*, *Ranunculus aquatilis trichophyllus*, *Elodea canadensis*, *Myriophyllum spicatum*, *Potamogeton obtusifolium*, and *P. perfoliatus*. The result of the experiments seems to prove clearly that these plants are dependent for an important part of their food on the substratum in which they are rooted; that there is an upward current through the plants; and that the roots serve not only for anchorage but also for absorption. He shows that most of these plants have root hairs through which absorption takes place. It is evident that the establishment of the fact of root absorption in aquatic plants is an important addition to botanical knowledge; but it has a wider and more important interest in connection with the problems of the relationships of the animals and plants in our lakes to each other and to their material environment. The introduction and the final discussion of the experiments serve to bring out very clearly the important bearing of these results on plankton problems. Without doubt most authors have supposed that aquatic plants draw their nutriment from the medium in which they live. This being the case, the general conclusion drawn by KOFOID, that submerged aquatics are accompanied by a relatively small amount of plankton, is easily understood. For if the plants draw their food from the water, there is less

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[2] POND, RAYMOND H., The biological relation of aquatic plants to the substratum. From U. S. Fish Com. Rep. for 1903.

left for plankton plants; but if these plants draw their food from the soil, they will, through this and their subsequent decay be adding to the material in the water which is available for the plankton organisms. In the discussion is brought out the way in which the work of KOFOID and of POND may be harmonized. In conclusion, the author points out the logical inference that a fish pond should have a good soil at bottom on which plants may grow and flourish, and thus add to the food available for fish. The problem of the relationship of the aquatic animals and plants is so complicated, however, that while the author ought to point out these inferences, less value attaches to the economic conclusions than to the main thesis of the paper. The paper is valuable as being a definite contribution to knowledge on a question which has been hitherto in doubt, and it is the kind of work that is much needed in solving the problems of the plankton. In the absence of just such work as this, much of our plankton literature has been speculative in character; and while there is a real value to be attached to good guessing, in the long run we must have demonstrated facts as the basis of our theories.—C. DWIGHT MARSH.

MISS EASTWOOD[3] has prepared a popular manual of the trees of California, the purpose being to give all the information necessary for identification so compactly that the book may be carried into the field. The numerous plates add greatly to the value of the book, many of them being reproductions of drawings left by Dr. ALBERT KELLOGG. Three keys are provided: the first based upon leaves, the second upon fruits, and the third upon the usual taxonomic characters. The trees of Oregon and Washington also are included, being placed in footnotes in case they do not occur in California. The only new species is *Quercus Alvordiana*.—J. M. C.

THE RELATIONSHIP between Sigillaria and Lepidodendron has been the subject of much discussion, and in connection with it *S. vascularis* and *L. selaginoides* have been prominent species. The identity of the two species has been urged and largely accepted upon evidence obtained from a study of their comparative anatomy. WEISS and LOMAX[4] have now described a specimen consisting of a stem of *S. vascularis* giving off branches of *L. selaginoides*. This demonstration of actual continuity closes the discussion.—J. M. C.

THE TWENTY-FIRST PART of ENGLER'S *Pflanzenreich* is a presentation of the sub-family Pothoideae of Araceae by ENGLER.[5] The sub-families of this family will be published in separate fascicles. Ten genera of Pothoideae are recognized, comprising 581 species, 489 of which belong to the great genus Anthurium, under

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[3] EASTWOOD, ALICE, A handbook of the trees of California. Calif. Acad. Sci. Occasional papers IX. pp. 86. *pls. 57.* 1905.

[4] WEISS, F. E., and LOMAX, JAMES, The stem and branches of *Lepidodendron selaginoides.* Manchester Memoirs **49**: no. 17. pp. 8. *figs. 4.* 1905.

[5] ENGLER, A., Das Pflanzenreich. Heft 21. Araceae-Pothoideae von A. Engler, pp. 330. Leipzig. Wilhelm Engelmann. 1905. *M*16.50.

which 55 new species are described. The next largest genus is Pothos, with 48 species, 5 of which are new.—J. M. C.

Bray[6] has published a description of the "sotol country" in Texas. The sotol is *Dasylirion texanum*, and gives name to characteristic areas of the arid southwest, whose vegetation is largely made up of plants of the cactus, agave, and yucca types. The general vegetation features of the country, the floristic elements, as well as the economic importance of the vegetation are presented.—J. M. C.

Seward has published descriptions of certain collections of fossil plants from Natal,[7] Victoria,[8] and Kashmir.[9] To be able to compare the floras and horizons of these regions with those of Europe and North America is looked forward to with great expectations, and every scrap of definite information is valuable.—J. M. C.

The fourth part of Schneider's *Illustriertes Handbuch*[10] concludes Spiraeaceae, includes Rosaceae, and begins Drupaceae. There are forty-five text figures. The general character and scope of the publication are stated in the notice of the first parts (Bot. Gazette **39**:373. 1905).—J. M. C.

NOTES FOR STUDENTS.

The last paper of Gerassimow[11] brings together concisely the principal conclusions of the interesting series of experimental studies on the cells of the Conjugales which have appeared in recent years. It will be remembered that by subjecting filaments of Spirogyra to a temperature at freezing point, or treating them for a short time to the anaesthetic influence of ether, chloroform, or chloral hydrate, Gerassimow was able to arrest the processes of mitosis at different stages, with the result that the protoplasm may become variously distributed in the daughter cells. (1) A daughter cell may be formed lacking a nucleus, but containing portions of the divided chromatophore in a peripheral layer of cytoplasm. (2) A single cell may contain the two daughter nuclei either separated

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[6] Bray, W. L., Vegetation of the sotol country in Texas. Bull. Univ. Texas no. 60. pp. 24. *pls. 11.* 1905.

[7] Seward, A. C., Report on collections of Natal fossil plants. Second Rep. Geol. Surv. Natal and Zululand. Pp. 97–104. *pls. 4–5.* 1904.

[8] Seward, A. C., On a collection of Jurassic plants from Victoria. Records Geol. Surv. Victoria 13:155–210. *pls. 8–19.* 1904.

[9] Seward, A. C., and Woodward, A. Smith, Permo-carboniferous plants and vertebrates from Kashmir. Memoirs Geol. Surv. India N. S. no. 2. pp. 14. *pls. 8–10.* 1905.

[10] Schneider, Camillo Karl, Illustriertes Handbuch der Laubholzkunde. Vierte Lieferung. Jena: Gustav Fischer. 1905. *M* 4.

[11] Gerassimow, J. J., Ueber die Grösse des Zellkernes. Beih. Bot. Centralbl. **18**:45–118. *pls. 3–4.* 1904.

from one another or more or less intimately associated and perhaps wholly fused, depending upon how far the processes of mitosis have progressed before the cells have been subjected to the shock of the experiment. (3) Binucleate cells may continue their growth with subsequent mitoses, which when treated as before may give daughter cells with three and one nuclei respectively, or with two each or indeed a cell containing four nuclei. Furthermore, these nuclei may fuse with one another to give structures with a greatly increased chromatin content. (4) In place of the non-nucleated cells, there may be formed chambers containing cytoplasm and chromatophores, but without nuclei, which remain in open communication with the nucleated companion protoplast, because the cell wall is not formed entirely across the mother cell.

GERASSIMOW presents the results of his observations on these various types of cells in many elaborate tables and diagrams, with the following chief conclusions. (1) Cells which come to contain unusually large nuclei through the suppression of mitosis, or by the reuniting of partially divided nuclei, increase proportionally in size and their further cell division is postponed. The nuclei of such cells have of course the peculiarity of an increased amount of chromatin content. The large nuclei may later fragment into two or more structures which separate and may come to be at a distance from one another in the cytoplasm. The fragments finally lose their powers of reproduction and exhibit marked evidence of degeneration. (2) Cells which lack nuclei may form starch in the usual manner in the presence of light, and exhibit for a short time a weaker general growth than normal nucleated cells. The power to develop a gelatinous sheath also becomes markedly weakened. Finally there results a decrease in the volume of the cell, a fading of the chromatophore and conditions which lead to eventual death. (3) Chambers which lack nuclei but are in protoplasmic union with nucleated cells may be contrasted sharply with the non-nucleated cells. They exhibit a much stronger growth for a longer time and with a greater power to form starch, although not so marked as in the nucleated cells, and the chromatophores retain their color. There is also a conspicuous development of the gelatinous sheath.—B. M. DAVIS.

CORRENS[12] presents a continuation of his studies on Mirabilis hybrids in which he had found[13] red appearing as a new character in hybrids between two constant races having respectively white and yellow flowers. Instead of assuming, as does TSCHERMAK,[14] that there is a latent allelomorph for red in one or other of these races, and that this is rendered active on crossing, he considers the red color to be a modification of the yellow produced through the activity of a distinct character-unit present in the white-flowered race, the antagonistic characters in

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[12] CORRENS, C., Zur Kenntniss der scheinbar neuen Merkmale der Bastarde. Zweite Mittheilung über Bastardierungsversuche mit Mirabilis-Sippen. Ber. Deutsch. Bot. Gesells. **23**:70–85. 1905.

[13] See BOT. GAZETTE, **37**:77. 1904.

[14] See BOT. GAZETTE **39**:302 and 303. 1905.

the two races being: color *vs.* no color, and no modification *vs.* modification of the yellow color to red. Pigmentation inherited from the yellow parent and the modifying element inherited from the white parent are dominant, giving all red-flowered offspring in the first generation, and rose-yellow-white nearly in the ratio 9:3:4 in the second generation.

The results were further complicated by the presence in the white-flowered race of a nearly latent striping which became active on crossing and behaved approximately as a Mendelian character. The attempt to explain this character on similar grounds as the red color is less satisfactory.

CORRENS[15] has also studied the inheritance of the petaloid calyx in the *calycanthemus*-forms of *Campanula medium* and *Mimulus tigrinus*. The *calycanthemus*-form of the former he finds never produces seed but has good pollen, so that all of the "hose-in-hose" Campanulas are hybrids between the *calycanthemus* and typical forms. The expected Mendelian proportion, DR×R, on the assumption that the hose-in-hose condition is dominant, is in this case 50 per cent. of each, and the result obtained was 44.5 per cent. to 55.5 per cent. hose-in-hose. The recessiveness of the typical form was further shown by the fact that when self-fertilized it produced 97.3 per cent. typical, the expected result being 100 per cent.

In *Mimulus tigrinus* both male and female germ cells of the *calycanthemus*-form are functional and the question of dominance could be more completely tested. It was determined that here also the hose-in-hose perianth is dominant over the normal. As the petaloid calyx is unquestionably a phylogenetically recent character, this result is the reverse of that expected from DEVRIES' law that phylogenetically older characters are dominant over newer. CORRENS suggests that the "higher" character dominates over the "lower," thus making DEVRIES' law apply only to retrogressive characters; but he also calls attention to several cases in which the "higher" character is obviously recessive, *e. g.*, the laciniate leaves of *Chelidonium majus laciniatus*, and the yellow color of flowers in the cross of *Polemonium coeruleum album* with *P. flavum*. As most varieties are retrogressive, the views of CORRENS and DEVRIES would equally fit the facts in a majority of cases.—G. H. SHULL.

ITEMS OF TAXONOMIC INTEREST are as follows: E. L. GREENE (Torreya 5:99–100. 1905) has described 3 new species of Ptelea.—L. M. UNDERWOOD (*idem* 106–107) has described a new Californian species of Botrychium.—B. F. BUSH (Ann. Rept. Mo. Bot. Gard. **16**:87–99. 1905) has revised the N. Am. species of Fuirena, recognizing 8 species, 2 of which are new; has described (*idem* 100–101) 2 new Texan species of Tradescantia; and in conjunction with K. K. MACKENZIE has described (*idem* 102–108) new species from Missouri under Sagittaria, Heuchera, Convolvulus, Dasystoma, Xanthium, and Senecio.—W. W. JONES (Proc. Amer. Acad. **41**:143–167. 1905) has revised the genus Zexmenia,

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[15] CORRENS, C., Einige Bastardierungsversuche mit anomalen Sippen und ihre algemeinen Ergebnisse. Jahrb. Wiss. Bot. **41**:458–484. 1905.

recognizing 42 species, 6 of which are new.—C. H. KAUFFMAN (Bull. Torr. Bot. Club **32**:301–325. *figs. 7.* 1905) has published a preliminary study of the genus Cortinarius, illustrated by half-tones from excellent photographs, in which, after a full description of the structure of the various parts, 7 new species are described.—E. L. GREENE (Pittonia **5**:205–308. 1905) has published a revision of Eschscholtzia, recognizing 112 species, 88 of which are new, thus breaking up what seems to have been a great aggregate of species collected under a few names; has published *Petromecon* as a new genus of Papaveraceae from Guadalupe Island, founded on *Eschscholtzia Palmeri* Rose and containing a new species; has presented a synopsis of Dendromecon, recognizing 17 species, 14 of which are new; and has suggested an extension of species under Sanguinaria by separating 4 new species from what has been treated as a monotypic plexus.—C. A. M. LINDMAN (Arkiv. Bot. K. Svenska Vetensk. **3**: no. 6. pp. 14. *figs. 10.* 1904; rev. in Bot. Centralbl. **98**:659. 1905) has published a new genus (*Regnellidium*) of Marsiliaceae from southern Brazil, which combines certain features of the two other genera with characters of its own.—M. L. FERNALD (Rhodora **7**:129–136. 1905), in continuing his presentation of the N. Am. species of Eriophorum, has discussed the generic status of Eriophorum and the status of the names *E. Chamissonis* and *E. Callitrix*.—J. M. C.

FITTING'S[16] full paper has recently appeared; an abstract of his preliminary report may be found in the January GAZETTE of this year. It is difficult to find an unnecessary paragraph among the one hundred seventy-five pages of this notable paper. Considerable ingenuity is displayed and this accounts for the author's success in reaching a much closer analysis of geotropic phenomena. Part I contains eight chapters exclusive of introduction and recapitulation. Description and explanation of apparatus constitute the first chapter. Elaborate cuts and diagrams contribute to a very clear presentation. Particularly satisfying is the second chapter, because here is answered the very fundamental and much controverted question of optimum position. CZAPEK'S answer of 135° deviation from position of normal equilibrium is proven incorrect, and the horizontal position of 90° deviation is demonstrated to be the optimum position for the plants tested. The variety of the latter is great enough to make a general statement for parallelotropic organs very probable. Positions at equal angles above or below the horizontal afford equal stimulation. The latter conclusion has already received confirmation in that the contrary conclusion of NEWCOMBE has been withdrawn, and evidence presented by him to support the author. Moreover the intensity of stimulation as determined by position varies approximately as the sine of the angle of deviation. In Part II the investigation endeavors, on the basis of demonstrations in Part I, to penetrate further the complicated processes involved in perception and response. Admirable caution is here manifest, a clear discrimination between demonstration and probability being maintained. The author

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[16] FITTING, HANS, Untersuchungen über den geotropischen Reizvorgang. Teilen II. Jahrb. Wiss. Bot. **41**:221–398. 1905.

is inclined to regard sensitiveness to gravitation far greater than hitherto supposed, even as much as to light. It is not at present considered possible to determine the time required for an organ to recover from stimulation, since the autotropic straightening merely indicates expiration of reaction. Other important conclusions are stated in the abstract mentioned.—RAYMOND H. POND.

NUCLEAR DIVISION in *Fritillaria imperialis* has been studied by SIJPKENS,[17] who uses a somewhat novel method. Material is fixed in Flemming's stronger solution for three weeks, after which it is thoroughly washed in water and run up to 96 per cent. alcohol. A piece of parietal endosperm with its nuclei is now brought into 6 per cent. celloidin, where it is kept an hour or so longer, care being taken not to let the celloidin become hard. With a pipette the piece with some celloidin is taken up and placed upon a cover glass where the celloidin flows out, forming a delicate film, which in a few minutes becomes rather tough. The film is moistened with 96 per cent. alcohol until it is easily separated from the cover. Stain in gentian violet, clear in origanum oil for two hours, imbed in paraffin, and cut sections about 2μ in thickness; then stain again in gentian violet.

Another method was also used. A piece of the parietal endosperm was brought into a drop of 50 per cent. chromic acid, which soon dissolves the protoplasm away from the nuclei. The nuclear membrane itself dissolves soon after, leaving only the chromatic network, which is washed in water and then stained with gentian violet.

From a study of such preparations SIJPKINS concludes that the reticulum of the resting nucleus is an anastomosing network with thick, irregular knots. There is no linin thread, with chromatin granules, but the network is a homogenous structure. The spindle arises inside the nucleus from protoplasm which has pressed into the nuclear cavity after the dissolution of the nuclear membrane. The threads reaching from pole to pole are formed first, the mantle fibers appearing later.—C. J. CHAMBERLAIN.

WITHOUT "hungering" for priority, FISCHER[18] shows wherein the theory of "blütenbildenden" substances, recently presented by LOEW, agrees closely with the author's view earlier expressed. Since neither LOEW nor the author have offered evidence more than enough to make the theory a rational hypothesis, the most important point to notice here is that the speculations of two independent writers lead to the same theory. The author's analysis is closer in that three kinds of *blütenbildenden* substance are distinguished, namely: *Formstoffe*, whose presence determines the habit or architecture of the plant; *Reizstoffe*, whose relative amount induces a tendency to reproduce at the expense of vegetation or *vice versa*. With SACHS, *Formstoffe* and *Reizstoffe* were identical; while accord-

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[17] SIJPKENS, B., Die Kernteilung bei *Fritillaria imperialis*. Recueil des travaux. Bot. Neerl. no. 2. (repaged) pp. 58. *pls. 4–6.*

[18] FISCHER, HUGO, Ueber die Blütenbildung in ihrer Abhängigkeit vom Licht und über die blütenbildenden Substanzen. Flora **94**:478–490. 1905.

ing to LOEW the latter would correspond to the author's *Baustoffe*, by which is understood substances which cause a differentiation of tissue, as into vegetative and reproductive. Such *Reizstoffe* arise or become governing under abnormal conditions and imply a disturbed equilibrium in the plant; while *Baustoffe* are normally active. Thus to an excess of carbohydrates caused by conditions favorable to photosynthesis (abundant light and little moisture), but unfavorable to vegetation (reduced absorption), the author attributes an overproduction of flowers.—RAYMOND H. POND.

THE ADDRESS GIVEN by Professor GOEBEL last year at the Congress of Arts and Science in St. Louis has been translated by Professor F. E. LLOYD and published in *Science*.[19] The subject was an assigned one, but could not have been more appropriate to the man and the occasion. The time was limited, so that the speaker was able only to outline rather than to develop his ideas; but the paper contains a statement of the relations between the old or formal morphology, phylogenetic morphology, and experimental morphology, from the standpoint of one of our most philosophical botanists, that will be illuminating and suggestive to many. All of the speaker's views may not be accepted by all, but that he has indicated the most needed direction of morphological investigation in the immediate future can hardly be doubted.—J. M. C.

BOLLEY[20] has announced that he has at last established definitely the fact that the uredospores of a number of rusts, including those of *Puccinia graminis*, can endure the winter uninjured. They were found successfully surviving upon dead leaves, dead straw, etc.; those of *P. graminis* remaining unimpaired when exposed to the driyng winds of autumn and to the intense cold of a North Dakota winter. The uredospores of *P. rubigo-vera* were found wintering freely in Mississippi, Texas, Illinois, Minnesota, and North Dakota, both upon living matured leaves and straw. The inference is drawn that although the aecidium stage may be a physiological necessity for the perpetuation of the species, its annual recurrence is not a necessity.—J. M. C.

COCKAYNE[21] has studied the vegetation of the Open Bay Islands, two small islands three nautical miles from the coast of New Zealand (South Westland). The most important vegetation consists of thickets formed by lianes. The conclusion is reached that "when attached to the mainland the present islands must have been occupied by subtropical evergreen rain-forest similar to that now existing on the adjacent coast. After separation, as the area of the islands became smaller and smaller, and the climatic conditions more and more severe, only those plants specially adapted to such conditions could survive, and of these certain of

---

[19] GOEBEL, K., The fundamental problems of present-day plant morphology. Science N. S. **22**:33–45. July 14, 1905.

[20] BOLLEY, HENRY L., New work upon wheat rust. Science N. S. **22**:50–51. 1905.

[21] COCKAYNE, L., Notes on the vegetation of the Open Bay Islands. Trans. N. Z. Inst. **37**:367–375. *pl. 23.* 1905.

the lianes, although most highly specialized forest plants, are the most suitable.—J. M. C.

RAMALEY[22] has continued his comparisons of the anatomy of cotyledons with that of leaves by giving an account, with illustrations, of the "foliaceous" cotyledons of eight species of tropical plants: *Jatropha curcas, Manihot glaziovii, Eriodendron anfractuosum, Bombax malabaricum, Couroupita guianensis, Ipomoea coccinea, Solanum quitoense,* and *Cosmos bipinnatus.* The conclusion is reached that these observations confirm the author's view, previously published, that cotyledons and leaves "are not really of the same nature."—J. M. C.

UNDERWOOD[23] has done good service in working out the itinerary of CHARLES WRIGHT's three explorations of Cuba. His sojourn in Cuba covered a period of nearly ten years, 1856 to 1867; but his travels were confined chiefly to the two ends of the island, leaving the great central portion largely unexplored.—J. M. C.

SHELDON[24] has announced that as a result of cultures and inoculations he has reached the conclusion that in all probability the bitter rot of the apple, the ripe rot of the grape, and the anthracnose of the sweet pea are caused by the same fungus.—J. M. C.

THE FULL PAPER by SCOTT[25] on a new type of strobilus in Sphenophyllum has appeared. A notice of the preliminary announcement, containing a summary of the results, was published in BOT. GAZETTE **39**:76. 1905.—J. M. C.

CHRYSLER[26] has shown that through the agency of man in planting conifers upon a bare area at Woods Holl, Mass., the second stage in reforestation—that of the oaks—has been nearly attained in fifty years.—J. M. C.

RECENT FLORISTIC PAPERS are those by KRAUSE[27] on the flora of Aden; and by VAHL[28] on the flora of the Madeiras.—J. M. C.

---

[22] RAMALEY, FRANCIS, A study of certain foliaceous cotyledons. Univ. Colorado Studies **2**:255–264. *figs. 42.* 1905.

[23] UNDERWOOD, LUCIEN M., A summary of Charles Wright's explorations in Cuba. Bull. Torr. Bot. Club **32**:291–300. *map.* 1905.

[24] SHELDON, JOHN L., Concerning the identity of the fungus causing an anthracnose of the sweet pea and the bitter rot of the apple. Science N. S. **22**:51–52. 1905.

[25] SCOTT, D. H., On the structure and affinities of fossil plants from the palaeozoic rocks. V. On a new type of sphenophyllaceous cone (*Sphenophyllum fertile*) from the lower Coal-measures. Phil. Trans. Roy. Soc. London B. **198**:17–39. *pls. 3–5. figs. 3.* 1905.

[26] CHRYSLER, M. A., Reforestation at Woods Holl, Massachusetts—A study in succession. Rhodora **7**:121–129. *pls. 62–63.* 1905.

[27] KRAUSE, K., Beiträge zur Kenntniss der Flora von Aden. Engler's Bot. Jahrb. **35**:657–662. 1905.

[28] VAHL, M., Ueber die Vegetation Madeiras. *Idem* **36**:253–349. 1905.

NEWS.

DR. F. W. T. HUNGER, Buitenzorg Botanic Garden, goes to the University of Utrecht.

THE DUTCH CROSS of Orange and Nassau has been conferred upon Professor Dr. JULIUS WIESNER.

PROFESSOR DR. G. HABERLANDT has been elected a foreign member of the Linnaean Society of London.

DR. GEORGE T. MOORE has resigned his position as physiologist and algologist in the Department of Agriculture.

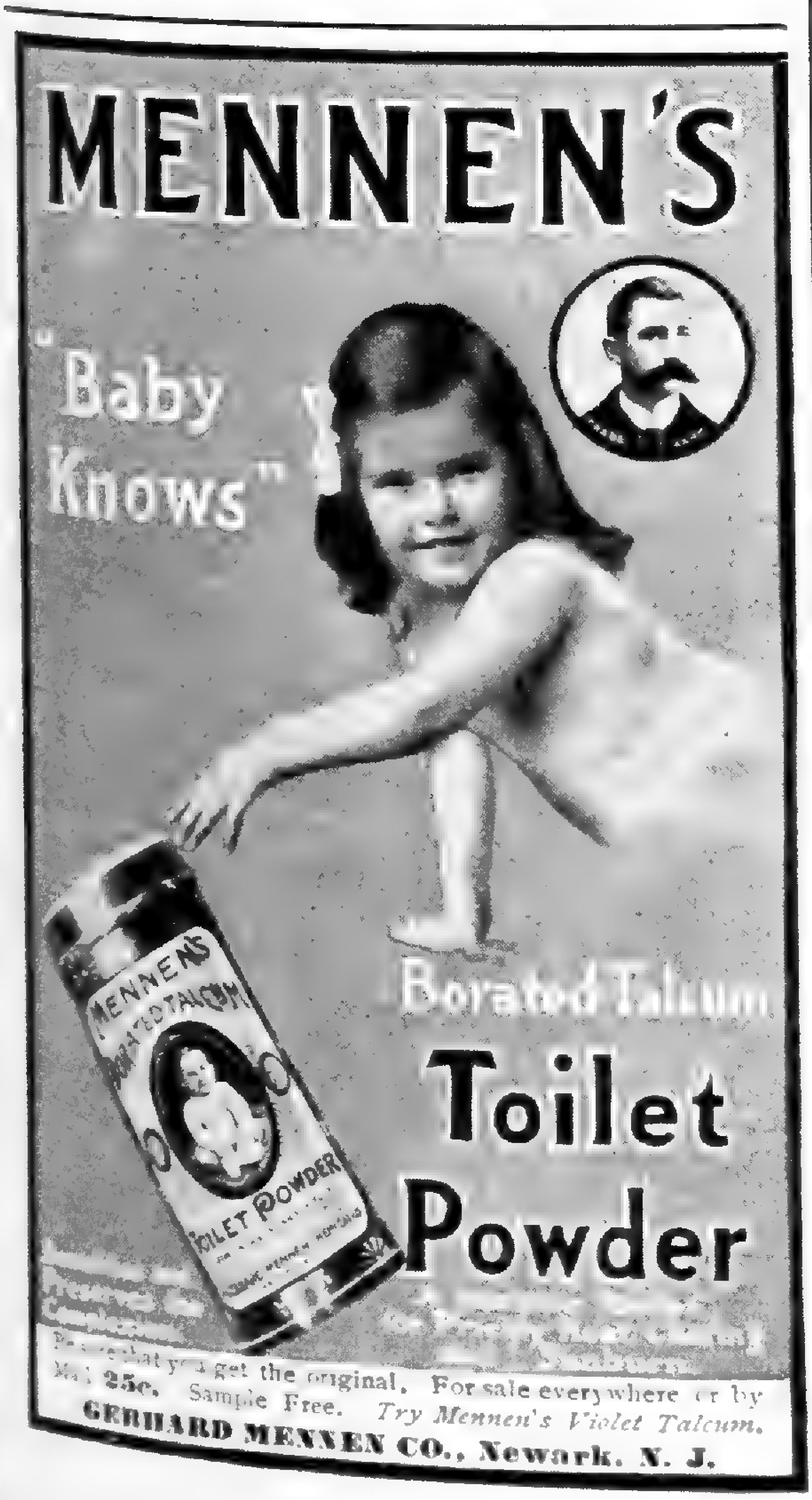
DR. E. ZEDERBAUER, formerly of the Botanical Institute of the University of Vienna, has been appointed assistant at the Royal Forestry Experiment Station in Mariabrunn near Vienna.

PROFESSOR DR. R. V. WETTSTEIN has been chosen president of the "Association Internationale des Botanistes" for three years. He has also been elected a member of the Royal Academy of Science in Madrid and of the Royal Physiographic Society in Lund.

THE HEIRS of Professor Dr. EUGEN ASKENASY have set aside a fund of 10,000 marks, the interest of which is to be devoted to "study-travels" of the members of the faculty of the University of Heidelberg, especially to the insufficiently paid docents, older doctors, or students of the colleges. The grants are to alternate regularly between botany and zoology.

THE PRUSSIAN ROYAL ACADEMY OF SCIENCE has made the following grants for botanical investigation: to Professor ENGLER for continuing work upon *Das Pflanzenreich*, 2,300 marks; to Dr. E. BAUER, for investigations on hybrids, 600 marks; to Professor Dr. H. GLÜCK, for the publication of a work entitled *Biologische und morphologische Untersuchungen über Wasser- und Sumpfgewächse*, 640 marks.

BIOGRAPHICAL SKETCHES of deceased members of the Deutsch. Bot. Gesells. appear in the *Berichte* (**22**: 10–83. 1905) as follows: A. MILLARDET by P. MAGNUS; JOSEF FREYN by V. SCHIFFNER; FRANÇOIS CRÉPIN by L. ERRERA; MAXIMILIAN WESTERMAIER (with portrait) by S. SCHWENDENER; KARL HAUSSKNECHT by B. HERGT; W. J. BEHRENS by ERNST KÜSTER; AUGUST GARCKE by H. ROTTENBACH; KARL SCHUMANN by G. VOLKENS; M. STAUB by J. BERNÁTSKY; RUDOLF AMANDUS PHILIPPI by KARL REICHE.

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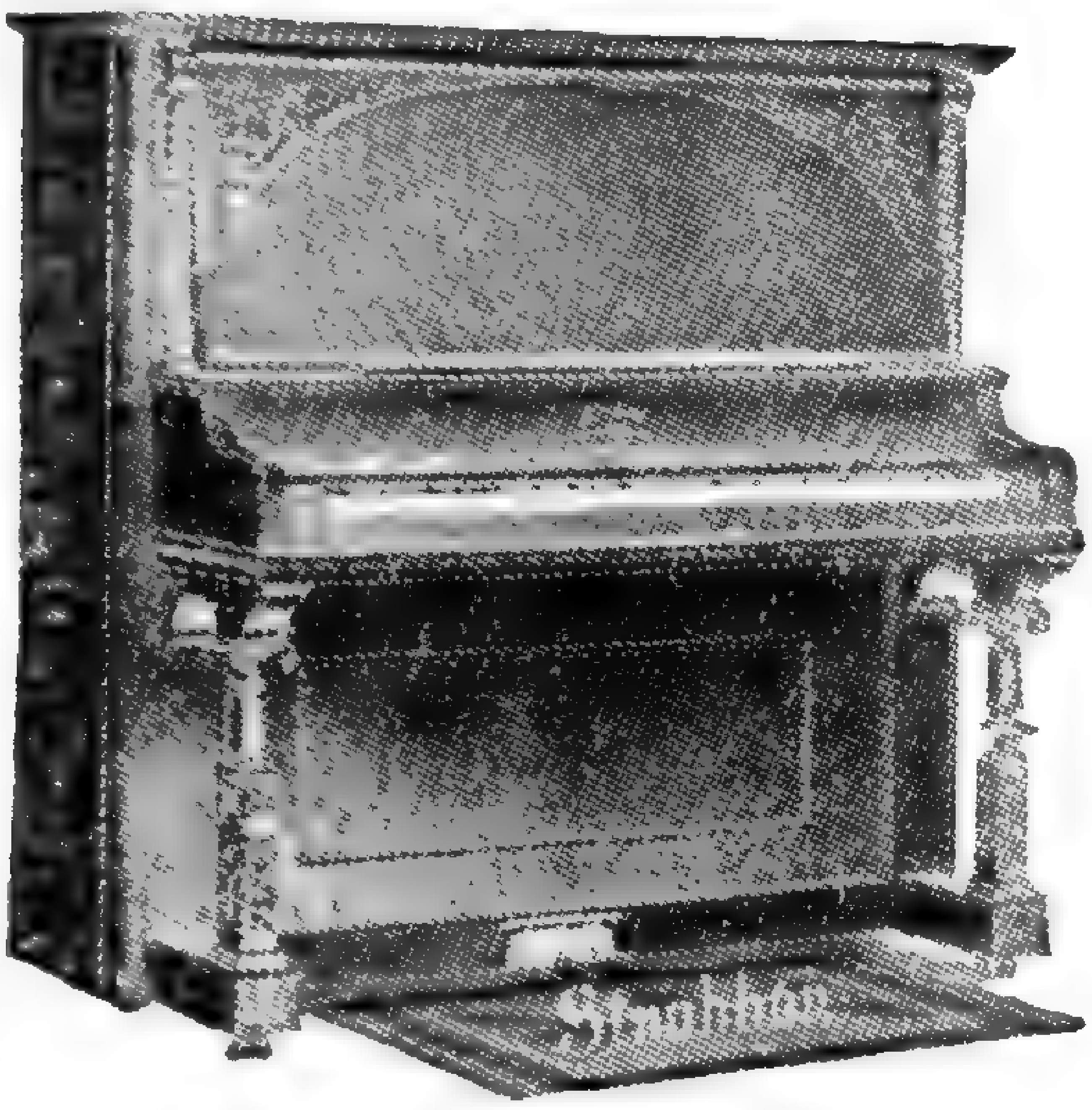

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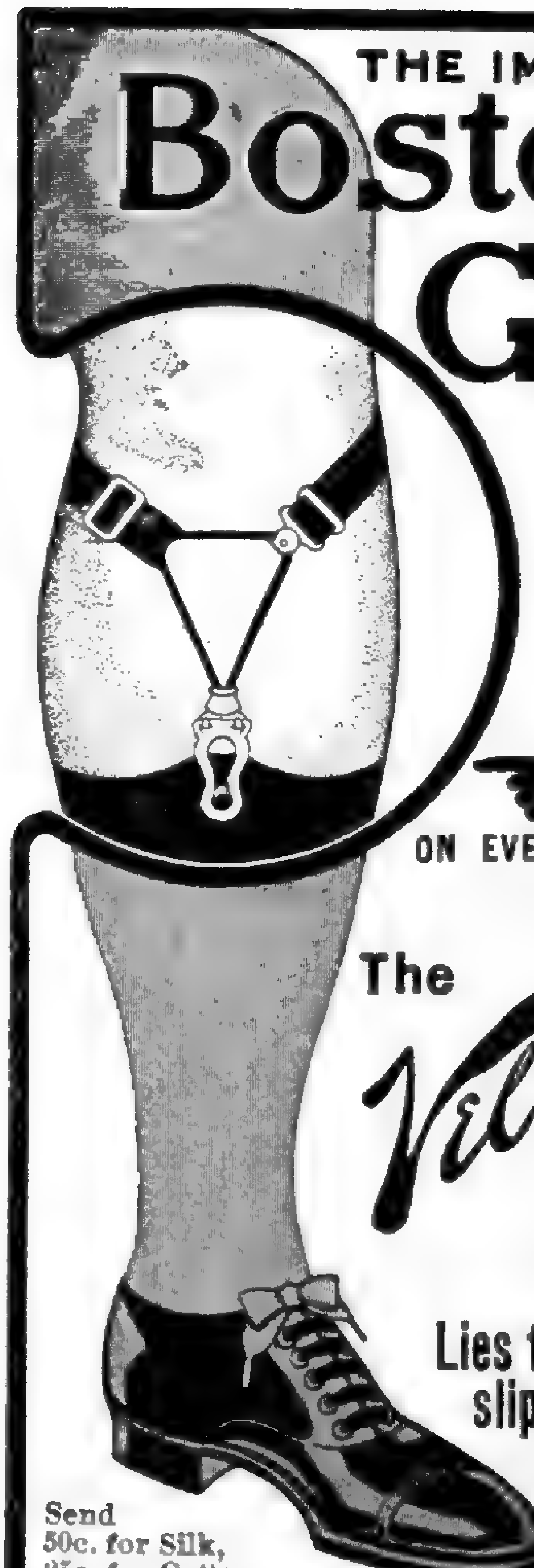

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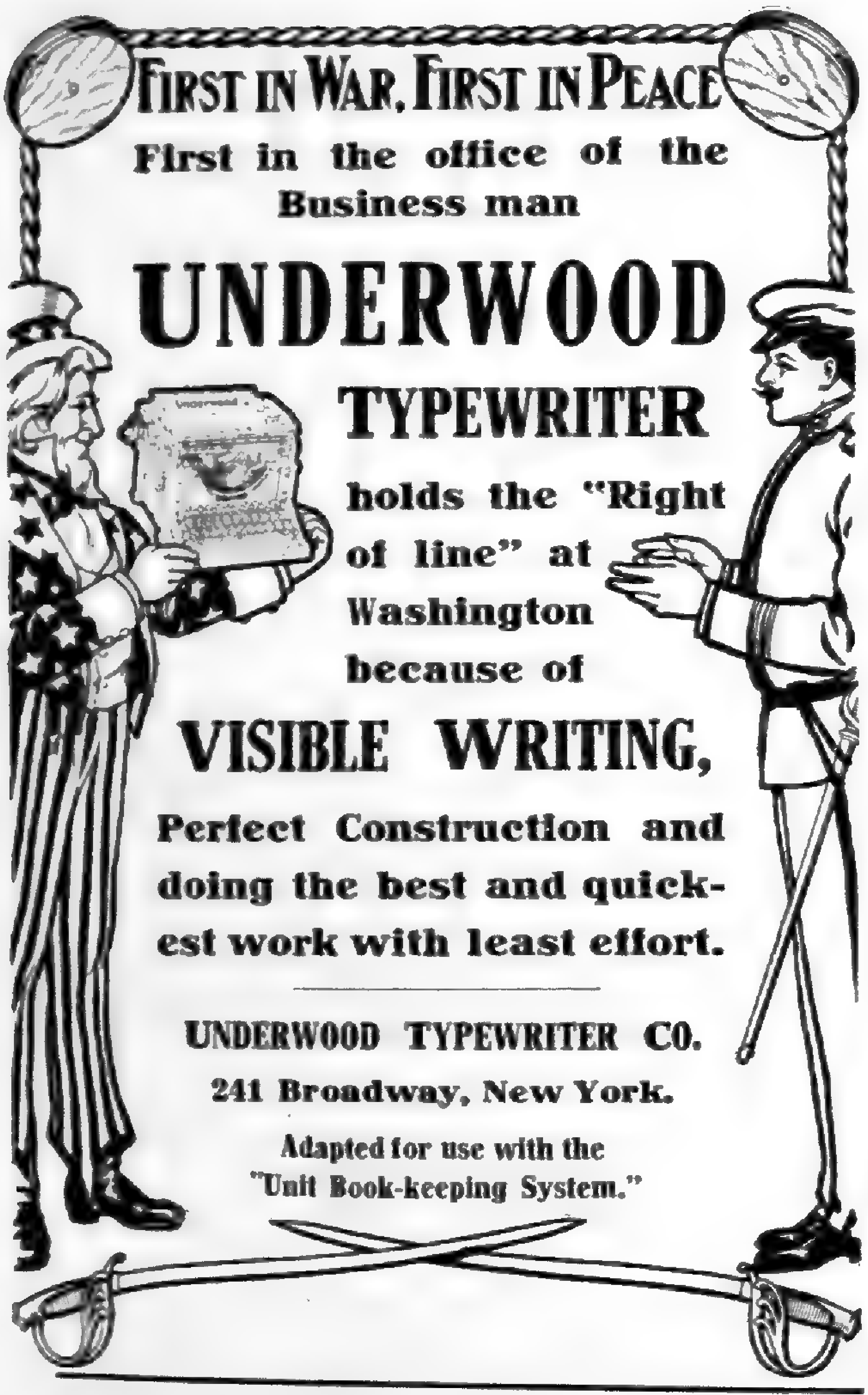

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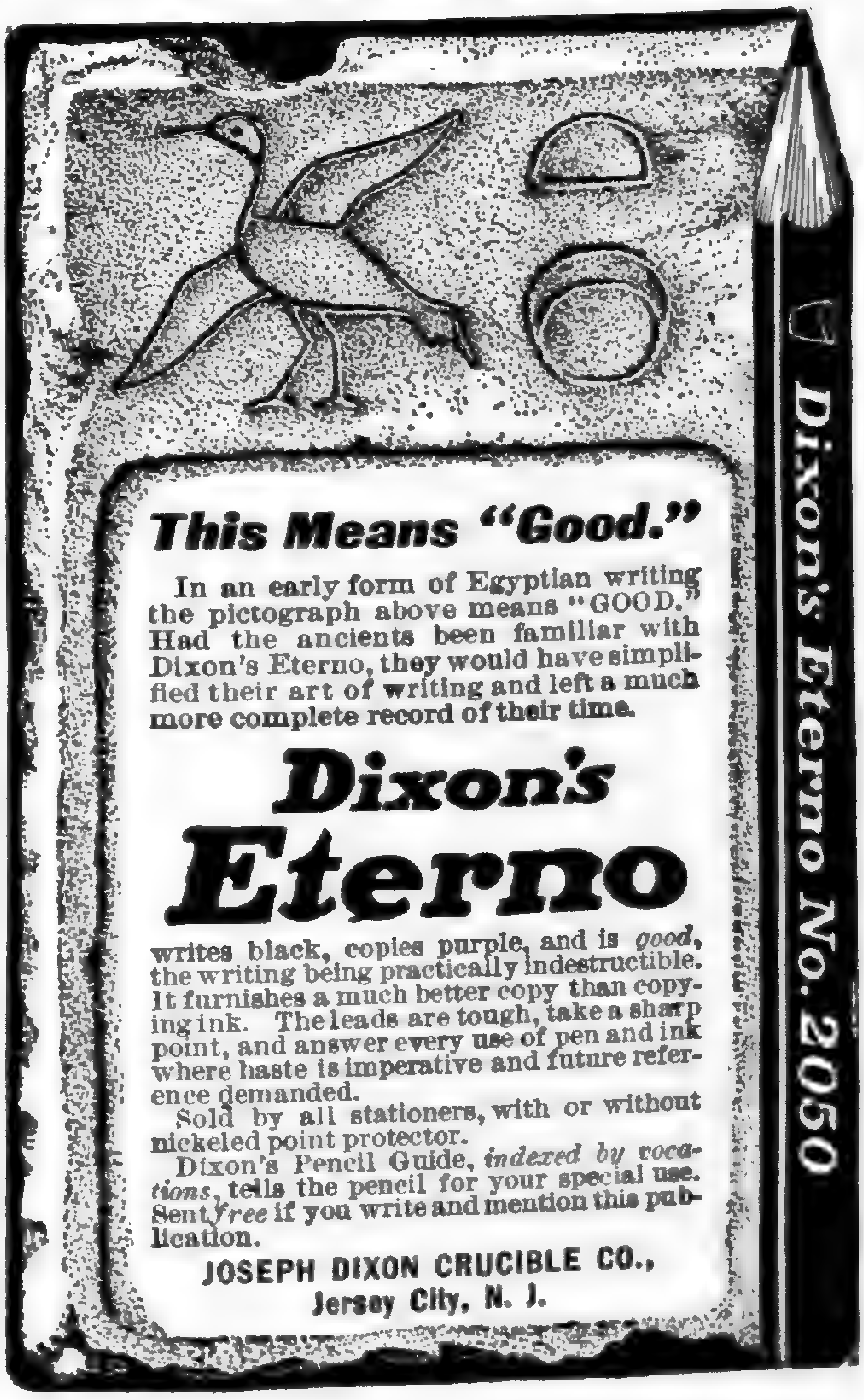
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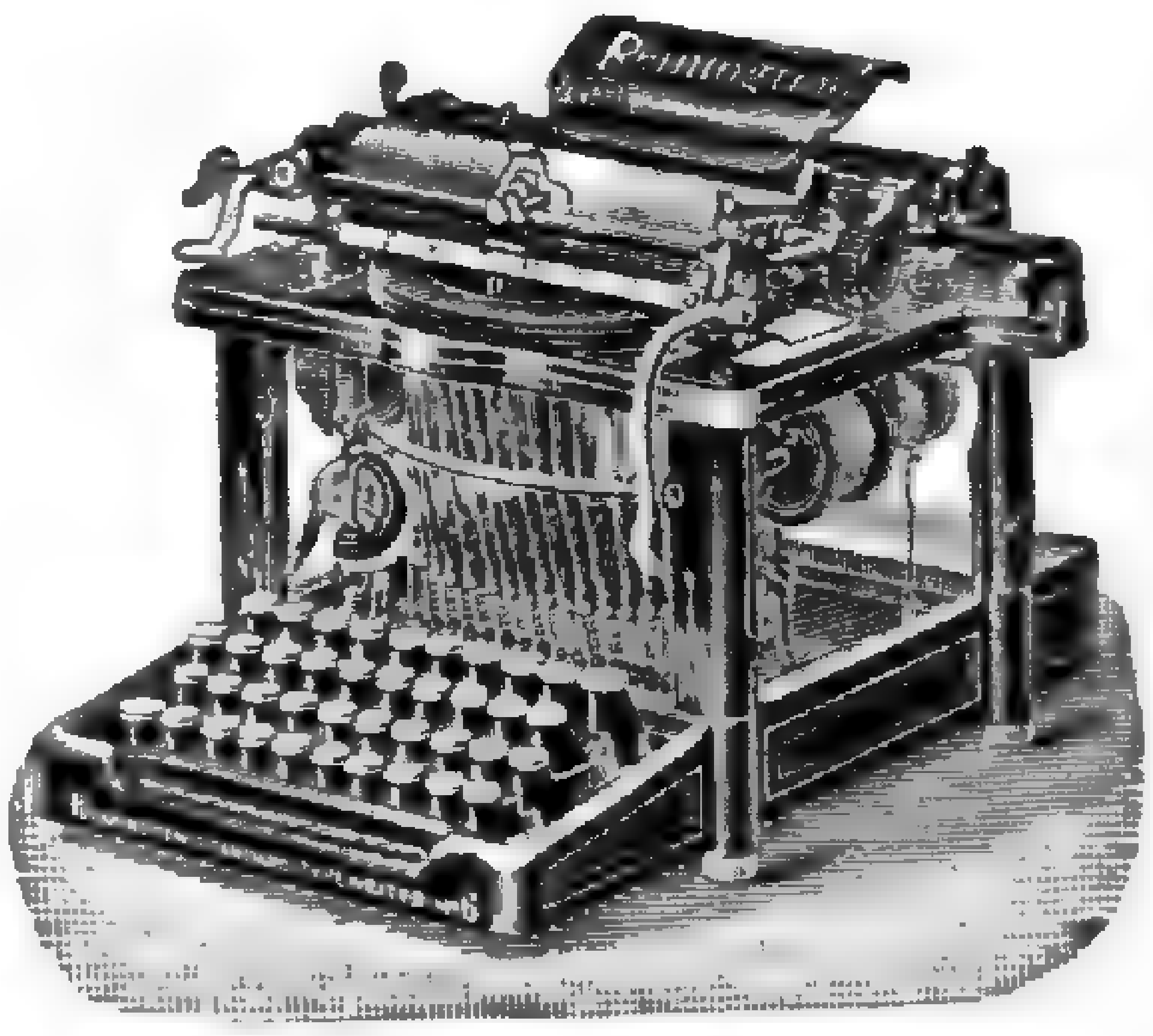

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THE BOTANICAL GAZETTE

October, 1905

Editors: JOHN M. COULTER and CHARLES R. BARNES

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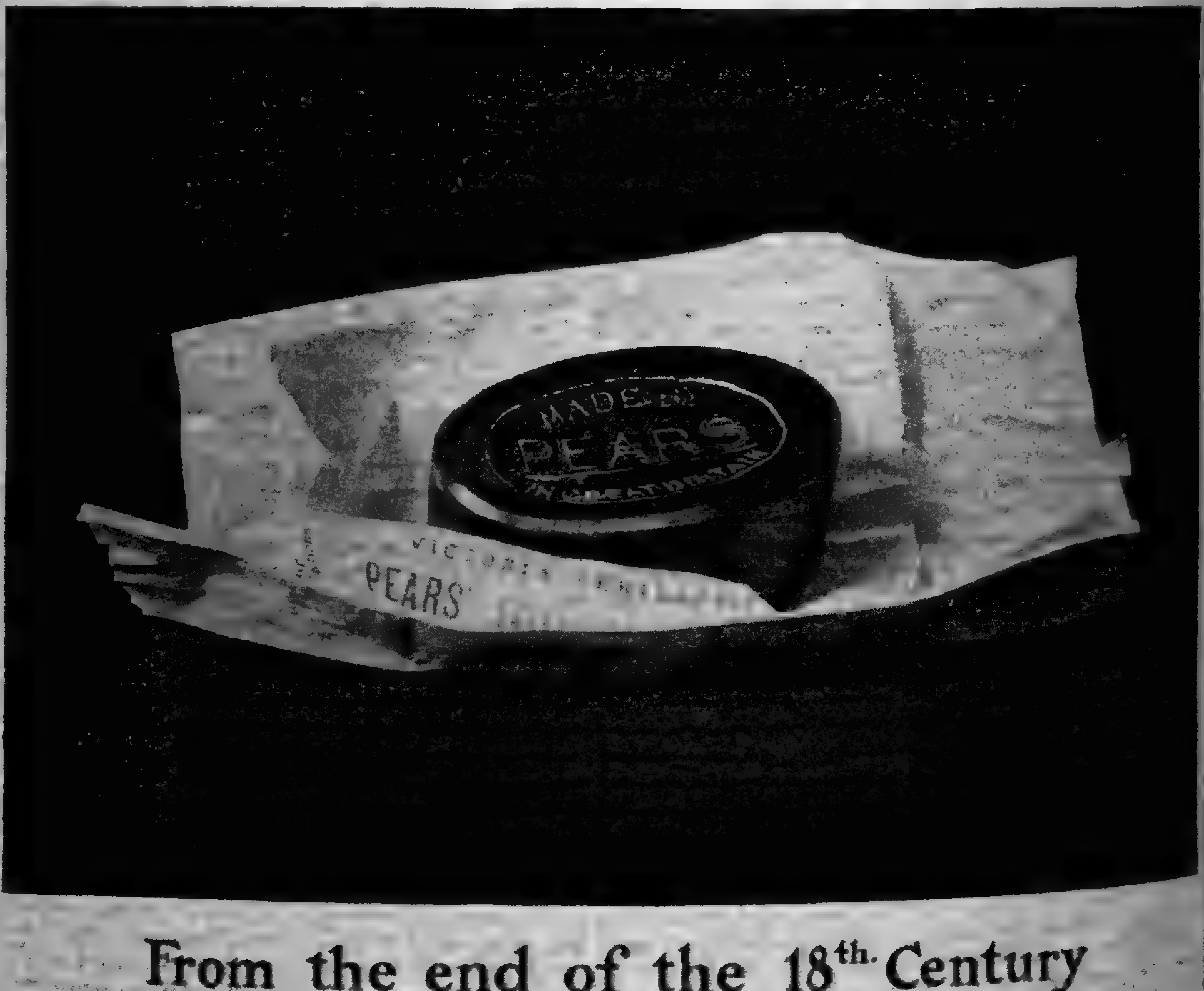
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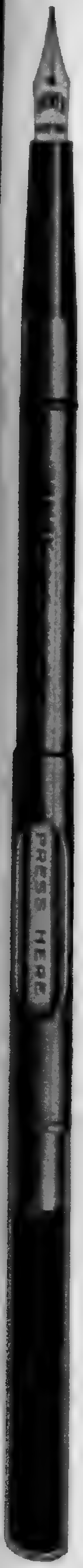

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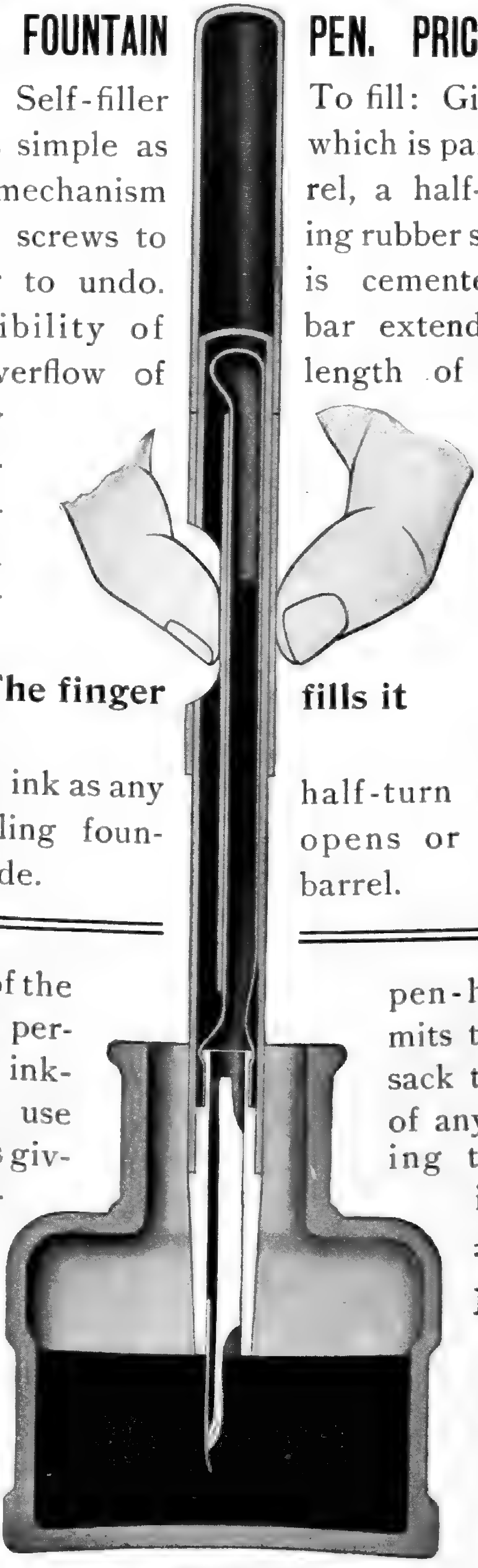

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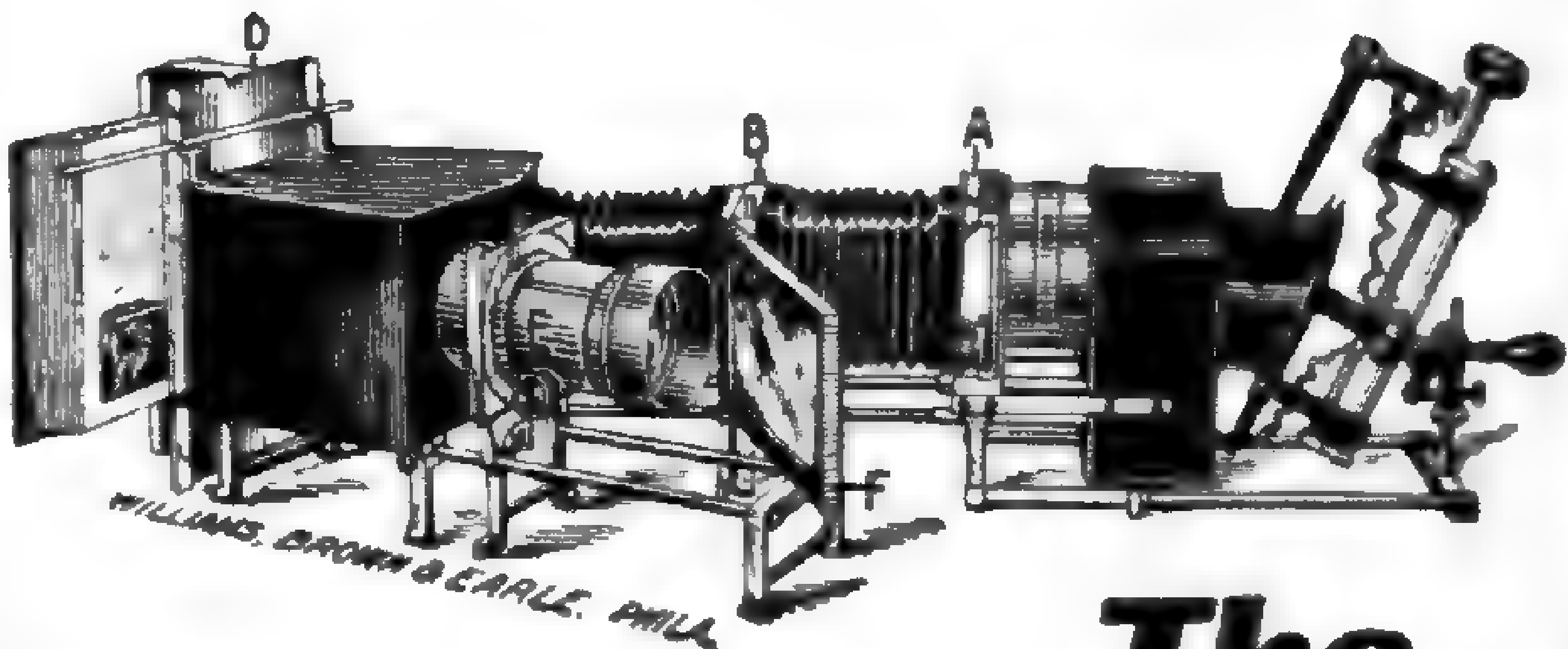
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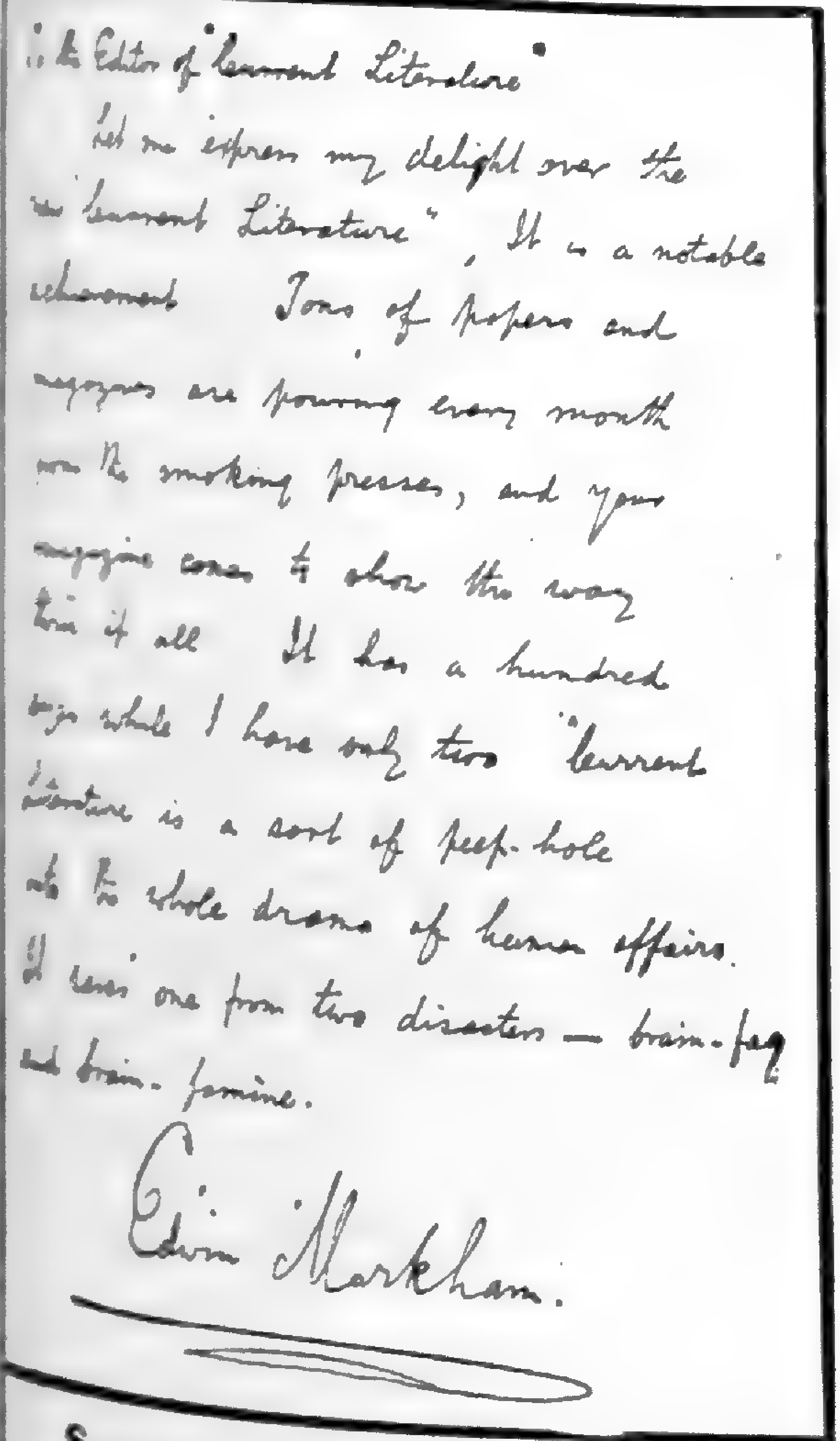

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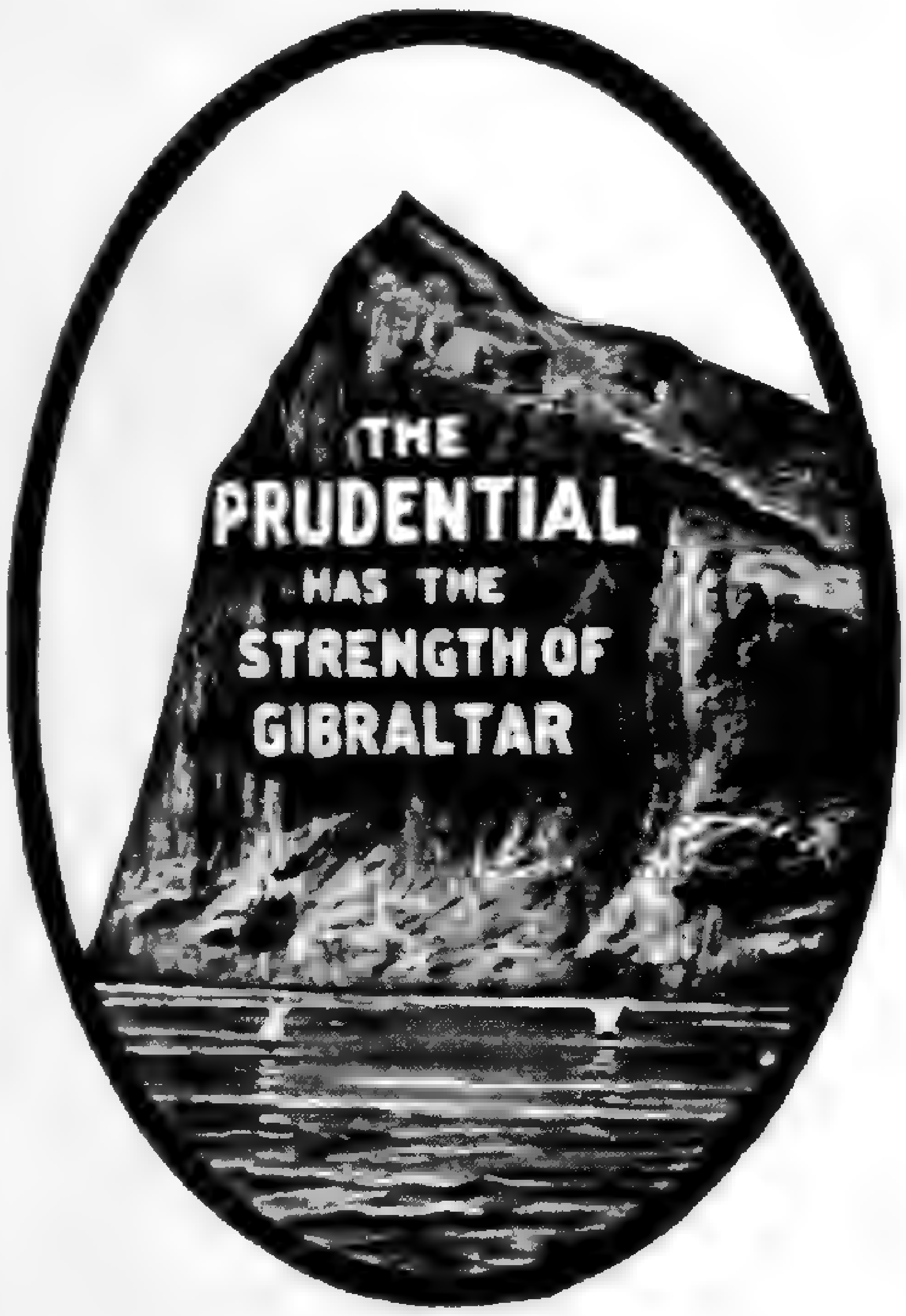
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VOLUME XL NUMBER 4

BOTANICAL GAZETTE

OCTOBER, 1905

REGENERATION IN PLANTS. II.[1]

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXIX.

WILLIAM BURNETT MCCALLUM.

(WITH NINE FIGURES)

WOUND STIMULUS.

THE influence of the wound has been put forward many times, either as the direct cause, or as an important factor in regeneration. WIESNER (**19**) has suggested that between the wounded part and the new structure formed there is a direct causal connection, due to substances developing in the wounded cells and passing to other parts, there inciting the reversion of mature cells into the meristematic condition. GOEBEL (**4**, p. 204) also believes the wound stimulus to be a factor. KLEBS (**9**), on the other hand, rather discredits this idea and thinks that the wound in itself is of no importance in regeneration. The possibility of the wound having a far reaching influence is not at all improbable, for many well-known cases of traumatropism show how cells may be affected at a distance from those actually concerned in the wound. Of the many experiments to determine if such an influence is operating, only a few need be mentioned, and in these cases only the results will be given.

It was seen that with Phaseolus the removal of the stem above the basal primordia is followed by the development of the latter. The removal of the cotyledons, while causing wounds still closer to the young bud, produces no such development; nor does the severing of the stem as close as possible below the primordia. Wounding the stem by cutting notches immediately above the primordia, as

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[1] The first paper was published in BOTANICAL GAZETTE **40**:97–120. 1905.

deep as four-fifths through the stem, has no influence. String was tied tightly around young stems, just above the primordia, and as the stems grew the string cut in deeply on all sides; no results followed. Longitudinal slices, the length of the epicotyl and three-fourths through the stem, produced no results.

Experiment 38.—Notches cut at different points in a spiral around the stem, so that all the bundles were severed, failed to incite the buds below.

Experiment 39.—Five plants 70–100^{cm} high, 6–9 internodes long, and with lower internodes old and hard were used. The tip of each plant was cut off and also the buds from all the nodes below. In three plants the basal primordia produced shoots; one plant died; and the others remained alive, but no shoots formed. Here the wound effect, if there was such, traveled through a distance of nine internodes. A wound, however severe, seems unable to cause the buds to develop if it does not include the complete removal of the growing apex; and even on a large plant the removal of the very tip is all that is necessary. Here, as in the willow and other plants (see experiment 43), the effect of the wound passes only down the stem; a wounding or a complete severance at any point along the stem has no effect on the buds above this point. As will be brought out later, the opposite is true of the roots; that is, the influence of the removal in inciting new roots only passes upwards. This would hardly be true if it were due to the diffusion of substances formed in the wounded cells, as WIESNER supposes. GOEBEL (**5**) has found that in Bryophyllum no wounding at all is needed to produce shoots on the leaves. He encased all the buds on the shoot in plaster so as to prevent further growth, and after a time the buds on the leaves developed. If the leaf blade of Cyclamen is cut off new leafy structures arise along the margins of the petals. But WINKLER (**19**) has shown that this removal is not necessary. He left the blades intact, but incased them in plaster, and soon the leaf-like outgrowths appeared as when the blade was removed. The blade was not injured or wounded in any way by this treatment, though undoubtedly some of its activities were suppressed.

As will be described in experiment 40, I inhibited the growth of the apex of Phaseolus by placing it in a hydrogen atmosphere. The basal primordia in the air below promptly developed. When the hydrogen was removed, the apex continued growing. Placing the roots in plaster, which inhibited any further growth on their part, also resulted in the development of roots along the stem. In these cases there was no wounding anywhere. It appears that while regeneration follows the removal of certain parts, neither this removal nor the wound incident to it are necessary, since the regeneration occurs equally well when the part is left uninjured and certain of its activities suppressed. The wound, therefore, is not in itself any part of the stimulus.

CORRELATION.

By correlation is meant the influence which one organ or part may exert over another. That the removal of certain parts leads to changes within the plant that may modify markedly the growth or function of other structures is a matter of common observation. Examples of this interdependence among the different members of the plant body are abundant. JOST (**8**) has shown that in Phaseolus the mere presence of the leaf is a necessary condition to the development of the bundles of the leaf trace. PISCHINGER (**16**) determined that if the large cotyledon of Streptocarpus be removed the small functionless one will develop into a large one. According to GOEBEL (**6**, p. 809) the early removal of foliage leaves induces the bud scales to develop into the foliar structures. If the upper end of a Taraxacum root be cut away, removing all the buds, new buds soon arise from the cortex below; this is true of many roots. IRMISCH and others (**10**) have shown in many species that if seedlings be cut off below the first node, new buds arise out of the tissue of the hypocotyl. The removal of the growing tip on many shoots is followed by the development of the dormant axillary buds. As is commonly observed in cultivation, if the lateral roots be destroyed, their place is taken by new roots, which otherwise would not have developed. GOEBEL (**2** and **5**) showed that in Begonia and Bryophyllum, and this is probably true for many other plants, the removal of all the buds on the shoot will result in the development of buds on the leaves.

The process by which such an influence is exerted by one part over another is the main problem to be solved in regeneration. GOEBEL attempts to explain it in one of two ways: either (1) the one part monopolizes the nutritive material to such an extent that the other parts concerned cannot obtain sufficient to enable growth to go on; or (2) he applies SACH'S *Stoff-form* hypothesis. According to this (**17**), there are formed in the plant small quantities of different substances, presumably of enzyme-like nature, each one having the capacity to incite the formation of a definite structure. These substances are supposed to move in definite directions, and where they accumulate in sufficient quantities start the development of the particular structure they are concerned with. In GOEBEL'S opinion (**4**, p. 204) the influence of external conditions are of little account in regeneration, the important cause being "the direction in which the constructive material moves." GOEBEL says (**3**, p. 42) "the vegetative points act as centers of attraction for the plastic material, their influence being stronger or weaker according to their position." In Bryophyllum, for example, the apex of the shoot is the strongest, then the lateral buds, and last of all the vegetative points on the leaves; so that the apex is able to draw to itself the greater part of the "constructive material;" but if this apex is removed, the lateral buds will be able to "attract" this substance; and in the absence of these lateral buds, the growing points on the leaf are able to appropriate it. In Begonia no growing points are present on the leaf, but when it is removed GOEBEL says bud-forming material accumulates at the base and induces the formation of buds there. If this material, formed in the leaves, moves toward the base of the leaf and passes out because it is "attracted" by the growing points on the stem, just why it should continue to flow in that direction and accumulate at the base, when all connection with these "centers of attraction" is broken, is one of the unexplained difficulties that beset this hypothesis on every hand. MORGAN (**12**) has strongly objected to this theory, but his evidence against it does not seem to me to be necessarily fatal. GOEBEL in a recent paper (**5**) is inclined to lay less stress on it than formerly, asserting that the non-development of the buds on the leaves is due to a checking influence exerted by the buds of the shoot; "but," he adds, "whether we are here dealing with a stimulus transmitted along the conducting system, or whether the building material (*Baustoffe*) flowing in the conducting channels is attracted more strongly by the shoot vegetative points than by those on the leaves remains uncertain."

Driesch (**1**), who has worked on animals more than on plants, recognizes in correlation the dominant factor in regeneration, and claims that the absence (*Nichtmehrvorhandensein*) of the one part is the cause of the development of the other. The plant, according to him, is not influenced in regeneration by external factors, but being sensitive to something lacking endeavors to replace it. Somewhat analogous to this is **Noll**'s idea (**14**) of a body-forming stimulus (*Körperformreizen*), by which he implies that there is an innate impulse in the organism toward a definite form, and when a part is removed the resulting disturbance (*Formstörung*) acts as a stimulus to the reconstruction of the whole.

Such hypotheses as these are at present as incapable of demonstration as they are of refutation, and can only serve a useful purpose if they form the starting point for experimentation. Unfortunately they can scarcely be said to do that. Quite different from these is the view held by **Klebs** (**9**, p. 109), who believes that the removal only serves to bring about those conditions, such as accumulation of moisture, changes of a nutritive nature, etc., which would under all other circumstances cause a similar development. To take a specific case, the normal absence of roots on the stems of Salix, **Klebs** says, is due to the retarding influence of light, of dry air, and to the fact that the water is being used by the leaves and young parts. When these conditions are supplanted by those of moist air and abundance of water, the roots develop quite independently of any removal or wounding. The experimental evidence that follows shows, however, that the problem is much more complicated than this.

The experiments described have shown the dependent relation that exists between the growth of the apex and the non-development of the buds below. On Phaseolus the basal primordia do not develop so long as there are buds above them developing. Indeed, only one bud is sufficient for this; for if the upper part be cut away and all the buds but one be removed, the basal buds do not start.

Experiment 40.—The stems were cut off at the second internode, and the buds from one side of the base of this were removed; and in some cases not only the bud but the leaf and one-half the diameter of the epicotyl for its entire length was sliced away. The remaining bud grew vigorously, but neither of the buds at the base developed. If at any time this bud was cut away those at the base promptly started.

Experiment 41.—The buds at all the nodes were removed from a larger number of plants, leaving the growing tip and the basal primordia; the latter did not develop. When the tip also was removed they started promptly, even though they were separated from it by a distance of 70^{cm}—six to nine internodes. *Figure 1* shows one with three internodes.

FIG. 1.—*Phaseolus:* Tip and all upper buds removed; buds at base soon developed shoots.

It has been shown that no amount of wounding short of the complete severance of the stem will produce this result. GOEBEL (**2**, p. 386) says that in Circaea if the central orthotropous shoot be allowed to grow in a dark chamber, it has the same effect on the lateral plagiotropic shoots as if it were removed; that is, one or more of these become orthotropous.

Experiment 42.—Young plants of Phaseolus were taken when the epicotyl was 5 or 6^{cm} long, the first pair of leaves just unfolding and the apex with the leaves directed into a dark chamber. The lower part of the stems were in light and the roots in soil. The parts in the dark elongated rapidly and soon were completely etiolated, but in no case did the buds below develop. Similar experiments with Salix showed this would not cause the axial buds below the part in the dark to develop. It would look as though a complete removal of the apex is necessary to start into activity the latent growing points below, but experiment 43 shows that this is not so, for there the tips of the four young plants were passed into a bell jar and sealed air tight with wax, and through the bell jar a continuous current of hydrogen gas was passed. The growth slowed down, and after about twenty-four hours ceased entirely; and in a few days the buds in the axils of the cotyledons below started to develop and grew quite vigorously. Upon the removal of the bell jar the apices of the shoots continued to grow. This shows that only a cessation of certain activities, presumably those concerned with growth, is necessary; and it has been shown above that however this may act on the buds below, it is not through any disturbance created in nutritive or water relations.

GOEBEL (5) has shown that if in Bryophyllum all the buds on the stem are prevented from growing by encasing them in plaster, the growing points on the leaves develop. HERING (7) showed that the small cotyledon of Streptocarpus would develop both structurally and functionally into the large one, if the latter were prevented mechanically—by plaster—from growing. WINKLER (19) has found that by a similar treatment of the leaf blade of Cyclamen the new leaf-like structures that develop when the blade is removed will arise from the margin of the petiole. He leaves us in doubt as to whether he selected leaves that had entirely ceased growth before his experiments began. He thinks that the regeneration is due to the interruption of one or more of the functions; either respiration, transpiration, or photosynthesis. My results show that for Phaseolus and Salix cessation of neither transpiration nor photosynthesis will cause regeneration. Respiration is checked in the hydrogen, but what other changes may be involved it is impossible to say.

On those plants whose growing tip soon ceases activity and dies, as *Syringa vulgaris*, I have not been able to induce the axillary buds to develop by removing the apical part of the shoot. In all of many cases tried, however, in which the terminal growing points continue their activity during the growing period, their early removal was followed by the sprouting of latent buds below (*fig. 2*). This is true even in those plants whose annual shoots are without branches, and in the axils of whose leaves the buds cannot be seen even with the aid of a lens.

Lack of space prohibits a detailed description of these experiments, and only the results need be given. In the majority of cases it is the buds near the apex that start (*fig. 3*), but occasionally almost every one on the shoot starts; and in one case, on a shoot of Salix, only those at the base started. The young shoots were either cut off and the base placed in water, or else they were left attached to the plant. If the tip is cut off and also all the leaves, the buds develop. Or if the tip is removed and the shoot placed in the moist chambers mentioned above, so that transpiration is entirely prevented, they also develop. In these moist chambers, however, with the tips still intact, no development of the buds occurs. If the shoot is removed and placed in darkness for a few days, until the food is mostly exhausted by the rapid growth, and then the apex cut off, the lateral buds still develop. The removal of the leaves has no influence on the buds, for from many shoots not only were all the larger leaves carefully cut away, but even those still folded in the buds, and in no case did the growing points develop. But when in addition the tip of the shoot was removed, they at once started. While these experiments were mostly on Salix, other plants, such as Cornus, Lycium, Ficus, Oleander, etc., gave similar results. Here, as in the basal primordia of Phaseolus, no matter how vigorous and well-nourished the plant may be, or how abundant its water supply, with the growing apex of the shoot intact, the young axillary buds remained dormant. When this tip is removed, the bud starts to develop even with a loss of water or in a starved condition. This capacity is greatest in the young shoot, and gradually declines with age as the seasonal growth ceases. In

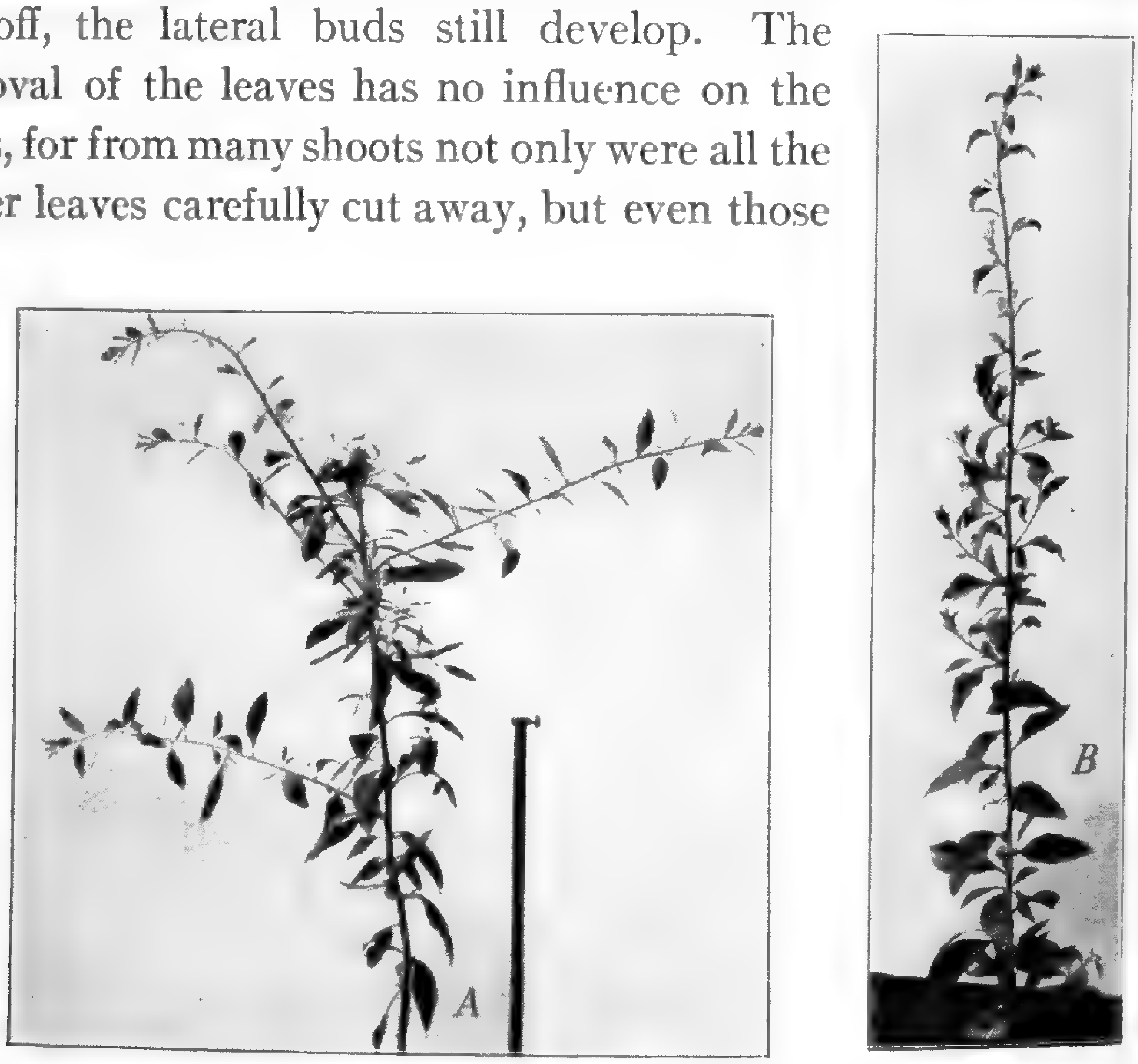

FIG. 2.—*Lycium halimifolium.* Two similar shoots were selected and from *A* the apex was removed; the photographs show them both three weeks later.

annuals, like Helianthus, whose axillary buds finally develop branches, the removal of the apex from young plants causes the buds to develop at once. *Silphium integrifolium* has a leafy stem, unbranched until late in the season when the flower branches arise; but if the apex is early removed, the minute axillary buds promptly produce branches.

FIG. 3.—Young shoot of *Salix amygdaloides*. The apex was cut off at *a* and four branches developed below this.

Not only does the growing apex exert an influence felt by the growing points below it, but those along the shoot exert a similar influence upon those lower down. VÖCHTING (**18**) showed that in isolated pieces of Salix stem only the buds toward the upper end of the piece develop. PFEFFER (**15**) found that if the upper buds are placed in plaster those lower down start. As a series of experiments on polarity will be published in an article to follow this one, only brief mention will be made here of the experiments in this connection. The plant used was Salix.

Experiment 43.—Four pieces of two-year old stem, 35^{cm} long, were placed with the basal ends in 6^{cm} of water. Two were erect, with the remaining parts in the moist air; the upper 8^{cm} of the other two were in a bell jar through which a current of hydrogen passed. In a few days the buds at the upper part of the first two started to develop; and, so far as could be observed, simultaneously with them those on the other two pieces just below the part in hydrogen. Those in hydrogen were not killed, and when the gas was removed started to grow. In a few weeks their shoots had surpassed those below them, which had now almost ceased growing.

Experiment 44.—Twelve similar pieces of stem were selected, 30^{cm} long. On three the buds were left only on the upper third;

on three more only on the middle third; on three more only on the lower third; while all the buds were left on the last three. These were all placed horizontal in moist air. On the last three mentioned only the upper buds formed shoots; and at the same time most of the buds, especially the uppermost ones, started on all the other pieces. Many tests showed that any bud at any place along the stem would develop if the buds above it were prevented from doing so. Here again, it is not a question of nutrition or water, for the stems and buds are filled with reserve food, and in a constant spray (in which the experiment was repeated) there can be no lack of water.

Whatever the influence of the growing buds may be, it is felt only on those below them, and not on the buds above them (that is, toward the apex of the axis). In the experiment just mentioned, in which the upper buds were inhibited by hydrogen, those below had gotten a good start and were forming shoots, but when the hydrogen was removed, the upper ones developed as usual.

Experiment 45.—A piece of Salix stem, 30^{cm} long, was placed so that the 12^{cm} in the center was in a continuous spray, and the two ends in quite dry air. The buds in the central portion swelled up and burst open before the others showed any signs of swelling. The whole piece was then placed horizontal in moist air. The buds at the apical end soon enlarged and developed shoots; but those at the lower part did not. These central buds, while able to prevent the buds below them from developing, had no influence on those above them. Finally, all the young shoots and buds were cut off from the upper two-thirds of the piece, and the upper ones on the basal third promptly started.

If the entire piece is surrounded by the same conditions, the shoots all appear at the apical end; but by placing the basal end in water and the rest in dry air, the buds in the water or close to the surface start first; but soon the upper ones commence to grow, apparently indifferent to those below them; and as the young shoots increase in size, those below become less vigorous and are often finally suppressed. Other experiments of a kindred nature might be mentioned, but these will suffice to indicate that the development of the buds at any region along the stem tends to suppress those below them from developing, but does not influence those above them.

Here we are dealing with growing points already laid down, but the same principle holds where these do not exist. If we place a root of Taraxacum in a moist condition, the buds at the top will soon develop; but if we remove all these buds, entirely new ones will be organized and develop. If these be prevented from growing, lower down others will be organized, as GOEBEL has shown (**2**, p. 492). Here the organization of new shoot primordia along the root does not occur so long as those at the top are allowed to grow. Here again we cannot attribute this to the monopolizing of the food or water by the upper part, for these are abundant everywhere. There is a direct relation between the growth of the shoots at the top and the non-formation of buds lower down, entirely independent of these two factors.

The development of new roots when those present are removed shows a similar phenomenon. The behavior of Phaseolus in this connection may be briefly mentioned. Plants grown with roots in water cultures developed a vigorous root system. From some of these all the lateral roots were removed, leaving only the main root. Soon numerous new lateral roots arose and grew vigorously; these were cut off and still others came on, though not so vigorously. In the mean time no new lateral roots had come out among the older ones on those that had not been so treated. If we cut off the main root transversely, numerous roots arise just above the cut; and if we cut away the whole root system by severing the stem at the base, new roots arise on the lower part of the stem. Sometimes the roots are so numerous here that I have counted eighty-one coming out of the lowest centimeter of a Phaseolus stem less than 5^{mm} in diameter. It was found almost impossible to produce roots on any part of the stem that is in direct connection with roots below, but when this connection is broken roots promptly start.

Experiment 46.—Local regions of several stems were surrounded by water in glass cylinders, as in *fig. 4*. On some the roots were intact, and from others the stem was cut off at the base. The roots and the lower ends of the stems were in water. On those with roots still attached no roots formed on the part of the stem surrounded by water; but the others produced abundant roots there and also at the lower end (*fig. 5*). Finally, from one of the former the root system was removed by severing the stem at the base, and vigorous roots then appeared in the cylinder, as well as on the lower end of the stem.

The influence exerted by the roots very evidently passes along the vascular bundles, for the transverse cutting of these at any place leads to the origin of roots just above the cut. The cutting of the cortex as deep as the bundles has no results. If a notch be cut in the stem so as to sever some of the bundles, roots appear only above, not below the notch (*fig. 6*). If the stem is cut off near the base, roots come at this place; but if it be cut off further up, the roots come there even more vigorously. If a series of notches, either one

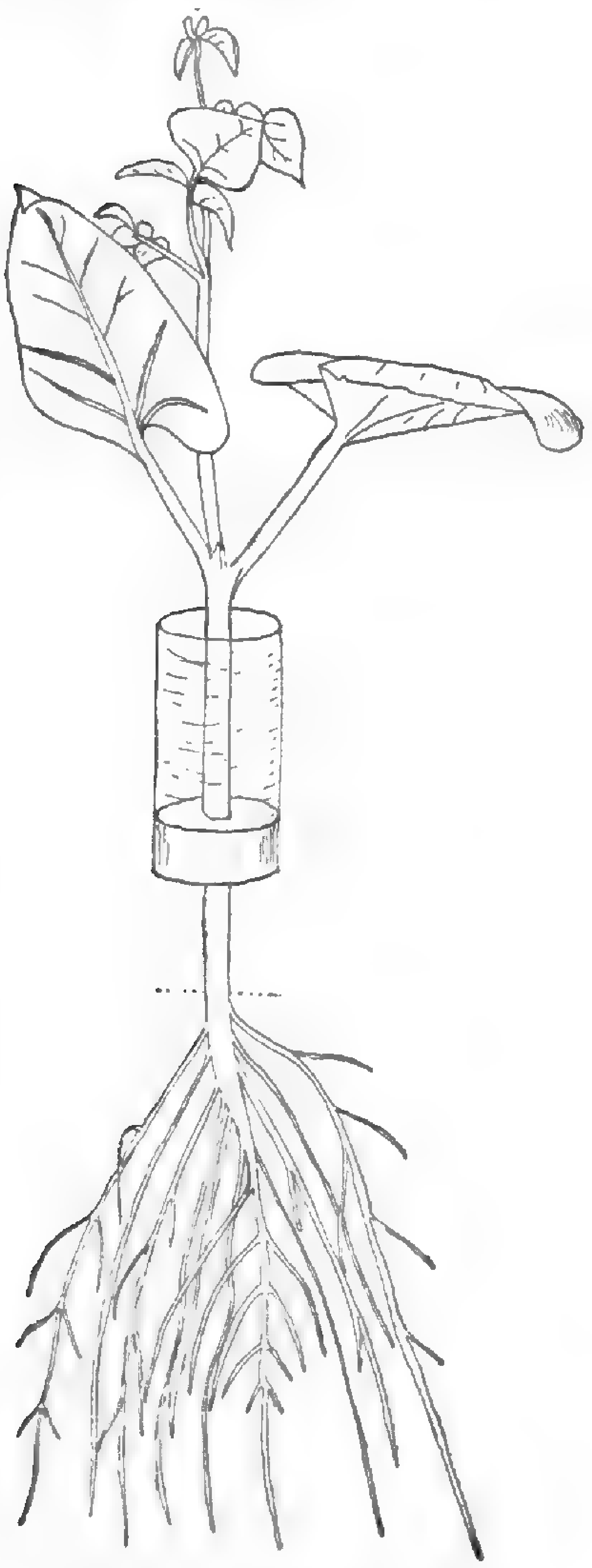

FIG. 4.—*Phaseolus:*—A short glass tube attached around stem and filled with water. Roots, grown in water culture, left uninjured and submerged. No roots formed on stem within tube.

FIG 5.—*Phaseolus:* Entire root system removed; otherwise as in *fig. 4*. Roots develop both in tube and in water at base of stem.

directly above the other or on different sides, be cut, roots come from above each of them, but more vigorously from the upper ones, due probably to that part being nearer the source of food supply. Or when stems are cut through, some at the base and some higher up, the roots appear perceptibly sooner on the latter. No matter where the stem is cut off, roots develop immediately above this point, showing that the pericycle has the power to produce roots at any point. Yet, as has been stated, if the stem be cut off, say near the base, roots come only here, though the whole stem is submerged in water. But when the cut ends of the stems were encased in plaster so as to prevent roots from coming there, they came further up. Also stems whose lower internodes were 10–12$^{\mathrm{cm}}$ long were placed in water, and every day 0.5$^{\mathrm{cm}}$ was cut off. In ten days roots appeared scattered along the remaining part.

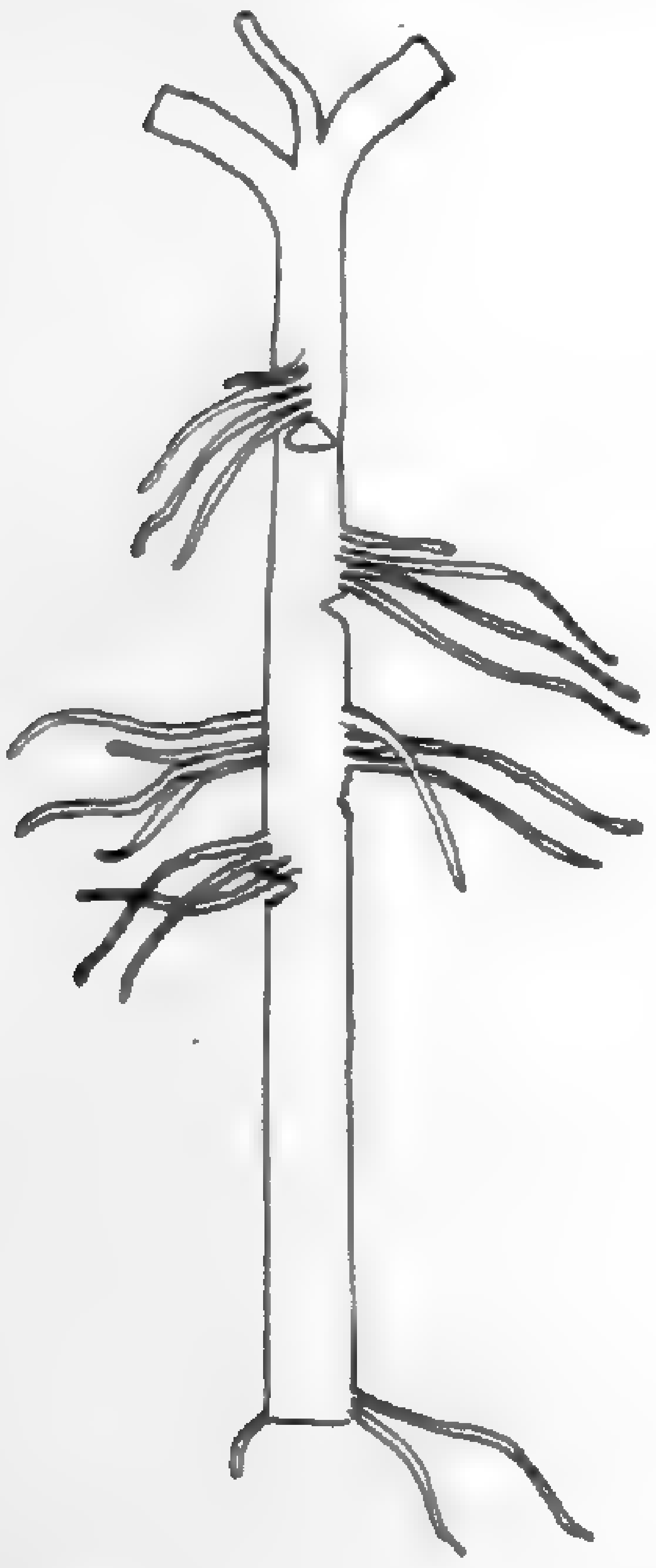

FIG. 6.—*Phaseolus:* Lower internode of stem notched on different sides and completely submerged. Roots appear only above the notches.

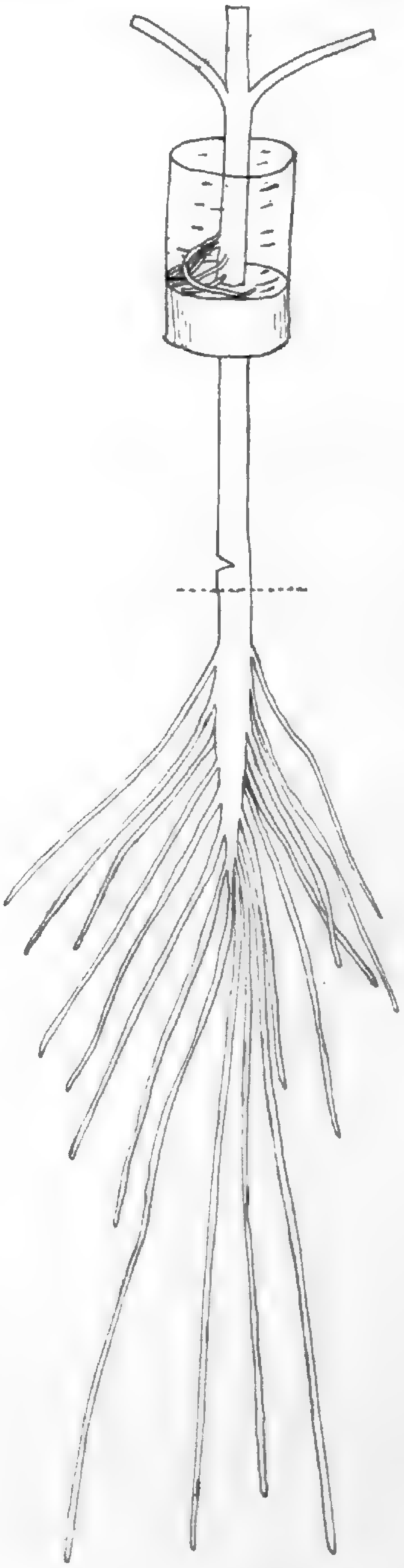

FIG. 7.—*Phaseolus:* Part of stem surrounded by water as in *fig. 4.* Roots intact and submerged to dotted line above which stem is notched to center. Roots appeared in tube, arising only on side directly above notch.

Experiment 47.—Portions of stems with roots intact were surrounded by glass cylinders 4–5$^{\mathrm{cm}}$ long and made air-tight at each end by means of rubber stoppers and wax, and opening into a vessel containing a 3 per cent. solution of ether. This seemed to anæsthetize the stem without killing it, and roots appeared just above this portion. The effect of the anæsthetic probably was to prevent any passage of stimuli through this part of the stem either up or down. Experiment 30 is instructive in this connection. It will be recalled that surrounding the stem at any place with water in glass cylinders will not start roots at that place if the connection with the roots below is unbroken; but, as shown in *fig. 7*, if a notch is cut in the stem some distance below, thus severing connection with the roots, roots will appear above the notch in the water, apparently coming from those bundles severed by the notch. In other words, the water supplies a favorable condition for root development, and the cells are able to act as soon as the connection with the roots below is broken. If the air be moist, roots come out also immediately above the notch.

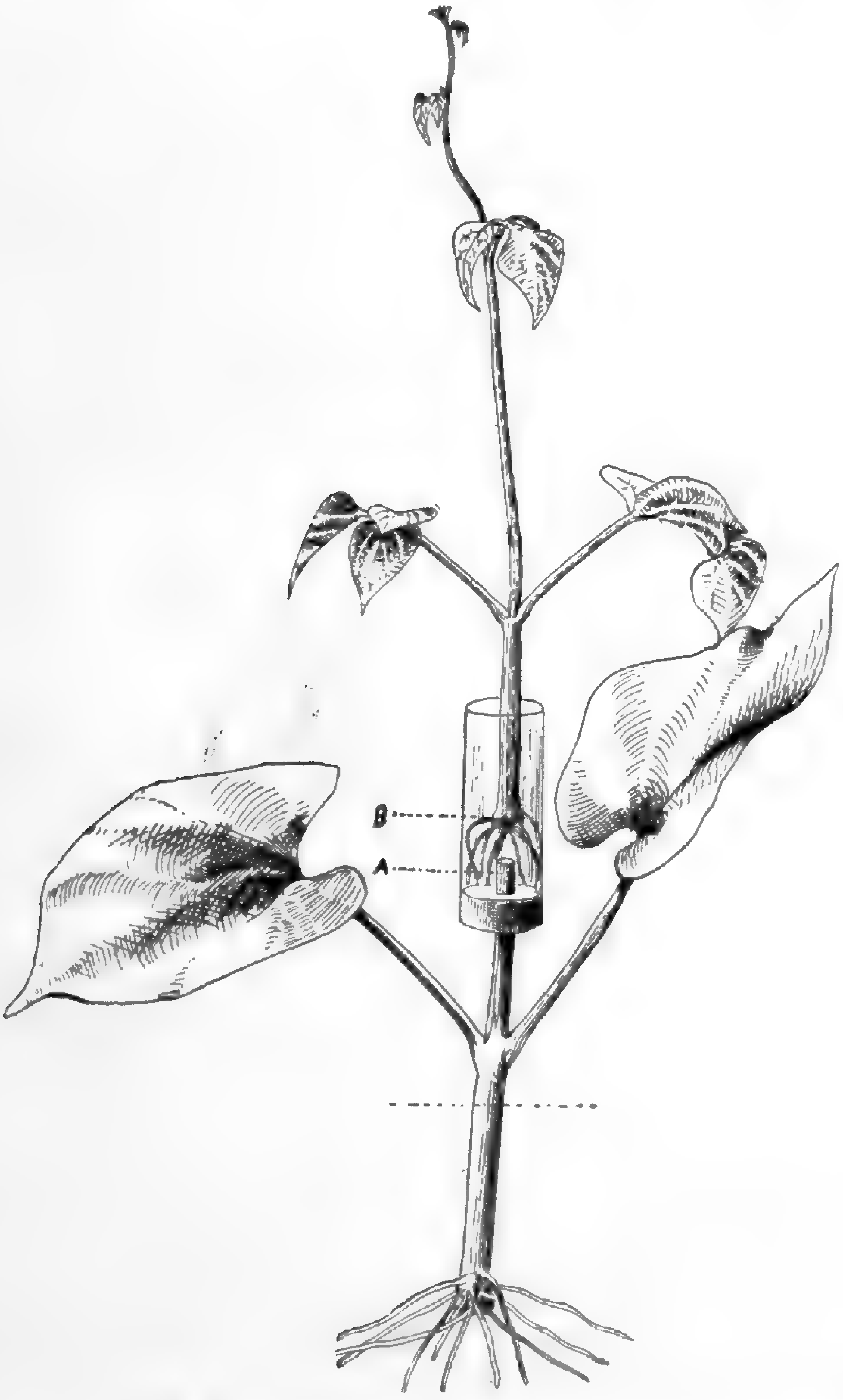

FIG. 8.—*Phaseolus:* Stem cut off at base; lower end submerged. Portion of next internode above surrounded by water as in *fig. 4*, and stem severed; *A*, *B*, ends slightly separated. Roots appeared only at *B*.

When a stem is arranged as in *fig. 8*, roots always arise on the part just above the cut, never on the part just below it, even though this piece is inverted with its end in water, as in *fig. 9*. This difference in the behavior of the cells at the two places cannot be due to any difference in the amount of water or nutritive material available at the two places, for both may be saturated with water and equally well provided with food. Nor can it be that the cells just below the cut have any less capacity for root production than those just above; for if the cut be made a little lower down, so that the cells which formed the upper part of the lower piece now form the lower part of the upper piece, they promptly produce roots. It is evident that there is some factor operating on the cells at the one point that is not present at the other; and it seems equally evident that this is not a condition of moisture, of nutrition, or of a wound influence, for all of these are equal in each case. As stated above, when no cut is made there is no tendency for any of these cells to form roots; but as soon as an incision is made, there is a change in the behavior of the cells above it, while those below remain uninfluenced. In the present state of our knowledge there seem only two possible lines of explanation: (1) as a result of the incision, new conditions are added to the cells above the cut which serve as a stimulus inciting them to root production, conditions not acting on the cells just below the cut; or (2) the cells above the cut have been relieved of some influence that previously prevented their growth, an influence still acting on the cells below the incision, and which acts on all the cells when no incision is made.

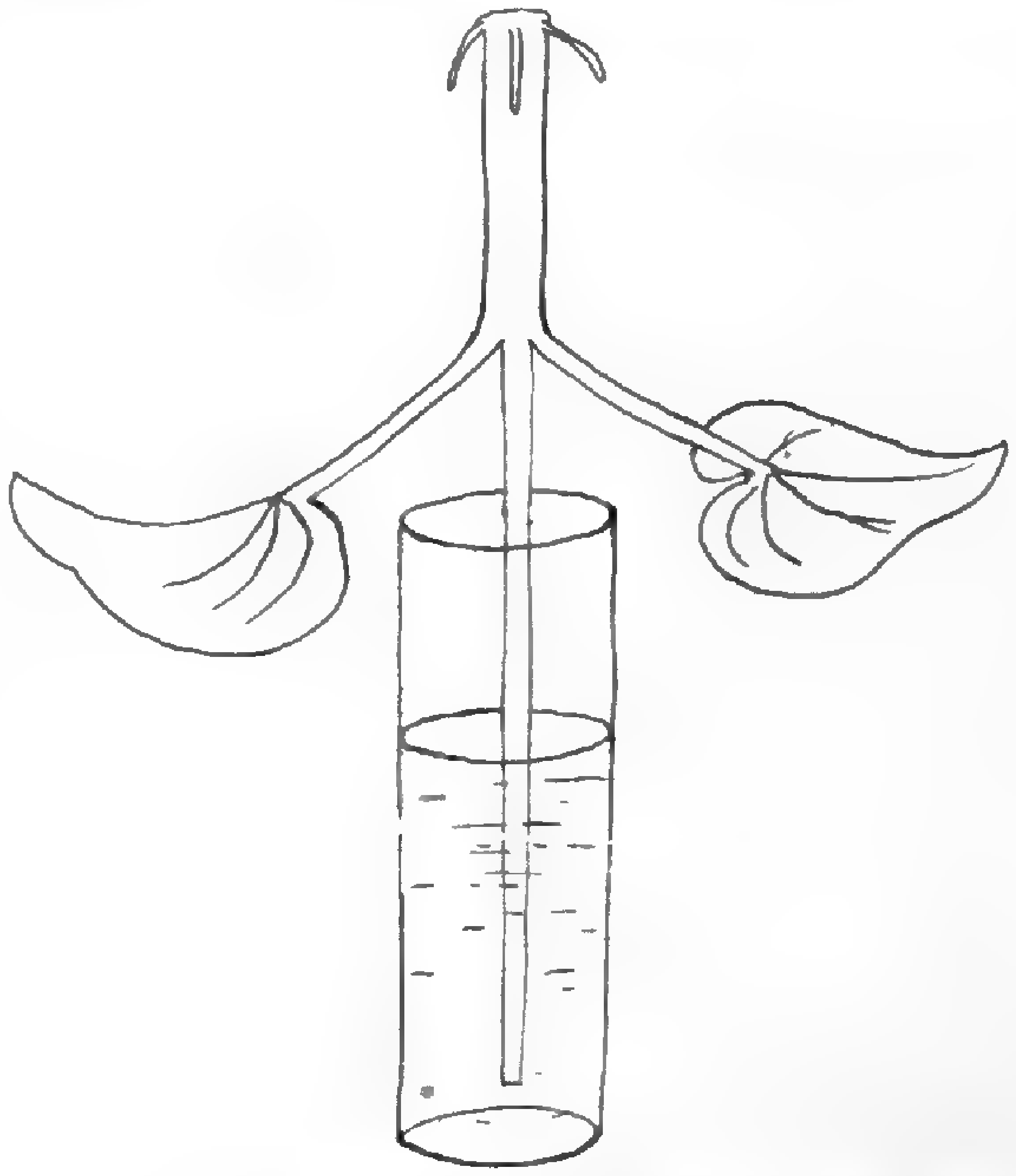

FIG. 9.—*Phaseolus:* Inverted stem with first pair of leaves and adjacent parts of internodes. Apex in water, base in moist air. Roots arising only on base.

Recurring to the first idea for a moment, we have noticed that there are two different conceptions current. The one is that these new conditions added are the results of changes induced by such factors as nutrition, moisture, wounding, light, gravity, aeration, etc. While light retards the development of roots in this case, it does not modify their distribution; and as the roots occur in the same way whether the piece is erect, horizontal, or inverted, gravity cannot be a determining factor. The other conception is that of specific formative substances, which in this case, moving toward the base, would accumulate at the lowest part and incite the formation of roots there. As this theory is to be discussed later, only two cases will be mentioned here to show its inefficiency. If in Salix, instead of cutting the stem off just above a bud, the bud is cut entirely away from the stem, it starts to develop just the same; or, as in *fig. 7*, where a notch is cut at the base of the stem, there can be no accumulation of these substances further up where the roots actually occur. It is not impossible that the upper parts, especially the leaves, exert some influence on the formation of roots on the stem. If so, it is not through the transpiration current, for the roots develop as well when transpiration is entirely checked as when it is quite active. Also, in *fig. 9* the leaves are transpiring and a current must be passing in through the end that does not produce roots. The removal of all leaves greatly decreases the vigor of the roots and also the number that are formed, but the same result is obtained by placing the leafy part in the dark, or in an atmosphere free from carbon dioxid. The fact that pieces of the internode produce roots indicates that the leaves are not necessary; their influence probably lies in keeping the stem better nourished.

On the other hand, the evidence seems to point to the second line of explanation, namely, that just as the growing shoots seem to exert a retarding influence on the buds below them, so the growing roots exert an influence which inhibits cells, otherwise able to do so, from forming roots. If, as just mentioned, the stem is cut off at its lower end and placed in water, and at the same time a portion of the stem higher up is surrounded with water, we get roots at both places. When these are growing well, if we cut off the lower part of the stem having the roots on and then submerge this end again, new roots soon appear at this point, although roots are growing vigorously a few centimeters above. In no case could I ever get a retarding influence of the roots to pass down the stem.

The problem to be solved in regeneration seems to be not so much the growth of parts following a removal (the causes here are those that induce growth everywhere), but the cause of non-development in the normal life of the plant; and this seems to lie in that influence which one part may exert over other parts or throughout the entire plant. A glance will show how universal this is among plants and the variety of ways in which it may manifest itself. If the main shoot of spruce is cut off, one or perhaps more of the dorsiventral plagiotropic lateral shoots will change their nature and become erect and radial. Many bulbous and tuberous plants do not produce seeds normally, but if the bulbs or tubers are removed seed production is then accomplished. This cannot be explained on the ground of specific bulb and seed forming substances, since if we assume the existence of these two substances, we must assume them to be different. GOEBEL (**3**, p. 213) says "in the normal condition the seed formation is hindered because the plastic material which might be used for the seeds streams into the bulb, where it is turned to account in the formation of bulbils for asexual reproduction." The assumption is that the nutritive materials, streaming to the point where the bulbs or tubers are to be formed, incite the formation of these organs; and if these are prevented from forming, the material will flow toward the flowers and there stimulate seed formation. This supposition is exactly the opposite of what actually occurs in plants. The nutritive, or any other soluble material, diffuses from its point of greatest density in all directions, as well toward the seed as toward the bulbs, and it will diffuse in one direction rather than the other because it is there being either changed or removed from solution by the activity of the cells. The "streaming" does not start the growth, but the growth activities remove the material from solution, and diffusion is set up in that direction due to the lowering of the concentration at that place. Growth or other cell activities involving a use or change of material must of necessity precede any movement other than diffusion in all directions. We have no reason for assuming that the food made in the leaves would diffuse toward the bulb any faster than toward the seed, and with the whole plant in a well-nourished condition it is scarcely possible that the amount available would be so slight that the embryos would still be in a condition of starvation so extreme that they could not even start to grow. If the latter were true, the diffusion of food materials from the leaves would be stronger toward this point than toward the tuber of any other point in the plant. There seems to be some factor dependent on the presence of growing tubers or bulbs which prevents the fertilized embryos from developing even in the presence of sufficient food and moisture. Kindred phenomena are common, *e. g.*, the death of the fern prothallium with the developing of the embryo. This cannot be due primarily to starvation, since each cell retains its own mechanism for food manufacture.

MORGAN (**11**, p. 272) has suggested that these phenomena are due to differences of tension existing throughout the plastic parts of the plants. "As long as the apical bud is present at the end of the stem or branch, or even near the apex, it exerts a pull or tension that holds the development of the parts in check; but if the apical bud is removed, the tension is relaxed and the chance for another bud developing is given." And further, MORGAN suggests that "from the apex of the plant to its base the tension is graded, being least at the apex and increasing as we pass to the base," so that, when the apex is removed, "those buds will develop first that are on the region of least tension, and then development will hold in check the other buds by increasing or establishing the tension on the lower part of the piece." Just what this "tension" may be is not very clear, and with GOEBEL I am unable to see that it makes the matter any plainer. MORGAN has suggested later (**12**) that if this idea of differences in tension is too vague, it can be given a more practical form by assuming it to be the outcome of osmotic differences in the cells. Diligent search has failed to reveal these in Salix or Phaseolus, and there seems to be no basis for the assumption.

MORGAN has more recently modified this hypothesis by another suggestion (**13**), according to which the difference in the development of buds at the two ends of a piece of stem is due to the relative state of development of the buds. In the willow, for example, those toward the apical end have reached a greater degree of maturity than those lower down, and so naturally are the first to develop. A few experiments will show this hypothesis to be quite untenable. Experiments already mentioned have indicated that when we take two pieces approximately alike, and remove all except the basal buds from one, these buds will develop simultaneously with the apical buds of the other. Indeed if any bud be selected, and the stem cut off just above it, the bud develops; but if the stem be cut off just below this same bud, so as to leave it at the base of the piece, it will not develop. Two pieces of Salix stem were selected as nearly alike as possible, and of exactly the same age. At about the center of each several buds, all alike, were selected; and each piece was cut in two, one so that these buds remained at the apical end, and the other so that they were at the basal end. In the former they developed and in the latter they did not. Experiments could be multiplied indefinitely to show that all the buds along the stem are equally able to develop; and whether any particular one does or not depends on whether the piece be cut so as to leave it near the apical or basal end.

The development of any plant involves the growth of a few and the suppression of many potential structures; and this is true not only of the vegetative buds, but also of other parts. In the ovary of Tilia, for example, ten ovules are present and may all be fertilized; but very soon nine cease activities and one only continues to form an embryo. A similar event occurs in Pinus and other plants. Were it merely a question of food, a fierce struggle would ensue among the developing embryos, and some at least would continue for a long time in a more or less starved condition. In Pinus practically all the embryos except one stop growing, while all about them are disintegrating tissues liberating food materials, some of which must pass by, or even through the arrested embryos to get to the one that continues growing. The formation of the embryo in many plants is accompanied—or immediately followed—by the development of other parts, often more or less distant, *e. g.*, the large fruit of the melon, an event that we cannot attribute to any increase of nutrition resulting from the developing of the embryo.

In addition to the growth at the meristematic growing points and along special regions which remain meristematic, as the cambium, the capacity for vegetative development is retained by many of the differentiated tissues in various parts of the plant body. That is, as the cells of the embryonic tissue differentiate into other forms and assume other functions they may still remain embryonic, in the sense of retaining complete reproductive capacity. So we find often matured cells of the leaf or cortex quite as able to form new organs as the cells of the meristematic apex of the shoot. In many cases, as *Tolmiea Menziesii, Cardamine pratensis, Asplenium bulbiferum, Camptosorus rhizophyllus*, in the ordinary course of development vegetative growing points arise on the leaves as well as on the shoot, and produce new members in the same way. As a rule, the more luxuriant the growth the more of these buds will be organized and develop; but usually, as in Tolmiea, even under the most favorable conditions not all the leaves on a plant will produce shoots. But I have found in this plant that every leaf produces a shoot when separated from the plant. In *Bryophyllum crenatum* there are numerous growing points along the margin of the leaf which do not usually develop further. They bear a similar relation to the growing points of the shoot as do the young axial buds of Salix to the growing point; for when the influence of these shoot buds is removed, those on the leaf form shoots.

On the other hand, in such leaves as Begonia the cells do not start to exercise this reproductive power by organizing growing points so long as they are in connection with other growing points of the plants; and GOEBEL showed that in Begonia, upon the removal of all the growing points of the stem, the leaf will organize them.

The same principle holds for other parts. In many roots the capacity for shoot development is expressed in the formation of "suckers," as in willows and other trees; but in other plants, probably the majority, as in Taraxacum, this ability seems able to express itself only when the influence of the shoot above has been removed.

Protoplasmic continuity from cell to cell throughout the entire living plant may fairly be accepted as demonstrated and the existence of various stimuli, either accelerating or retarding, emanating from different masses of tissue and affecting other even somewhat remote tissues is not at all impossible. Indeed, such a transmission of stimuli necessarily occurs in many of the tropisms, where the receptive region is separated by some distance from the region of response. The whole development of the plant body necessarily involves the suppression of many and the development of relatively few, either actual or potential, primordia; and the means by which this is accomplished (correlation if we must have a name) underlies in a most fundamental manner the entire organization of the plant. All the meristematic tissue and in many cases much of the differentiated tissue contains various potentialities of growth, potentialities which seem impossible of expression while in organic connection with certain growing parts. This interdependence of parts may be manifested in an inhibiting influence, as in the case of the roots or shoots mentioned, or in an accelerating effect, as in the growth of the fruit and adjoining parts after fertilization, or perhaps more correctly with the developing of the embryo. The experiments described indicate that the means of accomplishing this, that is the means by which, for example, a terminal bud suppresses the development of the other growing points on the stem or leaf, do not lie in the withdrawal by the former of the nutritive materials or the water. The theory of specific formative materials fails to account for it; nor does the tension hypothesis add anything to our knowledge of the process. Correlation, the endeavor of the plant to replace something lacking (DRIESCH), and form-stimulus (*Körperformreizen* of NOLL) are statements of the phenomenon and not at all explanations.

Protoplasmic stimuli emanating from various parts, reaching often throughout the entire organism, and affecting the behavior of the protoplasm of even remote portions are quite conceivable; so also are the formation and diffusion of ferments controlling growth; but we have yet no evidence of the existence of either.

SUMMARY.

A brief summary of the general conclusions thus far may be made as follows: The occurrence of regeneration in plants usually involves the replacement of parts removed, but the same result is often obtained when the organ is not removed, but is prevented from functioning. It is often inseparable from the ordinary growth of the plant, as for example when buds arise on the leaves of Tolmiea or Cardamine in ordinary course of the vegetative development of these plants; and the causes here are, no doubt, not different from those that induce the origin of buds on the growing points of the stem. The plant possesses innumerable growing points either organized or potential, the vast majority of which must not be allowed to develop if the plant body is to retain anything like a definite organization. In most cases this development does not occur in the ordinary life of the plant, because these cells, capable of producing new organs, are held in check by those parts already growing. This nondevelopment does not seem to be due to any lack of those conditions that favor growth, as nutrition and moisture; or to such influences as light and gravity; or to a lack of definite "formative substance;" but to some influence independent of all these, which an organ, acting perhaps along the protoplasmic connections, is able to exert over other parts and so prevent their growth. When this influence is removed, the favorable growth condition, present all the time, permits the growth of the part to occur. In such a controlling influence of growing organs over the numerous potential growing points throughout the plant there exists very evidently a principle of fundamental importance in plant organization.

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A BOTANICAL SURVEY OF THE HURON RIVER VALLEY.

III. THE PLANT SOCIETIES OF THE BAYOU AT YPSILANTI, MICHIGAN.

FORREST B. H. BROWN.

(WITH MAP AND FIVE FIGURES)

INTRODUCTION.

THE materials for the present paper were collected from a detailed survey of an area of sixty acres, known as the "bayou," which lies to the west and southwest of the Ypsilanti Highland Cemetery. It includes steep slopes, a large bayou, with a stretch of floodplain and stream, embracing a wide variety of conditions. From a reconnaissance of the entire course of the stream, it was found that many of the ecological conditions occurring from the source to the mouth were represented at the bayou area. In this small territory, the plant societies have reached an unmolested development, exceptionally favorable for their study.

The results here presented are the outcome of an attempt (1) to determine what plant societies are clearly represented, paying special attention to those which are found also in other parts of the stream course; (2) to determine so far as possible, from existing evidence, the influence of the factors of the environment which, both past and present, may account for their presence or explain their origin. Naturally the stream course societies are considered, leading to a different line of study from the two previous papers of this series, in which the glacial lakes included within the valley have been made the subject of treatment. A careful record of all species found upon the area was kept and a complete herbarium made, which is to be left at the herbarium of the University of Michigan. The work was carried on under the direction of Professor V. M. SPALDING, and the writer desires to express his indebtedness to him for many helpful suggestions.

DESCRIPTION.

1. TOPOGRAPHY AND PHYSICAL GEOGRAPHY.—In the vicinity of Ann Arbor, Ypsilanti, and other parts of its lower course, the Huron River flows through a wide valley with flats bordered by bluffs, often

very steep, which rise to a height of some 90 feet above the water. The portion mapped is a fair type of the portion between Ypsilanti and Rawsonville, a village four miles southeast of the bayou. Throughout this part of its course the stream makes a number of loops and bends that would cause a boat to journey over ten miles to reach a linear distance of four.

2. GEOLOGICAL HISTORY.—The cemetery bluff, shown in the upper middle part of the *map* (p. 266) and also in *fig. 1*, is a portion of an old sand bar, "which trends north about a mile, and connects with a beach leading in from the west, which forms the continuation of the western or main ridge found south of the Huron River."[1] This beach is one of two marking the northwest shore of Lake Maumee, which was the first of a series of large glacial lakes formed in this region with the retreat of the glacial ice. Later a change of outlet permitted the water to subside, forming Lake Whittlesey at a level some 75 feet below the upper Maumee beach. During its existence this lake formed the well defined Belmore beach, meeting the river about three miles southeast of the bayou. Still farther subsidence of the waters brought about the formation of Lake Warren, by whose waves the Forest beaches were made at levels of 60 to 90 feet below the Belmore, and at a distance of more than seven miles further down stream. From this point there is a stretch of fixed sand dunes extending to within eight miles of Lake Erie.

FIG. 1.—The cemetery bluff, shown in the upper middle part of map; a portion of an ancient sand bar.

During the Lake Maumee stages, ice and water had not yet uncovered the bayou area, except for high points of the sand bar. During the Lake Whittlesey stage, the stream was cutting its first

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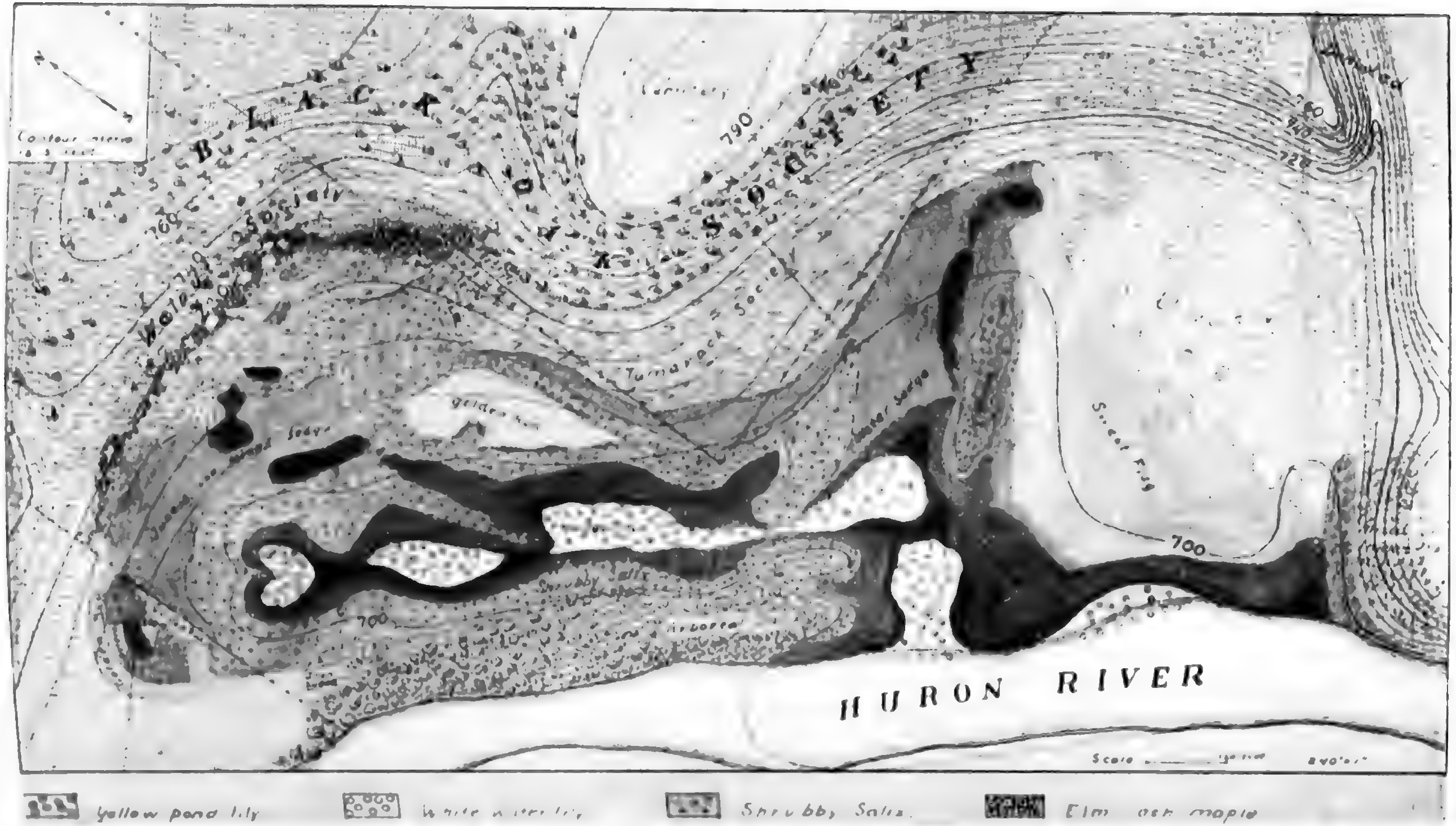
[1] LEVERETT, F., Glacial formations and drainage features of the Erie and Ohio Basins. U. S. Geol. Survey **41**: chaps. 14–16.



Map of bayou showing distribution of societies in relation to water and topography, scale 240 feet to the inch bluffs. As the waters had now subsided only about 50 feet, the base of the cemetery bluff was as yet under water; but the part exposed was free for the first vegetation to come in. It was not until the Lake Warren stage that the river, through the fall of waters at its mouth, cut still deeper in its channel and exposed the base of the cemetery bluff. The land area which was for a time submerged

FIG. 2.—*Carex stricta*, the deepest water sedge here, appears on the advance of the line of sedges, and forms tufts of great compactness and strength.

and then exposed by degrees forms the large relatively level portion of southeast Michigan, extending for thirty miles or more west from Lake Erie and the Detroit River, and nearly the same distance southward into Ohio. Westward from the basin area the surface is broken up into countless hills, ridges, and kettle-holes, characteristic of the morainal regions. It has been known for some time that the vegetation in this portion of the Huron-Erie basin is distinct from that of the morainal area, with a line of tension in sight of the east limits of the city of Ypsilanti; but an explanation of this has not yet been offered, and does not fall within the limits of the work in hand.

3. THE SOILS.—The distribution of surface soils is important because of the relations existing between soil types and plant societies. The floodplain, while having areas of peaty earth about the center and between the ponds and bluff, with an outwash of sand at the northwest and southeast, is fundamentally of compact till, which underlies the whole region and frequently appears elsewhere at the surface. The east bluffs are more porous, being composed of gravel or sand. A long ridge of mineral soil reaches from the northwest, forming a low barrier along the stream to the marsh about the bay, where it is bordered by peat-like earth. Humus is present everywhere except on the washed slopes of the bluffs. At the east is a line 600 feet in length, following the base of the cemetery bluff, where sand borders the till below with the sharpness of exposed strata. A profile was made through *B* (*map*), shown in *fig. 3*, which further explains this peculiarity in the structure of the bluff. The sand or gravel-capped bluff, with seepage springs along its soil line, and with its structure plainly revealed by the plant societies which inhabit its slope, occurs commonly in the valley.

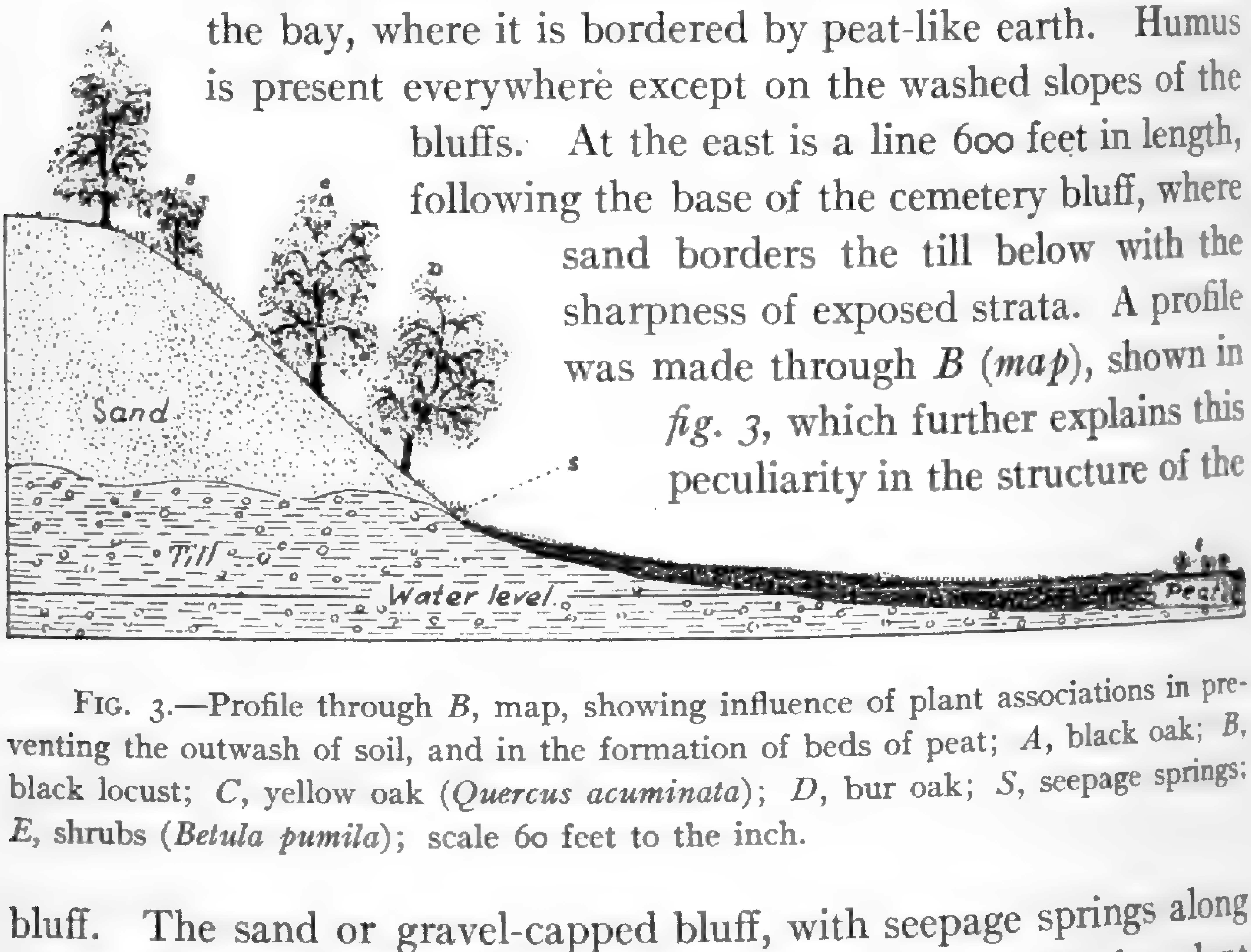


FIG. 3.—Profile through *B*, map, showing influence of plant associations in preventing the outwash of soil, and in the formation of beds of peat; *A*, black oak; *B*, black locust; *C*, yellow oak (*Quercus acuminata*); *D*, bur oak; *S*, seepage springs; *E*, shrubs (*Betula pumila*); scale 60 feet to the inch.

4. SOIL WATER.—The conditions of soil moisture, as influenced by varying soils and differences of elevation, have an obvious present bearing upon the distribution of plant societies. Conditions of extreme dryness are to be found in places along the brink of the steeper bluffs, where the combined effects are felt from the porous nature of the soil, elevation, and exposure to drying effects of wind and heat. More soil moisture is found on descending the slopes, and the change may be abrupt along soil lines where seepage springs occur. There is a slow but constant flow and percolation of spring

water from the base of the bluffs to the central ponds, giving rise to one of the main differences between the conditions existing in the bayou and the usual kettle-hole swamp or bog in which water is more or less standing. The ridge along the west is usually free from surface water, although always moist.

THE PLANT SOCIETIES.

The vegetation of the bayou and bluffs consists of a number of plant societies, which may be treated under three heads.

1. PEAT-FORMING SOCIETIES.—Under this head are included the societies commencing with the deepest submerged vegetation and reaching landward as far as the elms, red and green ash, and silver maple of the floodplain. A connected account of each in its order is given because the vertical succession of societies which occurs here seems to have been a common one on the wide floodplain areas below Ypsilanti, and would appear to possess some unusual features in the light of what has been written regarding the floodplains of other river valleys. This group comprises 131 species, or 32 per cent. of all species found upon the area surveyed. Seven distinct societies may be distinguished in order as follows, the number of species being given in parenthesis: 1, pondweed (7); 2, waterlily (5); 3, water smartweed (6); 4, Typha-Sparganium (10); 5, water sedge (19); 6, willow (71); 7, tamarack (13); total 131 species.

The first society is submerged, consisting chiefly of species of Potamogeton, and occurs only in the stream. The growth offers resistance to the flow of water, checking the current, and causes deposit of suspended particles in addition to that arising from vegetable decay. Following upon the submerged society, there appears one of floating plants, which still further checks the current. The waterlilies secure a firm anchorage. The white waterlily (*Castalia odorata*) is more common in the current. The yellow pond lily (*Nymphaea advena*) commences just back of this and occupies the bays where the current moves more slowly or is scarcely perceptible. The exchange of species in relation to habitat is best shown between the bay and the current (*map*). With the presence of the waterlily society, there is a marked tendency to secure room near the water surface. The potamogetons appear to rely on the anchorage offered by the waterlilies, sending out long stems with leaves clustered above. In this zone, when the surface of the water is quiet, occur such plants as Utricularia, Lemna, Spirodela, and Riccia. Peat-like material rapidly accumulates below as growth proceeds above. The interwoven rootstocks are firm enough to support the weight of a person. The several kinds of water smartweed are most active in forming this mat, although the yellow pond lilies add a good deal of firmness.

At length the intervening space between the surface growth above and the substratum below becomes filled in with an oozy accumulation of peat, and gradually two marsh societies appear, the Typha-Sparganium and the water sedge. These marsh plants are characterized by the possession of thickly matted root systems and rhizomes. *Carex stricta* is the deepest water sedge here. It appears on the advance of the line of sedges and forms tufts of great compactness and strength. These tufts persist through subsequent changes that occur, and long after the death of the sedge itself, finally become covered with *Potentilla fruticosa* and turf-forming grasses. They give rise to the peculiar mound or hummock configuration so characteristic of the numerous valley meadows which have been built up in this way. Sedges build up the peat bed in two ways: (1) by the death of the aerial parts; and (2) by the death of the roots and rootstocks, the latter often the more rapid of the two processes.

As the surface becomes rather free from water and firm, there appear the first woody types. Shrubby species of Salix are the first to grow in abundance, covering many parts so densely that other forms are almost excluded. *Rhus venenata*, *Naumburgia thyrsiflora*, *Asclepias incarnata*, and *Scutellaria lateriflora* act as pioneers in seizing decaying timbers, islands of sedge, and similar places of advantage. This results in the formation of a willow or drained swamp society, the vegetation of which is richer in individuals and species than that of any other association. From the map it will be seen that the arboreal species of Salix are confined chiefly to the ridge, which is mainly till in this portion. The shrubby kinds, on the other hand, prevail over the beds of black peat bordering the water.

Part of the drained swamp area has culminated in tamarack and other plants with xerophytic characters similar to those characteristic of the flora of the so-called undrained swamps. This stage does not appear to have been uncommon in the wider parts of the valley, and possesses points of unusual interest. This association forms a crescent-shaped area at the base of the cemetery bluff, commencing with the seepage springs (*fig. 2* and *map*) and reaching stream-ward as far as the water sedge. It is here 700 feet long and 200 feet wide, containing the following species listed in order of their relative abundance: *Scirpus americanus, Carex filiformis, Koellia flexuosa, Lysimachia quadrifolia, Campanula aparinoides, Lobelia Kalmii, Aster junceus, Parnassia caroliniana, Rynchospora alba, Gerardia paupercula, Solidago Riddellii, Sarracenia purpurea, Larex laricina* (once abundant, but now removed for firewood).

On comparing the composition of this society with that of others, it was found that the above species are peculiar to the one society and occur rarely if at all outside of it. A sharp line of separation occurs between it and neighboring societies. As a whole it may be said that the vegetation is the most distinct of all those studied. With but two exceptions all species are perennials, and a certain likeness of form characterizes the members, as if mutually adapted to xerophytic conditions, causing the vegetation to stand out in contrast with the neighboring broad-leaved hydrophytes. Regarding this group of plant societies the following points are to be noted.

1. Of the whole group, 5 per cent. of the species were found to be submerged, 32 per cent. amphibious, and 63 per cent. terrestrial. The willow society is richest in species, containing more than twice the number of species found in any other society of this group, and slightly more than any society to be discussed later.

2. Of the agencies active in filling the bayou, the first place is assigned to vegetation (*fig. 3*). Not more than one-third the material entering into the composition of earth so formed is inorganic matter, the proportion often being smaller. From the areas of organic soil frequently occurring along the flats it is plain that the process has been as active in past as in present times, converting numerous standing pools and deserted channels into dry land surface supporting a thrifty forest growth.

3. Most of the common species are gregarious, and tension lines are sharply marked.

4. The vertical succession of societies which build up the drained swamp may culminate in tamarack and other plants with xerophytic adaptations.

5. The bayou vegetation is similar to that of like areas along the stream, and only minor differences were brought out; but on comparing this vegetation with that of the glacial lakes about Ann Arbor, the most pronounced differences were discovered when the respective swamp and bog societies were compared. *Andromeda polifolia, Chamaedaphne calyculata, Arethusa bulbosa, Sarracenia purpurea, Oxycoccus macrocarpus, Drosera rotundifolia,* and sphagnums are common about lakes, but absent or very rare along the stream. In both cases, however, there is a dominance of northern forms.

2. FLOODPLAIN SOCIETIES.—The series of changes taking place in the previous group are continued until swamps and pools disappear, to be replaced by a dense woods of mixed mesophytic species. Three societies appear, often with a more or less zonal arrangement.

(1) *Moist sedge society.*—Turf-forming grasses here make their first appearance, but are not able to replace entirely the terrestrial sedges, which occupy occasional areas.

(2) *Elm-ash-maple society.*—There is little space not occupied by tree growth, except where clearings have been made. *Populus tremuloides* and *P. deltoides* appear early as pioneers, followed later by *Ulmus americana, U. pubescens, Fraxinus pennsylvanica, F. lanceolata, F. nigra, Acer saccharinum, A. rubrum, Platanus occidentalis,* and *Tilia americana;* which make up a woods characteristically mixed, dense, and vine-clad. Of the herbaceous forms, only the most shade-enduring kinds with broad thin leaves are to be met with in the forest. Of these *Urticastrum divaricatum, Acnida concatenata, Adicea pumila,* and *Lobelia cardinalis* are most common.

(3) *Walnut society.*—The most abundant and characteristic tree of this association is *Juglans nigra,* which appears to have been uniformly distributed, and often over three feet in diameter, as shown by stumps. It is one of the arboreal types which shows a tendency to follow along streams or bodies of water. It occurs mixed with *Juglans cinerea, Quercus macrocarpa, Hicoria minima, Quercus platanoides,* and other species. It was attempted to characterize the group as a bur oak-walnut association. This was

abandoned because the bur oak was found to occur not alone in moist situations, but with equal frequency under much more xerophytic conditions, such as prevail in the oak openings a few miles west from Ann Arbor. However, the bur oak of these drier situations differs in appearance from the walnut association form, which has drooping branches with heavy corky ridges. The walnut society occurs in the better drained parts of the floodplain and for a short distance up from the base of the slopes, as shown in the map. It grows best of all in the coves. Along the tension line nearest the water *Carpinus caroliniana* is common; along the drier tension line *Ostrya virginiana* is rarely absent. The most common associated herbaceous species are *Houstonia ciliolata, Mesadena atriplicifolia, Allium canadense, Verbesina alternifolia, Homalocenchrus virginicus, Falcata comosa*, and *F. Pitcheri.*

As a whole the vegetation of the floodplain is mesophytic. Its growth differs from that of the peat-forming group in being mainly forest, in the tendency of its species to grow in mixture, in possessing a greater number of southern forms in its composition, and in the greater shade endurance of its species. The composition does not vary much in similar parts of the valley, but certain elements occur which serve to distinguish the stream-course type from that which occurs in the more remote parts of the valley, where mesophytic associations are found. *Platanus occidentalis, Juglans nigra, Hicoria laciniosa, Houstonia ciliolata, Quercus acuminata, Meibomia canadensis, Fraxinus pennsylvanica, F. lanceolata*, and *Acer saccharinum* occur characteristically along stream; but *Fagus americana, Acer Saccharum, Asimina triloba*, and associated species, forming a distinct maple-beech society in some other parts of the valley, are rarely met with on the floodplain.

3. BLUFF SOCIETIES.—Like the floodplain, the bluffs are covered with forest, but of a quite different character. The woods are more open and share in common with other vegetation numerous xerophytic adaptations. Four societies need to be distinguished in an account of existing relations.

(1) *Oak-hickory society.*—Beyond the few hickories at the north, this society is little represented at the bayou. This may be partly explained by the absence of the more moist till slopes, upon which

it is abundantly represented in the vicinity. A variety of hickories is found, most common of which are *Hicoria ovata, H. alba, H. odorata*, and *H. glabra*. These are associated with *Quercus rubra*, and *Q. alba* is present.

The other vegetation also shows a number of easily recognized characteristics. The proportion of leguminous species (Melilotus, Trifolium, Vicia) is high; composites (*Aster laevis* and other summer-blooming species) are frequent; *Podophyllum peltatum*, Erythronium, *Muhlenbergia diffusa, Scrophularia marylandica*, and *Cornus candidissima* are common species. Counting in the smaller vegetation, the society is not rich in species, but is rich in southern forms.

(2) *Black oak society*.—The cemetery bluff conditions, brought about partly by the porous sand and partly by slope, are much more arid than the till bluffs. The hickories and red oak disappear from the forest, and *Quercus velutina* becomes most common, 53 per cent. of the individuals on the slope above the 760-foot contour line being black oaks. *Quercus alba* is common, and in places west of Ann Arbor *Q. imbricaria*.

Comparing the other vegetation with that of the oak-hickory society, it is found that equal differences exist. The May apple is rarely found; there are fewer leguminous species; ericaceous shrubs are common; and the proportion of composites is high. The vegetation is rich in species, characteristic of which are *Lespedeza capitata, L. violacea, Solidago caesia, S. speciosa, S. nemoralis, S. rigida, Gaultheria procumbens, Gaylussacia resinosa, Vaccinium vacillans, Angelica villosa, Viola pedata, Lupinus perennis*.

All of the numerous species of grass which clothe the steeper slopes have prominent adaptations serving to bind down and hold the soil from outwash. They are all perennials, have deep root systems, strong woody stems and rhizomes, and grow in compact tufts which offer the greatest resistance both to being torn apart and to being displaced. Even loose sand, which otherwise would be quickly washed away, is by this means held in place indefinitely, and the steepness of slope so formed is often surprisingly great. It was found that the angle of repose of the dry sand composing the bluff was 28° 35′. The mean angle of the slope was 39° 55′; or the actual slope of the bluff as held by the soil binders is 11° 20′ steeper than the dry, loose sand would take by gravity alone. *Andropogon scoparius*, *A. furcatus*, *Chrysopogon avenaceus*, and *Stipa spartea* are the most common of these soil binders.

(3) *Juniper heath.*—The conifers are restricted to open or unfavorable situations, and thrive where other arborescent forms do not. Only isolated individuals of juniper and cedar are met with at the bayou; but southeast from the city are found slopes covered by them. On the brink of a bluff which has been undermined by the stream so as to leave the slopes bare of any vegetation, *Juniperus communis* makes an early appearance. From this point it throws out decumbent rooting stems, which, partly directed by the movement of the unstable soil, come to extend down the slope, and the growth is continued from above downward. A covering is soon made, in which also occur *J. virginiana*, *Lepargyraea canadensis*, *Rhus aromatica*, and *Stipa spartea.*

None of the other societies occur under conditions equally xerophytic. The juniper and cedar are most common (*fig. 4*), but not so characteristic of such situations as other less frequent members, like buffalo berry or porcupine grass. If we compare slopes of different ages, evidence will be found showing that the juniper slope is transformed into an oak slope as conditions become more favorable for the growth of vegetation. In the heath appear *Populus grandidentata* and *P. tremuloides* and seedlings of black locust, basswood, and oak. Cedar Bend, Ann Arbor, has gone a step farther. Here the oaks are dominant, but there is still much juniper, cedar, and aspen. Even the final black oak stage is not without decayed logs, stumps, and isolated individuals, suggesting the former prevalence of the juniper and other members of that society.

(4) *Thicket societies.*—One of the most characteristic features of the river vegetation as a whole is the large proportion and variety of shrubs which it contains. Along the bluffs these shrubs occur either as scattered individuals or mixed together as thickets or undergrowth. The numerous species of thorn and bramble, Ampelopsis, Smilax, Celastrus, Vitis, and other vines, occur most frequently in dense mixed thickets, where an open ledge or slope affords a chance. *Rhus hirta* and *R. glabra,* however, do not tend to mix with other shrubs, or even with each other, but form patches of pure growth, which distinguish at once the sumac thicket from all others.

As a whole, the bluff vegetation is made up of light-requiring species. The prevailing forest trees are among the least shade-enduring kinds to be found in the region. Such trees never crowd together to form the dense type of woods common on the floodplain; but, like the black oak woods, or like the openings of bur oak west of Ann Arbor, the trees stand far enough apart to permit an abundant growth of smaller vegetation to spring up in the woods. Also there is less tendency to growth in mixture. The sumac and junipers are gregarious, and there is not the variety of trees in the oak woods that there is in case of the more mesophytic kinds. The tendency of the black oak group to occur on sands, and of the hickories to occur on clays, are among the most constant relations which societies have been found to bear to soil types.

FIG. 4.—Washed slope in juniper-heath stage; the ground juniper appears in patches in the foreground, with red cedar forming a dense grove in the background; near Rawsonville, Michigan.

OTHER BIOLOGICAL GROUPS.

The account thus far deals mainly with indigenous plants which seem to bear a more or less constant relation to the environment, and includes a total of 316 species which have been classified into societies. There remain eighty-four species found upon the area surveyed, which occur in widely varying situations. These have been classified into two groups.

1. THE HETEROPHYTES.—A group of twenty-one native species were found to occur in so wide a range of habitat as to be best termed heterophytes. The most common of these are *Onagra biennis, Taraxacum Taraxacum*, *Poa pratensis*, *Aster novae-angliae*, and *Solidago canadensis*.

2. INTRODUCED WEEDS.—A second group, the exotics, embracing the introduced weeds, is characterized by a similar wide range of habitat. Their presence is due solely to the agency of man, and serves to indicate the extent to which he has changed the composition of the original vegetation by clearing away the forest and cultivating areas in the vicinity. Nearly one-seventh of all the species collected at the bayou have been introduced. Of these fifty-two are European, four (*Amaranthus retroflexus*, *Chenopodium ambrosioides*, *Mollugo verticillata*, *Datura Tatula*) are tropical American; one (*Ailanthus glandulosa*) Chinese; one (*Lonicera Tatarica*) northern Asiatic; one (*Abutilon Abutilon*) southern Asiatic. The important fact is brought out in the study of the bayou vegetation that the aquatic and swamp societies are almost free from introduced species. Only five species were found in this area: *Solanum Dulcamara*, *Mentha piperita*, *Roripa Nasturtium*, *Salix purpurea*, and *S. alba vitellina*. These were confined mainly to the drained swamp. The juniper-heath is also nearly free from exotic species. The largest number of exotic species occurs in the grain-bearing or grass-producing societies, the highest percentage being associated with the black oak and the oak-hickory societies.

PROMINENT INTER-RELATIONS.

From the fact that members of a plant society live together under common conditions, it is to be expected that individual species of a group would possess common adaptations and hence resemble one another. This is seen to be the case in the tamarack society, for example, where there is a marked morphological resemblance. But it is possible to trace the resemblance much further. With this in view, the percentages of spring, summer, and autumn blooming species were obtained for each society. Fall percentages were taken as positive, summer percentages as zero, and spring percentages as negative, the results being shown in the accompanying table. A curve was then plotted from the summation of such percentages. The curve suggests that in general similar societies possess similar habit. The societies which bloom earliest have a high per cent. of northern forms. Like many of the willows, poplars, and maples, the flowers often appear before the leaves. Also the leaves unfold and the fruit matures before more southern types like the oak, hickory, walnut, and sycamore. The bluff societies, except for the juniper, possess the southern habit.

TABLE SHOWING PERCENTAGE OF SPRING, SUMMER, AND FALL BLOOMING SPECIES; AND THE PERCENTAGE OF NORTHERN, CONTINENTAL AND TEMPERATE, AND SOUTHERN SPECIES IN EACH SOCIETY.

SPECIES			TIME OF BLOOMING							GEOGRAPHICAL DISTRIBUTION						
No.	Society	No. of sp.	Spring –		Summer o		Fall +		Value	Northern –		Temperate and Continental		Southern +		Value
			No.	%	No.	%	No.	%		No.	%	No.	%	No.	%	
1	Juniper-heath..	5	5	100	0	0	0	0	–100	4	80	0	0	1	20	–60
2	Black oak.....	62	15	24	45	73	2	3	–22	4	6	29	47	29	47	+41
3	Sumac........	2	0	0	2	100	0	0	0	0	0	2	100	0	0	0
4	Oak-hickory...	26	8	31	17	65	1	4	–27	0	0	15	58	11	42	+42
5	Walnut.......	50	20	40	30	60	0	0	–40	2	4	25	50	23	46	+42
6	Elm-ash-maple	46	22	48	24	52	0	0	–48	6	13	31	67	9	20	+7
7	Moist sedge....	3	1	33	2	67	0	0	–33	1	33	2	67	0	0	–33
8	Tamarack.....	13	2	15	11	85	0	0	–15	9	70	4	30	0	0	–70
9	Willow........	71	32	45	39	55	0	0	–45	28	40	32	45	11	15	–25
10	Water sedge...	19	3	16	16	84	0	0	–16	5	27	13	68	1	5	–22
11	Typha-Sparganium.	10	3	30	7	70	0	0	–30	0	0	8	80	2	20	+20
12	Water smartweed..	6	0	0	6	100	0	0	0	0	0	4	66	2	34	+34
13	Waterlily......	5	0	0	5	100	0	0	0	0	0	5	100	0	0	0
14	Pondweed.....	6	1	17	5	83	0	0	–17	0	0	6	100	0	0	0

The trees are mainly nut-bearing and ripen their fruits, unfold their leaves, and bloom relatively late. Thus we commonly see a tamarack swamp or a floodplain forest with young foliage well along before the surrounding oaks have begun to show marked signs of life. Both curves show that the highest per cent. of vernal as well as northern forms occurs in the floodplain societies and on the juniper slopes. The highest per cent. of southern forms occurs along the favorable slopes of the bluff and in the aquatic societies.

CONTROLLING FACTORS.

1. Climatic.—A number of species have been pointed out whose distribution is more or less restricted to the stream, although this will be shown to be less true near the mouth. Most common of these are the hickories, walnut, yellow oak (*Q. acuminata*), red elm, silver maple, red and green oak, sycamore, hoptree, *Rhus aromatica, Juniperus communis, J. virginiana, Iris versicolor, Meibomia canadensis, M. grandiflora, Ambrosia trifida, Dioscorea villosa, Sanguisorba canadensis,* and *Mesadenia atriplicifolia.* Most of these are near the northern limits of their range. Since many of these forms occur in a wider range of habitat in the south, it may be assumed that climate plays some part independent of other factors in causing such species to become limited to the neighborhood of the stream.

2. Atmospheric.—The fact that the forest is usually open along the edge of the bluffs seems to account in large part for the presence here of the juniper and associated species. Their behavior indicates exacting light requirements, as they thrive only in open situations, and early show a decline when shaded. To a less degree the sumac society occupies open places in a similar manner.

3. Mechanical.—The mechanical effects of stream erosion are continually bringing about changes of topography and soil to which the plant societies are in turn conforming. Although a number of bluffs are being denuded by the cutting of the current, the floodplain areas are not likely to be very greatly increased; since it has been shown that a stream cuts within the limits of a belt not over eighteen times the width of the stream at that point.[3] The fact that Populus

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[2] Jefferson, M. S. W., Limiting width of meander belts. Nat. Geog. Mag. —:373–384. 1902.

and Salix are often the first woody types to appear on the exposed places of the floodplain and bluffs appears to be due to nothing beyond the fact that they were first on the ground. Judging from the shrubs, dispersal by wind may be more rapid than dispersal by animals, but it is certainly far less prevalent, as will be shown later.

4. EDAPHIC.—Of all the local conditions, the societies sustain the most obvious relation to the amount of available moisture in the soil. It is this which in large measure gives the distinctive characters to the bluff societies as compared with those of the floodplain or the peat-forming group. The relation which tension lines bear to water supply takes on particular interest in case of the bayou peat-forming societies indicated in the map. There is a slope toward the center in which there occurs a pond-like bay. The main part of the surface water discharged from the seepage springs along the cemetery bluff is carried to the southeast to a point near the fence, where it makes a good sized stream as it flows directly to the ponds. A similar discharge of surface water comes from several points along the elm-ash-maple zone. The map shows the general tendency of tension lines to arrange themselves concentrically about the bay; also a tendency to arrange themselves parallel to the stream, and the complex pattern of the peat-forming societies is the resultant of these conflicting tendencies.

A chemical analysis was made of the soil water about the springs in the hope that peculiarities might be detected to account for the xerophytic adaptations noticed in the vegetation. The water was found to be neither acid nor alkaline. It contains sulfates, chlorids, and carbonates, with iron, calcium, and sodium, but not different from the usual spring water. The water, however, is cold and keeps the swamp at a low temperature. There are five of the societies which stand in so definite a relation to soil types that they give fairly reliable information as to the kind of soil merely by their occurrence. The black oak society may be taken to indicate dry sand or gravels; the oak-hickory society, till or clay; the tamarack society, peat; the elm-ash-maple society, wet soils; the maple-beech society, richness of soil. Such soil relations do not appear to be limited to the valley alone, but to hold true over a considerable area outside.

5. BIOTIC FACTORS.—It is due to the interaction of one life form

upon another that there have been produced areas of turf which otherwise would have been very limited or wholly absent. Along the brink of the cemetery bluff a line of tension is easily traced. It is not sharp like the swamp lines; but, like the usual upland type, there is an area over which the societies blend. *Poa compressa*, *Andropogon scoparius*, *A. furcatus*, and *Stipa spartea* crowd their way for a distance of one to six feet into the turf of *Poa pratensis* and *Trifolium repens*, where they fade out altogether.

It is plain that animal life has played an important if not a chief part in the dispersal of seeds in the valley. Squirrels and like animals were formerly more common than now, but birds are yet numerous; the blue-jays,[3] cat bird,[4] and crow blackbird[5] alone feed upon a variety of fruits that includes more than one-half of the woody species at the bayou, exclusive of the large trees.

Besides these, there are the red-winged blackbird, vireo, oriole, woodpeckers, song sparrows, cowbirds, and robins, which are common all along the stream and are known to devour fruits. This has resulted in scattering the seeds of a number of shrubs, vines, and small trees in the open places of the forest. At the bayou there are sixty-one species of this kind, 82 per cent. of which have adaptations for seed dispersal by animals; 72 per cent. have the brightly colored fruits eaten by birds, of these 22 are red, 10 black, 7 blue, and 5 white. It is possible that this may indicate something with regard to the relative attractiveness of the several colors.

Over two-thirds of the species with colored fruits occur in the bluff societies, and are most numerous with the juniper, sumac, and black oak. This fact is not so easily explained by any habit of the birds as it is by the character of the woods. The same relations appear to hold true of corresponding societies away from streams,

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[3] BEAL, F. E. L., The blue-jay and its food. Yearbook, U. S. Dept. Agric. **1896**: 202.

[4] JUDD, S. D., Birds of a Maryland farm. Bull. 17, U. S. Dept. Agric. Div. Biol. Survey, p. 104.

[5] BEAL, F. E. L., Food of the bobolink, blackbirds, and grackles. Bull. 13, U. S. Dept. Agric., Div. Biol. Survey, p. 64.

——, The crow blackbirds and their food. Yearbook, U. S. Dept. Agric. **1894**: 243.

where the forest has been undisturbed. Blueberry, barberry, blackberry, hackberry, huckleberry, raspberry, strawberry, currants, cornel, cedar, juniper, sumac, sassafras, black cherry, pin cherry, choke cherry, and black haw occur commonly in the dry sand of oak woods, less commonly with the hickories, and least of all in the maple-beech woods. Oaks, however, have thin crowns, are not shade-enduring, and do not grow crowded together, forming open woods that give a chance for the growth of a variety of herbs, shrubs, and vines on the forest floor. On the other hand, the beech, maple, and ash are distinctly shade-enduring, have thick crowns, and grow crowded together, forming a dense woods in which there is little chance for undergrowth to come in. In such woods there are so few shrubs and vines that the average woodsman is not aware of their presence at all, and finds himself at a loss to account for the thick berry patch that springs up wherever he cuts a few trees. It is plain that seeds are scattered in all woods, but only the open woods afford a chance for their growth.

6. THE HISTORIC FACTOR.—The presence of Sarracenia near cold seepage springs, and of the white pine on the bluffs, suggests that those plants may be relics of a past northern flora, which followed closely the retreat of the ice. While the tamarack society probably does not date back to this period in its origin, its flora may have been derived in large part from species so left, in the same way that the juniper-heath spreads out over exposures as fast as made on the bluffs. The fact that 70 per cent. of the species associated are northern adds confirmation, and accounts for the dissimilarity between it and neighboring societies. With further investigation it does not seem improbable that many if not all of the peat bog forms may be found lurking in the neighborhood of springs of this character.

Societies of the favorable places of the floodplain and bluffs have a pronounced southern flora. A few northern forms occur in all the floodplain societies; but the oak-hickory society, in which there occurs a high per cent. of southern forms, has so few northern species that their occurrence may be regarded as accidental. The curve (*fig. 5*) shows how in land situations southern tendencies fade out as conditions become more and more unfavorable.

SUMMARY

1. The bayou of Ypsilanti, as indicated in the sketch of its geological history, is of relatively late origin, and relics of postglacial floras have been nearly obliterated by more recent changes, which render the portion of the valley directly affected by the stream not so suitable for the preservation of ancient floras as the secluded swamps or bogs of the morainal regions. But the seepage springs and bluff exposures of sufficient age and isolation still retain such relicts of a past northern flora which followed closely the retreat of the ice.

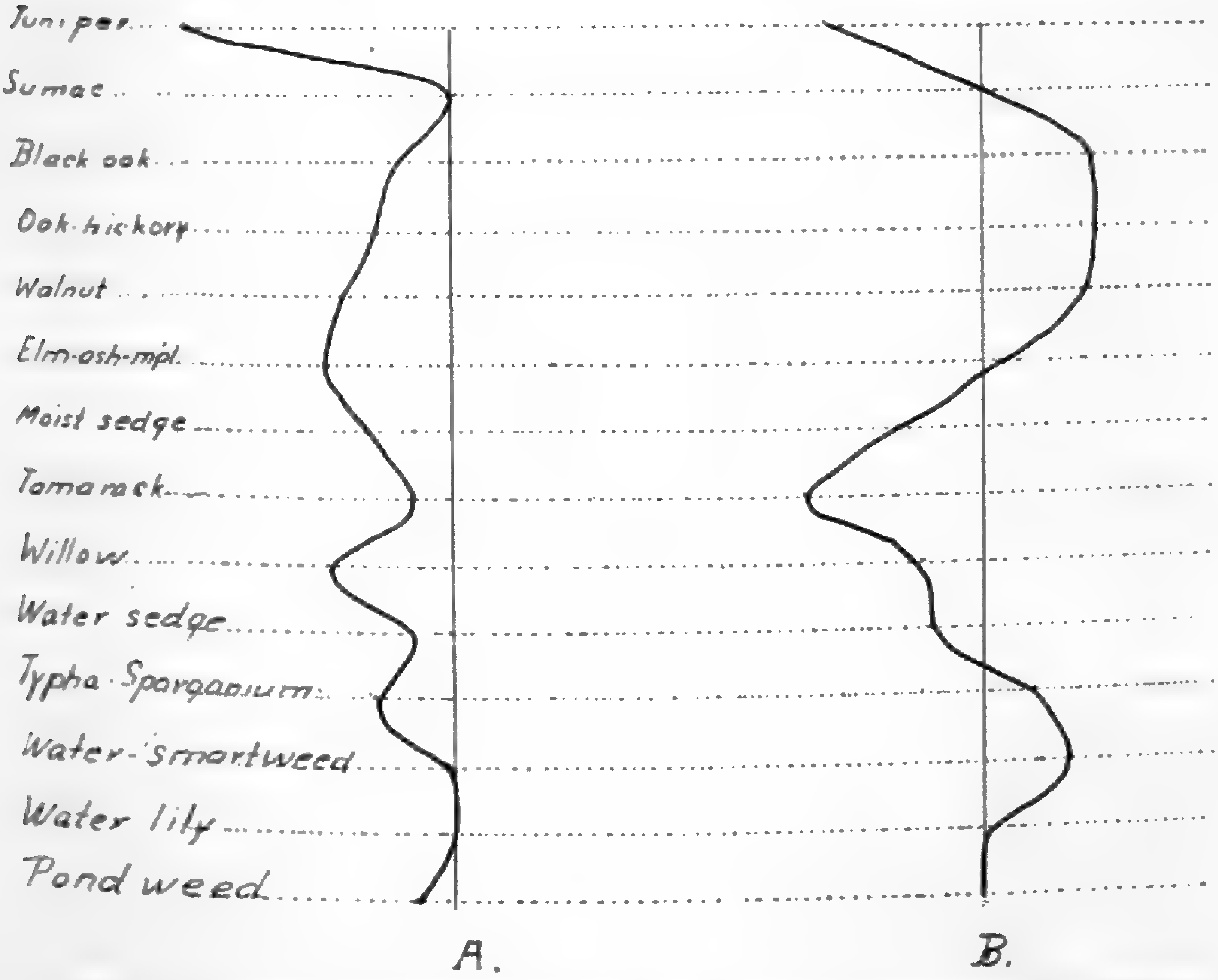

FIG. 5.—*A*, curve of period of bloom; *B*, curve of geographical distribution; curves drawn from values obtained in map.

2. The societies of river swamps, such as the bayou here described, are distinct from those of the lake swamp or bog. In both, however, xerophytic adaptations are conspicuous, which cannot be explained by the absence of drainage currents nor by the presence of humus acids.

3. The peat-forming societies show sharp tension lines, conforming to depth of water, characteristic of pond vegetation. Such tension

lines become obscured in the floodplain societies, and still more so in the bluff societies, but in each of them the relation of distribution to soil water, as a controlling factor, is plainly marked. The definite relation of certain societies to soil types, shown to exist here, appears to be due primarily to the capacity of these various soils for water.

4. Of other factors to which the plant societies are evidently related, the influence of light is conspicuously manifest, as for example in the place taken by light-requiring species in the bluff vegetation. Quite as manifest, though far more complicated, is the coincident operation of biotic factors, which are so numerous and varied in their manifold interrelations as still to demand much special study.

5. The high per cent. of northern species in early blooming societies, the occurrence of various southern forms along the river near the northern limit of their range, the occupation of favorable places by societies of distinctively southern cast, and of unfavorable ones by those of pronounced northern composition, are all indicative of the close relation of the members of these societies to slowly changing climatic conditions. A discussion of the migrations of these plants in connection with geographic and climatic changes is deferred until a greater accumulation of data has been made.

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THE SPORE COATS OF SELAGINELLA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXX.

FLORENCE LYON.

(WITH PLATES X AND XI)

SINCE the development of the modern technique in botany, comparatively little has been done in investigating the mode of formation of cell walls or of spore coats, and botanists are still much in the dark as to the nature, as well as the morphology, of certain complex structures protecting the protoplasm of spores. A recent contribution to this subject by FITTING[1] is of special importance, because as a result of his study of the development of the spore coats of certain species of Selaginella, he advanced a theory that they grow quite independently of the protoplasm of the spore, with which during the time of their greatest increase in bulk they have no organic connection except at one point. This, of course, is revolutionary and quite at variance with all previous ideas of the growth of membranes; and if it is true that protoplasm "can act at a distance," and without organic connection can build massive structures, the fact is of the greatest importance.

At the time that FITTING's paper appeared, I was investigating certain phases in the life history of two native species of Selaginella—*S. apus* and *S. rupestris*. In the main the peculiar phenomena connected with the formation of the spore coats of the first named species seemed to agree with those described by FITTING; but the development of the spores of *S. rupestris* differed so completely that it became a matter of interest to determine whether there were two distinct types of spore formation in this genus or whether the differences were more apparent than real. The present work was undertaken with a view to throwing some light upon this question. The difficulties which all investigators have encountered at every stage

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[1] FITTING, HANS, Bau und Entwickelungsgeschichte der Makrosporen von Isoetes und Selaginella und ihre Bedeutung für die Kenntniss des Wachsthums pflanzlicher Zellmembranen. Bot. Zeitung **58**^{1}: 107–164. 1900.

of technique, fixing, embedding, sectioning, and staining, together with the fact that Selaginella spores are *sui generis*, and one has no standard of comparison, make one fearful of drawing conclusions from artifacts. Apparently the only way to lessen this danger and make results convincing, is to have a very large number of preparations killed and treated in various ways, for little critical study can be made of the living spore. This has made my investigation an exceedingly tedious one, for in the early development of the spore, transformation takes place so rapidly that important phases are obtained with difficulty, and if not found the danger of misinterpretation is very great. The results of my work fail to confirm FITTING's theory, nor am I able to accept his description of the origin of the coats for the species that I have investigated. It is quite certain, I think, that the spore coats of *S. rupestris* do not lose their complete organic connection with the protoplast during growth, and I have a growing conviction that to our imperfect technique are due the phenomena which gave rise to FITTING's theory and were described by FITTING, CAMPBELL, and all other workers in this group, including myself.

Very complete series of three species—*S. apus*, *S. Emmeliana*, and *S. rupestris*—from the origin of the sporangium to the development of the embryo sporophyte have been studied. Throughout its history *S. rupestris* is aberrant, and proves to be a plant of much importance and interest, as it has characteristics supposed to be peculiar to the seed plants. Normally, and in a greater number of cases, only two megaspores were found to develop in a sporangium. These may be two of a tetrad, the others failing to develop after the division of the mother cell; or, more important still, the mother cell may divide only into two spores. These megaspores are not shed from the megasporangium at all! The female gametophytes and the young sporophytes are retained in the old strobilus until the latter have roots, stems, and leaves; then the tissue of the sporangium and megasporophyll decays, thus liberating the bodies that lack only integuments to be seeds. A still further reduction of megaspores to *one* is infrequently found. In tracing the growth of the spores, I again emphasize the fact that at no time is there any appearance which would suggest that the protoplasm is not in contact *at every point* with the thick gelatinous membrane from which the coats are formed.

The megaspore mother cell in all species may be distinguished from the other sporogenous cells (*fig. 1*) at the time that the sporangium wall is differentiated into three layers. It is slightly larger, more granular, and stains intensely as contrasted with its sister cells. Its wall thickens slightly, stretching and probably growing somewhat, and persists until the enclosed spores are more than half grown. I shall refer to it as the *mother cell membrane*, to distinguish it from a second membrane, the *spore membrane*, that shortly appears upon its inner surface in contact with the protoplasm (*fig. 1*). The mother cell membrane remains comparatively thin; whereas the spore membrane is gelatinous in nature, becomes very massive, and dissolves readily in many of the fixing reagents, especially in very young stages. It increases rapidly in bulk, forming a thick layer about the protoplast which for a period grows imperceptibly, if at all (*fig. 2*). As the mother cell divides, it assumes a dumb-bell shape, the two resulting spores often not completely separating from each other until half grown (*fig. 3*). At this early stage, each spore consists of a protoplast with a relatively large nucleus, and an envelop of thick gelatinous matter, the spore membrane. The two spores lie within the mother cell membrane. Whether any part of the spore membrane is formed in connection with a nuclear plate at the time of cell division could not be determined, owing to the diminutive size of the spindles and their infrequency in the material investigated. The protoplast becomes vacuolate. Many small vacuoles ultimately coalesce to form a very large one centrally placed, so that the protoplast comes to be a delicate vesicle (*fig. 4*).

The first indication of a coat is detected as a transformation of a portion of the gelatinous spore membrane. A clear homogeneous region at some little distance from the protoplast stands out in contrast to the rest of the membrane, which has become granular (*fig. 4*). This area soon becomes convoluted upon its outer surface, and these convolutions coincide with radiations in the outer granular portion of the membrane that suggest fixed diffusion currents (*fig. 4*) of solutions passing through the two membranes from the sporangium. At this time, the sporangium is turgid with fluid made up of disorganizing sporogenous cells, and a secretion poured out by the tapetum, which is the source of nourishment of the two young spores.

The spore membrane itself is a somewhat viscid substance, almost fluid in character, that flows out of the hole if a living sporangium be pricked with a needle. The spore membrane becomes much thicker at the base of the spore, so that the remarkably small protoplast lies near the apex (*fig. 5*). The growth and differentiation of the spore membrane into regions are extraordinarily rapid. Just inside of the clear area described above, a part of the membrane is much denser than elsewhere. These two regions, *i. e.*, the clear and the denser (*fig. 5*), constitute the preliminary stage of the first or outside coat, the *exospore*. It is possible in a close series of preparations to note gradual changes in structure as the coat matures. Chemical tests to determine the nature of the transforming spore membrane and of the resultant coats were very unsatisfactory. In all early stages the minute living spores are so difficult to manipulate that no reliable results could be obtained. On the other hand, material that is sectioned and upon the slide where it can be handled has already been subjected to the action of many reagents. The clear area, or outer layer of the exospore (*fig. 6*), is gradually transformed into a granulated condition, while the inner layer and the rest of the spore membrane becomes reticulated. All the regions are quite distinct and react differently to the stains used.

Up to this time the protoplast has not altered in size or density, but now it suddenly dilates—like a bubble which is blown up—and presses outward toward the exospore. When its diameter is about half that of the entire spore, a second delicate coat, the *endospore*, may be detected, having formed upon the outer surface of the protoplast. This is difficult to demonstrate unless the coat and protoplast become torn apart and displaced; for it is little more than a faint line in section during the entire period that the protoplast is expanding and pressing it back against the outer coat. The portion of the spore membrane (*fig. 6*) which is not directly transformed into the exospore, and against which the protoplast presses (*fig. 7*), disappears as the protoplast and endospore dilate. As the exospore has been undergoing modifications (*figs. 7* and *8, ee*) during this time, which render it more impervious to the entrance of solutions from the sporangium, this undifferentiated portion of the membrane in its turn has probably served for nutriment or has been taken into the protoplast. Often, however, a little of the original membrane may be detected crowded back against the exospore, forming a layer that easily may be misinterpreted as an additional coat, if intervening stages have been overlooked (*fig. 8, h*).

As the spores now nearly fill the sporangium cavity and the tapetal cells are disorganized, all future growth must be at the expense of the central vacuole. The principal changes in the maturing of the spore are the increase in the amount of protoplasm, with marked growth of the nucleus, and the thickening of the endospore by successive laminae upon its inner surface, which is in contact with the protoplast at first only in the region of the nucleus (*fig. 9*). Eventually, however, it becomes a layer of equal thickness throughout (*fig. 10*). The exospore is elaborately bossed and sculptured, and the protuberances form a layer—the so-called perinium—that stains quite differently from the part in contact with the endospore (*figs. 7-10*). It seems to me from its formation that it should not be regarded as a distinct coat, however, but as the outer region of the exospore. The central vacuole throughout the spore development is filled with a transparent fluid, which in early stages disappears in preparing the slide, but which becomes a coagulable mass as the female gametophyte forms (*fig. 11*).

The most conspicuous differences between *S. Emmeliana* or *S. apus* (taken as a type) and *S. rupestris*, described above, are due I think to the *simultaneous* transformation of the spore membrane of the former two coats, and to certain phenomena due to mechanical strains that arise between these two coats and the protoplast. In *S. Emmeliana*, as in all other species hitherto studied, the mother cell normally divides into a tetrad. The same difficulty arose as in the preceding species about determining the origin of that portion of the spore membrane on the contiguous surfaces (*fig. 14*). Earlier stages show the formation of nuclear plates, and there is no such appearance of lobing of the spore mother cell as in *S. rupestris*. At first the spore membrane is homogeneous and translucent (*fig. 15*), but when its thickness is about half the diameter of the protoplast (*fig. 16*), a portion of it lying in contact with the protoplast stains differently and marks the beginning of the two coats. This layer, almost as soon as it can be detected at all, shows a dual nature. It appears in section as a shaded band not sharply marked off from the undifferentiated portion of the spore membrane. Its outer region stains more vividly than the inner, perhaps because it is denser. Gradually a difference in structure becomes apparent, which I have attempted to show in *fig. 17*.

The spores are so small, stain so intensely during this critical stage, and the changes in the metamorphosing spore membrane occur with such rapidity that it has been with difficulty that I could demonstrate to my own satisfaction that one coat was not formed after the other, but both simultaneously. FITTING thinks that the endospore is formed after the first and arises *de novo* as a new formation of the protoplast. The spore is much smaller, and the changes much more rapid in this form; consequently they are harder to follow than in *S. rupestris*. The outer denser region with its roughened surface becomes the exospore, the inner the endospore. The protoplast becomes a vesicle by the formation of one large central vacuole. It is at this time when there are two coats of distinctly different structure that the peculiar phenomena occur which led FITTING to draw the conclusion that the protoplast is not concerned in the conspicuous growth of the spore coats.

As the spore grows larger, the outer coat increases in diameter and thickness much more rapidly than the inner, producing a strain in the viscid mass of which the two are concentric layers. FITTING thinks this results normally in a complete separation of the two, thus developing between them a comparatively large empty space. In a like fashion, due to the fact that the protoplast is quiescent and the endospore growing, a second "empty space" is formed between them, except at one point, thus severing all organic connection of the protoplast with the developing coats except at this point of tangency. There is no doubt that the majority of preparations have precisely this appearance. Moreover, the living spore examined in a normal salt solution seems to confirm FITTING's view of a separation of the coats, and on this fact he lays great stress. The spaces, according to him, are afterward partially filled with a solution which has entered the spore from the sporangium.[2] I have come to believe, however, that where actual gaps occur they are due to shrinkage and the dissolution wholly or in part of the intervening substance, and that the appearance of separation in the living spore can be explained by the different density of the concentric layers. In material showing no shrinkage elsewhere, I found that these regions were not empty, but completely filled with matter closely resembling the spore membrane at different periods of its transformation into coats.

It must be understood that the entire substance of the spore outside of the protoplast is a viscous mass of the consistency of thin syrup, in which two regions are becoming not only different in their physical but also in their chemical natures. This substance retains a plastic condition until the spore has attained its full size and the two coats their entire bulk. Then follow the changes which result in their hard horny or woody character. Into the viscid mass are passing solutions from the sporangium. The direct physical effect upon this mass as a whole would be a tendency to increase in diameter and bulk; but apparently all regions do not swell alike, the more resistant regions where coats are forming become drawn apart, having between them a stretched area of less dense nature, very easily dissolved by reagents, subject to great shrinkage and liable to be torn and not readily stained. From material fixed in bichromate of potassium and exposed to light, the gelatinous nature of the substance in these regions was clearly demonstrated. They always stain like the undifferentiated part of the spore membrane. **Fitting** also remarks that "sie verhalten sich bei allen Arten gegenüber Rengentien wie die Special Mutterzellmembranen."

There seem to be three possibilities: (1) **Fitting**'s view that the regions between protoplast and under coat, and between inner and

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[2] "Die Zwischenräume zwischen den Häuten und zwischen dem Mesospor und dem Plasma sind an lebenden Sporen ganz hyalin. . . . An fixirtem und mit dem Mikrotom geschnittenem Material sind in ihnen Gerinnungsmassen, je nach dem Entwickelungsstadium in verschiedener Menge, vorhanden. Wenn die Abhebung der Membranen gerade begonnen hat, ist von ihnen noch nichts zu sehen, erst wenn die Hohlräume etwas grösser geworden sind, werden in ihnen kleinere und grössere, hier und da netzartig verbundene sichtbar die während der Vergrösserung der Sporen schnell vermehrt werden. In noch älteren Stadien bilden sie . . . . sowohl zwischen Exospor und Mesospor, wie auch zwischen diesem und der Plasmablase je eine hyaline, glasartig durchsichtige Masse, die die beiden Räume meist nicht vollständig ausfüllt."

outer coat, are spaces filled with a solution—comparable to a vacuole; (2) that possibly there are protoplasmic connections between the protoplast and the two coats, and that the intervening substance is protoplasm, penetrating the endospore and extending to the exospore; (3) the suggestion, made above, that normally there are no clefts in the spore, but that the matter outside of the protoplast is to be regarded as an envelop of gelatinous matter in process of local transformation into concentric layers of different physical nature, and at the same time increasing enormously in size by the imbibition of matter from the sporangium. Much time was expended in trying to demonstrate protoplasmic continuity through the coats but without success.

The third view grows convincing, as it *is* possible to obtain sections which show the spores to be a solid mass without spaces, the regions of the developing coats not being sharply marked off from the substances that FITTING regards as foreign matter, and that I believe to be merely stretched areas of the gelatinous membrane out of which the spore coats are differentiating. Indirect evidence is afforded by the growth of the coats in *S. rupestris* in which there is at no time any suggestion of "spaces filled with nutrient solutions."

The further development of the megaspore consists in the expansion of the protoplast which soon overtakes the endospore, which in turn is carried along and stretched against the exospore. The portion of the exospore in contact with the endospore (*fig. 18*) usually fails to coalesce completely with the outer part (*figs. 18* and *19*), and if one has failed to follow its behavior closely might readily be interpreted as an intermediate distinct coat. This account fails to agree with FITTING's and CAMPBELL's.[3] The two coats I have shown in *figs. 17–19* they call exospore and mesospore. The endospore they describe as arising *de novo* after the protoplast is fully expanded, and in contact with it, thus making *three* distinct coats. In the species which I have investigated—*S. rupestris, S. apus, S. Emmeliana, S. densa, S. cinerascens*, and two unnamed species from Jamaica—I can demonstrate only two distinct coats. May it not be possible that others have made the same error that I did in my

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[3] CAMPBELL, D. H., Studies in the gametophyte of Selaginella. Ann. Botany **16**:419–4 8. *pl. 19*. 1902.

former paper[4] when I interpreted the inner region of the exospore as a separate membrane?

In a late paper by BEER,[5] the author states that he has observed a separation of coats in the pollen grains of certain Onagraceae that is quite comparable to the condition described by FITTING as occurring normally in the megaspores of certain species of Selaginella. His forthcoming paper on the subject will be one of interest, especially if he finds evidence to support FITTING'S view of protoplasm acting at a distance.

THE UNIVERSITY OF CHICAGO.

EXPLANATION OF PLATES X AND XI.

In all figures, *a* indicates mother cell membrane; *b* the protoplast, *c* the spore membrane, *d* the nucleolus, *n* the nucleus, and *v* the vacuole.

PLATE X. Selaginella rupestris.

FIG. 1. Median section of megaspore mother cell with three sporogenous cells that fail to form spores. ×1250.

FIG. 2. Not quite median section of megaspore mother cell showing slight lobing, before division into two spores. ×1250.

FIG. 3. Nearly median section of two megaspores not completely separated from each other; that portion of the spore membrane between the two protoplasts is apparently formed by the lobing of the mother cell and not in connection with a nuclear plate. ×1250.

FIG. 4. Median section of megaspore after the formation of a large central vacuole and at the time the spore membrane shows a region differentiating into the exospore or outside coat; *e*, region differentiating into exospore; *f*, possibly diffusion currents of solution passing into spore from sporangium. ×600.

FIG. 5. Sections of two megaspores lying near the sporangium wall; by greater growth of the spore membrane at one side the protoplast has come to lie near the apex of the spore; the spore *A* is in nearly median section, *B* is not; *e*, exospore, *s*, sporogenous cells that failed to divide into megaspores. ×600.

FIG. 6. Portion of median section of megaspore (drawing not completed at base); to show further differentiation of spore membrane; *e*, exospore showing three different regions. ×600.

FIG. 7. Apical portion of median section of more advanced stage of megaspore to show the first appearance of the second coat—endospore—and the changes in the exospore; the undifferentiated part of the spore membrane (*h*)

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[4] LYON, FLORENCE, A study of the sporangia and gametophytes of *Selaginella apus* and *Selaginella rupestris*. BOT. GAZETTE **31**:124–193. *pls. 5–9.* 1901.

[5] BEER, RUDOLPH, The present position of cell-wall research. *New Phytologist* 3:159–164. 1904.

between the expospore and endospore shows signs of dissolution; *c*, spore membrane (includes everything between *a* and *g*); *e*, portion of spore membrane becoming transformed into exospore; *g*, endospore. ×600.

FIG. 8. Small portion of median section of apical region of megaspore more advanced; the protoplast *b* with the endospore *g* on its outer face has expanded until it has come to lie close to the outside *e;* the undifferentiated part *h* of the spore membrane has almost entirely disappeared; *e*, exospore; *g*, endospore (black line); *h*, layer of granular matter which is all that remains of region between *c* and *g* in *fig. 7*. ×60.

FIG. 9. Apical region of median section of older megaspore; the mother cell membrane has disappeared entirely; *b*, protoplast increasing rapidly; *e*, exospore; *g*, endospore (increasing in thickness by successive laminae formed on its inner surface in the vicinity of the nucleus). ×600.

FIG. 10. Portion of apical region of median section of mature megaspore in the region of the nucleus; the protoplast has increased in thickness at the expense of the central vacuole near which the nucleus lies; the protoplasm contains much proteid matter which stains deeply; *e*, exospore; *g*, endospore. ×600.

FIG. 11. Part of median section of female gametophyte after cell walls have begun to form; the proteid granules have increased in number and in size; *e*, exospore; *g*, endospore; *nn*, nuclei. ×600.

PLATE XI. Selaginella Emmeliana.

FIG. 12. Megaspore mother cell in optical median section, after the formation of the spore membrane. ×1250.

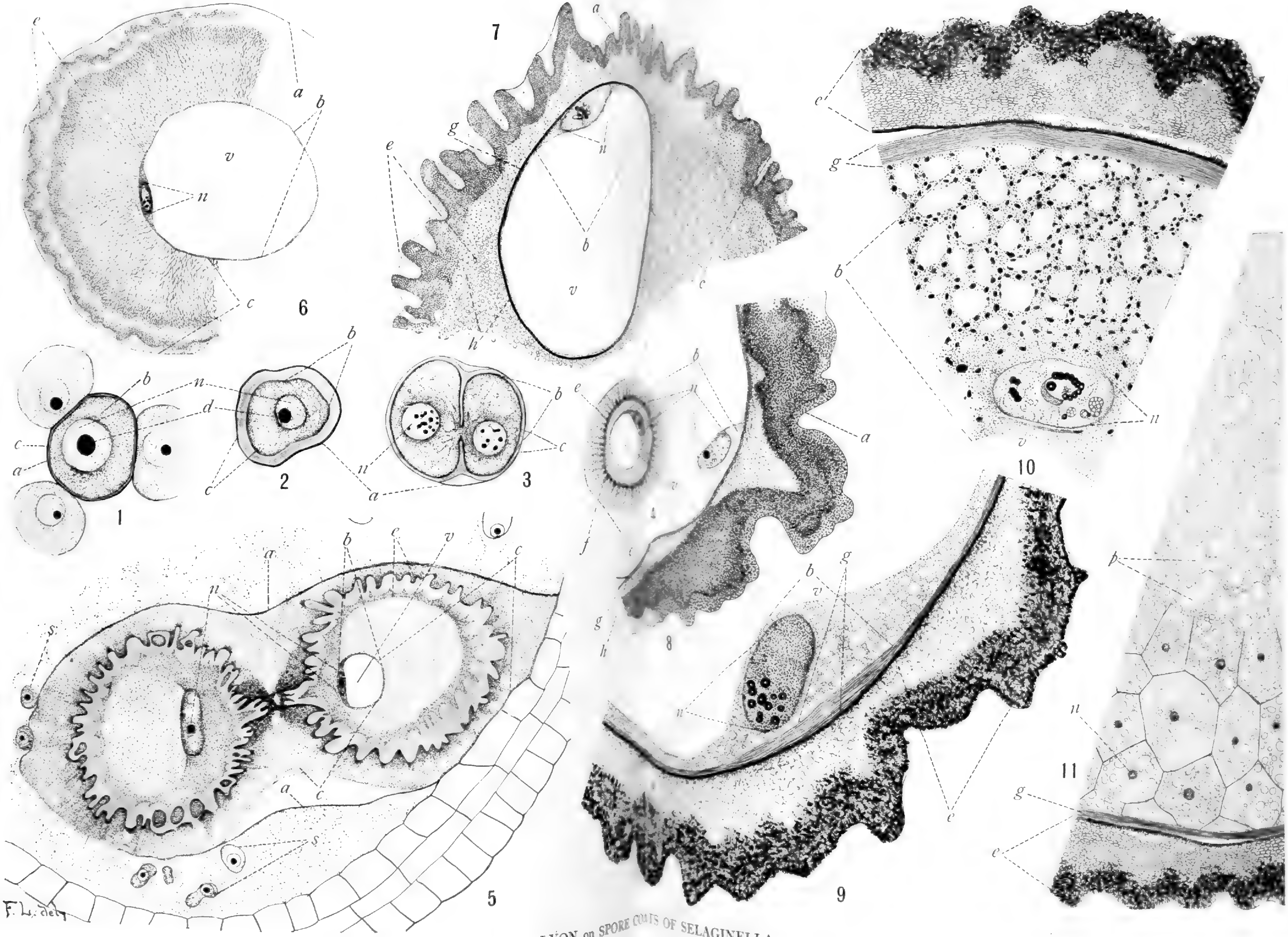
FIG. 13. Median section of megaspore mother cell in process of division into tetrad; nuclear plates forming; *x*, nuclear plate; *y*, spindle fibers. ×1250.

FIG. 14. Median section of megaspore tetrad showing completion of spore membrane along the nuclear plates. ×1250.

FIG. 15. Median section of somewhat older tetrad, showing increase in thickness of spore membrane between the protoplasts of the spores; protoplasm becoming vacuolate. ×1250.

FIG. 16. Median section of tetrad showing the differentiation of a layer of the spore membrane; the outer region of the shaded band with the convoluted border becomes the exospore, the inner region in contact with the protoplast becomes the endospore; outside of the forming exospore, between it and the mother cell membrane, is a layer of the undifferentiated spore membrane; *d*, portion of spore membrane in process of transformation into coats; *e*, region of exospore; *f*, region of endospore; *m*, undifferentiated portion of spore membrane. ×1250.

FIG. 17. Nearly median section of tetrad showing farther differentiation of exospore and endospore; two megaspores show the effect of the mechanical strain between exospore and endospore which has a tendency to split the exospore into two layers; stages between *fig. 16* and *fig. 17* were not found among several hundred preparations; the transformation of the spore membrane into coats is



LYON on SPORE COATS OF SELAGINELLA

LYON on SELAGINELLA

very rapid; *e*, exospore; *f*, endospore; *m*, undifferentiated part of spore membrane; *p*, outer sculptured part of exospore (so-called perinium); *g*, strained region in exospore. ×375.

FIG. 18. Nearly median section of a megaspore at a later stage than *fig. 6;* the specimen was slightly shrunken, which gives the appearance of a cleft in the exospore traversed by some unbroken strands; the undifferentiated portion of the spore membrane between the exospore and the protoplast (*fig. 16, m*) has been transformed into endospore; at this stage the protoplast increases in diameter rapidly; *e*, exospore; *f*, endospore; *g*, stretched and partially split region in the substance of the exospore. ×375.

FIG. 19. Small portion of the median section of a nearly mature megaspore in the apical region; coats fully formed; the cleft separating the exospore into two layers is probably due to the action of reagents; *e*, exospore; *f*, endospore; *g*, cleft in substance of exospore; *m*, undifferentiated remnant of spore membrane. ×375.

CONTRIBUTIONS TO THE BIOLOGY OF RHIZOBIA. V. THE ISOLATION AND CULTIVATION OF RHIZOBIA IN ARTIFICIAL MEDIA.

ALBERT SCHNEIDER.

IT is with a somewhat guilty conscience that this paper is submitted. It is directly prompted by the fact that numerous inquiries have been received as to details regarding the isolation and cultivation of the root nodule microbe of leguminous plants. While I am now well satisfied that rhizobia are very easily isolated and grown in artificial culture media, I am nevertheless only too conscious of my earlier repeated failures and mistakes, and the failures of others. These facts should have prompted me to publish the finally successful efforts as soon as possible in order to assist and simplify the work of others who were contemplating research along similar lines. In a recent article by GROSVENOR,[1] outlining some rhizobia culture work done by Dr. GEORGE T. MOORE of the Department of Agriculture, the statement is made that "after much labor he (MOORE) isolated the nitrogen-fixing bacteria," from which we are led to conjecture that even at this late date similar difficulties were encountered. With perhaps the one exception of Miss DAWSON, so far as can be ascertained, no investigator has published a detailed description of the methods of procedure in the isolation and cultivation of rhizobia. It is then with the view of correcting this neglect that this paper is submitted.

The rhizobia of the various leguminous plants examined, isolated, and cultivated by the writer, such as those of red clover, white clover, bur clover, sweet clover, garden peas, and alfalfa, gave practically the same results so far as methods were concerned. The early difficulties and failures were due entirely to ignorance with regard to the behavior of these organisms in artificial media, as has been set forth in previous papers. However, in spite of the readiness with which rhizobia are cultivated, the student must observe certain pre-

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[1] GROSVENOR, GILBERT H., Inoculating the ground. A remarkable discovery in scientific agriculture. *The Century Magazine* **68**:831–839 (October). 1904.

cautions in order that satisfactory results may be obtained. After numerous trials I have finally found the following methods to give the most satisfactory and most uniform results.

1. *Securing tubercle-bearing roots.*—Taking it for granted that it is desired to isolate and cultivate the rhizobium of some herbaceous leguminous plant, it is of considerable importance that the roots should be taken from plants growing in soil free from contamination with surface sewage, away from thickly populated areas, as vacant lots in large cities, etc. The object is to obtain tubercles which are comparatively free from foreign bacteria. Experiments with roots and nodules from plants growing in vacant lots in Chicago showed that they were covered externally with multitudes of microbes, which interfered very considerably with the rhizobia experiments.

Select healthy looking plants growing in loose soil, dig up the roots carefully; shake off the dirt very carefully, as the nodules are quite easily removed. By means of a sharp knife cut off root portions having well-developed single nodules or small groups (two or three) of nodules, and place them in a clean sterile container in which to carry them to the laboratory. Do not take roots with nodules that appear quite dark (bluish hue) at the base, as these are old tubercles and are quite badly contaminated with foreign soil microbes. Do not take roots with large tufts of nodules for similar reasons, and for the further reason that these nodule clusters are difficult to clean.

2. *Cleaning and garbling roots.*—At the laboratory look the material over carefully. Remove all foreign vegetable substances. Reject all roots or rootlets showing decay or discoloration. By means of the pocket knife cut away root portions which are undesirable. Now place this carefully garbled material under a faucet and let the water run over it to wash away dirt and sand. Care is necessary, as a strong flow or careless handling may remove the most desirable nodules. Remove all dirt, using a small brush, if necessary, to remove clinging sand and soil particles.

3. *Selecting nodules.*—After this cleansing, look the material over carefully. By means of a pair of small, blunt-pointed, clean, sterile tweezers pick off young, clean-looking, but well-developed nodules and drop them into a small, clean, sterile beaker about half full of thoroughly boiled water (boil this water yourself for half an hour).

About ten nodules should be selected. This is more than is required but allowance should be made for loss through accident.

4. *Brushing and washing nodules.*—Take up each tubercle by means of the blunt tweezers and clean it by means of a sterile camel's hair brush, rinse back and forth in the water, and then drop the cleansed nodules into a second small beaker half full of boiled water. Stir the tubercles about in this second beaker by means of a sterile glass rod or a small section lifter. By means of the section lifter transfer the nodules to a sterile test tube, about half full of boiled water. The camel's hair brush removes many microbes and sand and soil particles which cannot be removed in the following rinsing process.

5. *Rinsing the nodules in the test tube.*—Place the thumb over the mouth of the test tube and shake vigorously for five to ten seconds. Decant the water by holding a sterile wire gauze over the mouth of the test tube (after a little practice the water can be decanted without the use of the wire gauze). Add more water, shake, and decant as before. Repeat this process *ten* times. The object is still further to get rid of microbes clinging to the exterior of the nodules.

6. *Sterilizing the exterior of the nodules.*—After the last rinsing, described in the previous section, add to the test tube, in the place of water, a 5 per cent. carbolic acid or formalin solution and shake vigorously for eight seconds and decant the disinfectant immediately. The object is to kill microbes which may still be present upon the exterior and in the cork tissue and epidermal cells of the nodules. Naturally the antiseptic must be used quickly to prevent it from entering the interior of the nodule and killing the rhizobia themselves. Of these two disinfectants I am inclined to favor the carbolic acid, as it penetrates tissues less readily.

7. *Removing the disinfectant.*—This must be done at once. Rinse in boiled water (as in section 5) *five* times in rapid succession, to get rid of all traces of the disinfectant. The importance of this is evident, for should any considerable trace of the disinfectant remain it would destroy the rhizobia in the next process.. No tests have been made to determine what the resisting power of rhizobia is to these disinfectants. I am inclined to believe that they have considerable resisting power, as is evidenced by their behavior in acid culture

media. Microbes differ widely in this regard. For example, typhoid fever germs and others, survive in a 0.5 per cent. carbolic acid solution.

8. *Crushing the nodules.*—Decant the last supply of water and transfer the tubercles to a thoroughly sterilized watch glass or similar small container (small salt cellar does well), and crush the tubercles with a sterile solid glass rod with rounded end. The crushed tubercles with the moisture that remained from the last rinsing form a pulpy mass. Cover with a sterile cover, such as a glass plate or a watch crystal, and set aside until ready to make the isolation cultures. If some time is required, the covered crush preparation should be placed upon a sterilized portion of the table and covered with a sterilized beaker or bell jar to present contamination by means of air microbes.

9. *Preparations for isolating rhizobia.*—It is assumed that the desired culture media have been prepared in the usual way. I would advise using the usual very slightly alkaline solid media of beef extract, salt, gelatin, and agar. Only sufficient agar should be used to give it solidity (about 1.5 per cent.). A number of test tubes about one-half to two-thirds full of the culture medium, sterilized by the fractional method, should be on hand ready for use. Six of these tubes should be placed in the steam sterilizer so that the medium may be thoroughty liquefied. This will require half an hour or more. They should be placed in the sterilizer about the time that the work of cleaning the tubercles is begun. Three thoroughly sterilized Petri dishes should be on hand ready for use. Number these one, two, and three.

10. *Preparing the test tubes for inoculation.*—When the culture medium in the test tubes is thoroughly liquefied, place the tubes into a beaker of moderately cool water. As soon as the water becomes hot from the heat of the tubes, replace it with fresh moderately cool water. While the tubes are still quite warm to the touch, place them in a beaker of water having a temperature of about 50° C., the object being to keep the medium liquefied. In this considerable care is necessary. The medium must not be too hot, nor should any portion of it be allowed to coagulate. The tubes should feel warm (not hot) to the touch when used. The tubes can be cooled

much more rapidly by holding them under a faucet of running water, but this is not recommended to the beginner because of the danger of cooling the tubes too much. Number four of the tubes and add two with blank labels for reserve purposes in case of accident or special requirement.

11. *Preparations for making the inoculations.*—A lighted Bunsen burner and a platinum wire loop fastened into a glass rod are all that is required. Wipe the table on which the work is to be done with a cloth moistened in some disinfecting solution.

12. *Inoculating tube no. 1; first attenuation.*—Heat the platinum loop in the Bunsen flame, allow it to cool and dip into the root nodule crush preparation, being careful not to include larger portions of tubercles, and introduce the loopful into test tube no. 1, shaking the platinum loop back and forth a few times within the medium. Replace the cotton plug in the tube, heat the loop in the Bunsen flame to a red glow, and place to one side. Now roll the test tube, kept in vertical position, between the hands to mix thoroughly the contents. Roll for five or six seconds.

13. *Inoculating tube no. 2; second attenuation.*—Take two loopfuls out of tube no. 1 and transfer them to tube no. 2; sterilize needle flames as before, and roll tube no. 2 as above.

14. *Inoculating tube no. 3; third attenuation.*—Take two or three loopfuls out of tube no. 2 and transfer to tube no. 3 and proceed as under section 12.

15. *Inoculating tube no. 4; fourth attenuation.*—Take three loopfuls out of tube no. 3 and transfer to tube no. 4 and proceed as under section 12.

Immediately after rolling, the tubes are to be replaced in the beaker of warm water to prevent the media from coagulating. Close application to detail is very important in order to avoid confusion. It is well to rehearse mentally the different manipulations before beginning with the tube inoculations or attenuations.

16. *Plating contents of inoculated tubes.*—Tube no. 1 may be rejected, but it is preferable to set it aside for control observations. Roughly estimated it contains several thousand rhizobia quite evenly distributed. Pour contents of tube no. 2 into Petri dish no. 1 which has been kept in a warm place (about 50° C.), spread the medium

evenly by inclining the dish slightly from side to side and set aside to cool. Pour contents of tube no. 3 into Petri dish no. 2, and contents of tube no. 4 into dish no. 3, spread medium and set aside. After the media in the Petri dishes are well coagulated, place the dishes where they will not be interfered with. They may be placed in an incubator provided the temperature is kept well below the melting point of the culture medium. I have obtained the most uniform results by keeping the plate cultures at the normal temperature of the laboratory.

About the third day the growths will begin to appear as very small light grayish specks; several hundred, more or less, in dish no. 1; twenty-five to thirty in dish no. 2; and perhaps only five to ten in dish no. 3. These are rhizobia cultures, and if the work was well done there will in all probability be no foreign microbes present. The cultures on the upper surface of the medium will be circular in outline, while those within the medium will be spindle-shaped. Growth of cultures is comparatively slow, thus giving ample time for study and to make tube cultures, plate cultures, etc. Tube cultures have been quite fully described in previous papers, likewise the morphology of the rhizobia grown in various artificial media.

Various other methods of isolating rhizobia have been tried successfully, but the method just described is recommended as giving the best results. It is somewhat lengthy in detail, but nevertheless simple in operation. It will be found that the isolation and cultivation of rhizobia is indeed simple, and even the beginner in the study of bacteriology will wonder what might have been the cause of the difficulties encountered by the earlier (1886 and later) investigators of the root nodule organisms. The difficulties however will become somewhat evident on examining the cultures microscopically. The morphological characteristics are found to be entirely changed, so that there is no similarity between the organism as it appears in the nodule and the organism as it appears in the artificial culture media.

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BRIEFER ARTICLES.

THE PHYSIOLOGICAL CONSTANTS OF PLANTS COMMONLY USED IN AMERICAN BOTANICAL LABORATORIES. I.

THE series of papers of which this is the first will give the results of careful study undertaken to find which of our common plants are best adapted for the demonstration of each of the physiological phenomena of plant life. The work is being done in the Laboratory of Plant Physiology at Smith College with the advice of Professor W. F. GANONG. The literature of the various subjects is of course being used; but citation will be omitted for the most part, because the work is all being done *de novo*, and for the sake of teachers rather than investigators. It is intended that the resultant data shall enable teachers of botany to select in each case the best plant for the particular experiment in hand, and to know quantitatively the physiological behavior of each of the common kinds. Since most of the teaching of botany in this country is necessarily done in the winter, when out-of-door plants are not available, only greenhouse plants have been considered; and of these for the most part only the more common kinds, which can be grown in any ordinary room. Exceptions have been made in a few cases where a less common plant has been found to be especially good.

I. CHLOROPHYLL SPECTRA.

In order to compare the spectra of chlorophyll from different plants, it is necessary to adopt some standard solution and some uniform method of examining the leaves. The optimum amount of leaf for giving a clear solution, without filtering, from most leaves was found to be $25^{\text{sq cm}}$ of the leaf in 15^{cc} of 95 per cent. ethyl alcohol, and accordingly I have taken this as the standard solution. A larger proportion of leaf gives a clouded solution, which must either be filtered or be cleared by adding more alcohol. Solutions may be made equally well with methyl or wood alcohol.

The solutions were made as follows: A beaker was fitted with a cork in which three holes were made to allow two test tubes, holding the solutions, and a thermometer to be suspended in the beaker. The beaker was filled with water and set on a tripod over a Bunsen burner. The optimum temperature for extraction of the chlorophyll was found to be 50–55° C., at which the water in the beaker was kept. A tin hood was set over the beaker to exclude all light during the extraction of the chlorophyll. In order to eliminate individual peculiarities, each experiment was done in duplicate for two different plants of each species studied. The time required for extraction of the chlorophyll from leaves of different species varied widely and is recorded for each case in the table following. Except where otherwise stated, half-grown leaves were used, as in most cases they yield the best solution in the shortest time.

It was found that the transparency of living leaves was increased if the air was driven from the intercellular spaces and its place was taken by water. Accordingly in these experiments the leaves were put in water under the air pump for half an hour and examined at once. If they are allowed to stand in water for an hour, leaves like Pelargonium, Begonia, Oxalis, etc., show the characteristic spectrum of incipient decomposition of chlorophyll. In the table the spectrum of a single leaf is given in each case.

The spectra were observed by a Kohl spectroscope, Hoffman form, with a comparison prism; one which is ample for all educational work. The Welsbach light was used.

As is well known, chlorophyll when examined by means of a spectroscope shows in all seven distinct absorption bands which are usually designated by the Roman numerals. I is a broad black band in the red; II is a narrow gray band in the red, near the orange; III is a gray band in the orange near the yellow; IV is a dark band in the middle of the green; V, VI, and VII are broad black bands in the blue, usually absorbing it to such a degree that with a few exceptions they can be seen separately only in a very thin layer of a dilute solution. These seven bands are never all present at one time.

In the following table the letter *d* means the band is dark; *f* that it is faint; *vf* that it is very faint; and *o* that it is absent. Where the spectrum of a living leaf differs from that of the chlorophyll solution its differences are indicated by the bracketed letters. The time required for the extraction of the chlorophyll is given in minutes. The thickness of the layer of the solution in each case was 15^{mm}. "Typical green" means the average unchanged color of chlorophyll.

In the table it will be seen that certain leaves are described as yielding a yellow-green solution. In all these cases the solution gives an acid reaction with litmus paper and the spectrum is of a distinct character from that of the other leaves. These facts, with others developed in the course of this study, show that we must distinguish between two distinct classes of chlorophyll spectra: the "normal chlorophyll spectrum" show-

Name of plant	Time in mins.	Color of solution	Bands						
			I	II	III	IV	V	VI	VII
Abutilon (golden bells) (young leaf)	5	typical green	d	d (o)	f	o	d	d	d
Asparagus Sprengeri	30	light green	d	vf	vf	o	o	d	d
Avena sativa (oats)	5	bright green	d	d	f	o	d	d	d
Begonia coccinea	2	yellow	d	o	o	f	d	d	d
Begonia coccinea	15	brown-yellow	d	d (f)	o (f)	d (o)	d	d	d
Cineraria cruenta	10	bright green	d	o (f)	o (f)	o	o	d	d
Cestrum elegans (young leaf)	5	dark green	d	f (vf)	f	o	d	d	d
Chrysanthemum frutescens	30	pale green	d	f (o)	o	o	d	d	d
Euphorbia pulcherrima (Poinsettia) (young leaf)	10	dark green	d	f (o)	f	o	d	d	d
Ficus elastica (rubber plant)	120	pale green	d	f	o	f	d	d	d
Ficus elastica (young leaf)	15	pale green	d	d (o)	f (o)	f (o)	d	d	d
Ficus repens (young leaves)	10	pale green	d	f (o)	f (o)	o	d	d	d
Fuchsia speciosa	15	yellow-green	d	o (f)	o (f)	f (o)	d	d	d
Hedera Helix (English ivy)	5	dark green	d	d (o)	f (d)	vf (o)	d	d	d
Heliotropium peruvianum (Heliotrope)	30	pale green	d	f (vf)	o (f)	o	d	d	d
Impatiens Sultani	15	bright green	d	f (o)	o (vf)	o	d	d	d
Jacobinia magnifica (young leaf)	30	dark green	d	f	f	o	d	d	d
Lycopersicum esculentum (tomato)	10	pale green	d	vf	vf (f)	o	d	d	d
Oxalis Bowiei	15	yellow-green	d	f	o (f)	d(o)f(o)	o (d)	d	d
Pelargonium domesticum	15	yellow-green	d	f	o (f)	d (o)	d	d	d
Pelargonium peltatum	15	green-yellow	d	f (o)	o (o)	d (o)	d	d	d
Pelargonium zonale	15	brown-yellow	d	f	o (f)	d (o)	d	d	d
Primula obconica	1	bright green	d	f (o)	f (vf)	o	d	d	d
Primula sinensis (Chinese primrose)	15	dark green	d	d (vf)	f	o	d	d	c
Primula verticillata	5	pale green	d	f (o)	f (vf)	o	d	d	d
Raphanus sativus (radish)	2	bright green	d	d (o)	f (vf)	o	d	d	d
Ricinus communis (castor bean)	15	pale green	d	f (vf)	f (vf)	o	d	d	d
Salvia involucrata	30	pale green	d	f (o)	f	o	d	d	d
Senecio mikanioides	15	pale green	d (f)	o	o	o	o	d(o)	d
Senecio Petasitis	15	typical green	d	f	f	o	d	d	d
Tropaeolum majus (nasturtium)	30	typical green	d (f)	o	o	o	d (o)	d (c)	d
Vicia Faba (horse bean)	2	bright green	d	f	f	o	d	d	d

ing bands I, II, III, V, VI, and VII, given by living leaves and by solutions made by extracting the chlorophyll quickly with only a minimum amount of heat; and the "decomposition chlorophyll spectrum," having bands I, II, IV, V, VI, and VII. This decomposition spectrum is given by solutions (*a*) from boiled leaves, (*b*) from leaves which contain acid salts (Oxalis, etc.), (*c*) by solutions made by prolonged immersion of leaves in cold alcohol, (*d*) by solutions in which the chlorophyll is decomposed by adding a drop of hydrochloric acid, or by exposure to direct sunlight for a few minutes, and (*e*) by living leaves after standing in water several hours.

On further decomposition of chlorophyll by light or acids an extra band appears in the green beyond IV and band V in the blue disappears. It is to be remembered that these spectra were given by standard solutions made as described above. With weaker solutions the bands become fainter, and with increasing diluteness bands II and III disappear.

Comparatively few living leaves show all the bands of the normal chlorophyll spectrum in a single leaf, but all leaves give all these bands when two or three are used. The bands in the spectrum of a solution of chlorophyll were compared with those in the living leaf in two ways: (1) by observing the two spectra at the same time, one with direct light and the other by means of the comparison prism; (2) by observing the position of the bands in direct sunlight with reference to the Fraunhofer lines. In all cases the bands appear in exactly the same place in the spectrum of a leaf as in that of a standard solution giving the normal chlorophyll spectrum.

From the above it is plain that the most typical spectra are yielded by those non-acid leaves from which the chlorophyll can be extracted most easily, namely (in the order of their excellence) *Primula obconica, Raphanus sativus, Vicia Faba, Abutilon* (young leaf), *Avena sativa, Cestrum elegans* (young leaf), *Euphorbia pulcherrima* (young leaf), *Lycopersicum esculentum, Primula sinensis,* and *Ricinus communis.*

Another well-known optical property of chlorophyll is its fluorescence, all solutions of chlorophyll being slightly fluorescent. The products of the decomposition of chlorophyll, however, seem to be more fluorescent than chlorophyll itself. A solution of chlorophyll extracted with boiling alcohol from boiled leaves in the light is more fluorescent than a solution of unchanged chlorophyll. Of course some leaves are better than others, and of all the leaves in the above table, the very best are *Jacobinia magnifica, Cineraria cruenta* (the dark-leaved varieties), *Cestrum elegans,* and *Hedera Helix.* Standard solutions from these leaves give a brilliant blood-red fluorescence.—SOPHIA ECKERSON, *Smith College, Northampton, Mass.*

FURTHER OBSERVATIONS ON THE STRUCTURE OF THE STARCH GRAIN.[1]

IN a previous paper (1) on the structure of the starch grain, I showed that the peripheral layer of the potato starch grain breaks and recurves on treatment with certain reagents, much like the cutin layer of an epidermal cell on treatment with sulfuric acid. While I had previously observed that this peripheral layer is stained with certain of the aniline dyes, I thought that the effect might probably be due to the remains of plastids or protoplasmic material, rather than to the presence of a distinct membrane. I am now satisfied, however, that it can be demonstrated that the peripheral layer of the starch grain is a distinct membrane.

It is well known that upon the addition of an iodin solution to unaltered

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[1] Read at the meeting of the Society for Plant Morphology and Physiology, December 1903.

starch grains at the ordinary temperature, the grains are colored blue; while the solution or filtrate remains colorless or some shade of yellow, depending upon the amount or strength of iodine solution that has been used. If on the other hand the grains are triturated with sand (one part of starch to five of sand) for a short time previous to the addition of the water, the filtrate will be colored a deep blue upon the addition of an iodin solution. Heretofore it has been supposed by some that the blue coloration was due to the presence of fine particles which went through the filter and were suspended in the filtrate, while in reality there is a true solution of the starch; or in other words the soluble starch has been liberated from the grain by the rupture of the peripheral layer. A polariscopic examination of the starch solutions, after clarification by means of talcum, showed that they have marked dextro-rotatory properties. The angle of rotation for solutions of corn, wheat, maranta, and potato starch ranged from 0.3814 to 0.8770°. Furthermore, a microscopic examination of the triturated starch shows the grains to be in various stages of disintegration, and this taken together with the behavior of starch toward iodin, as well as the other observations referred to, would indicate that the starch grain consists of a membrane that is insoluble in water at ordinary temperature; and an interior portion which is at least in part soluble in water at ordinary temperature, that is consists of soluble starch or starch that is colored blue with iodin. This technique enables us to differentiate at once the soluble starch present, which heretofore has not been supposed to exist in the unaltered starch grain. As to whether this substance is identical with the granulose of NÄGELI (2) is a problem which remains to be determined. It may be added that this method furnishes a means of separating the constituents in the unaltered grain, and is to be preferred to the methods which have been employed heretofore, of using solutions of ferments or mineral acids, which give rise to altered substances, and hence do not give a true differentiation of the substances as they naturally occur in the starch grain.

This brings us then to consider the views of RASPAIL (3), in connection with those of others, in regard to the nature of the starch grain, which may be summarized as follows:

1. The starch grain consists of a membrane which is insoluble in water, and a more or less soluble content, as pointed out by RASPAIL.

2. It develops from a centric or excentric point, to which layer after layer is added, a view first advanced by FRITSCHE (4), and subsequently enlarged upon by SCHIMPER (5), who demonstrated that its growth is dependent upon the function of the leucoplastids.

3. The content of the grain consists of at least two different substances, as first pointed out by NÄGELI (**2**), and later confirmed by MEYER (**6**), SCHIMPER (**5**), and others, who showed in addition that the structure might be compared to that of sphero-crystalloids.

THE ACTION OF IODIN UPON STARCH.

The effect of iodin upon starch has been the subject of considerable investigation and speculation by both botanists and chemists. MYLIUS (**7**) held to the view that the blue coloration formed on the addition of iodin to starch is due to the formation of a compound of hydriodic acid and starch. MEINEKE (**8**) also contended that hydriodic acid is essential to the formation of the blue color of an iodin-starch solution. STOCKS (**9**), SEYFERT (**10**), and ROUVIER (**11**) are of the opinion, however, that this colored compound does not contain hydriodic acid, the last named investigator having shown that it may be formed in the presence of alcohol as well as water, and all of them agreeing that a true chemical compound (iodid of starch) is formed.

On the other hand, KÜSTER (**12**) and MEYER (**6**) believe that the so-called iodid of starch is not a true chemical compound, but that the iodin and starch are combined in much the same way as the ingredients in an emulsion. This latter view has been more or less sanctioned on account of the statements in the textbooks that the iodin is removed from the combination on treatment with carbon disulfid. My observations, however, show that if the starch is in excess of the iodin (using 1^{gm} of potato starch and 10^{cc} of a solution containing 0.1 per cent. of iodin and 0.5 per cent. of potassium iodid), or if the iodin and starch be in such proportion that all of the free iodin is taken up, and the mixture is dried before adding the carbon disulfid, even on allowing it to act for six months, the carbon disulfid is not colored; that is, does not take up the iodin, the same being true of alcohol and chloroform. This result, taken together with the previous experiments in the treatment of starch with sand and then with iodin, would seem to confirm the view that a true chemical compound is produced by iodin and soluble starch, whether in the grain or in solution.

That the amount of soluble starch varies in the starch grains of different origin can be demonstrated by the treatment of definite amounts of the starches with definite quantities of iodin solution. On treating 0.5^{gm} of the several commercial starches with 2^{cc} of iodin solution (0.1 per cent. of iodin and 0.5 per cent. of potassium iodid), it will be found that there is a marked difference in the intensity of the color in the grains, those of potato and maranta being colored deep blue, while those of corn and wheat are scarcely at all colored, the mixtures being somewhat of a purplish color. These observations seem to accord with the experiments of ROUVIER (**13**), who found that the different classes of starch took up varying amounts of iodin, and are contrary to the statement by STOCKS (**9**) that the shade of color varies with the amount of iodin but not with the different starches. In other words, the shade and intensity of color not only vary according to the strength of iodin solution, but also according to the kind of starch used.

It is well known that if a starch solution be treated with iodin in the cold, a blue coloration will be the result, and that if this solution be then heated the blue color will disappear, but will return on cooling the solution, though less intensely than before. This peculiar behavior of starch and iodin has never been satisfactorily explained. NÄGELI and SCHWENDENER (**14**) consider that the loss of color on the application of heat is due to the production of hydriodic acid; but this does not explain the reappearance of the color on cooling; and so far as I am aware no one has ever demonstrated the presence of this acid. If this acid were present, then according to MYLIUS (**7**) and MEINEKE (**8**), the blue color would remain on heating the solution, since they claim, as already pointed out, that the blue color is due to the presence of this acid. It is thus apparent that there is considerable contradiction in the arguments that have been presented on this subject.

The following experiments tend to explain this phenomenon. If we take 0.5^{gm} of potato starch and mix it with 50^{cc} of water and heat the mixture in an Erlenmeyer flask of about 100^{cc} capacity on a water bath to a temperature of about 80° C. for one hour, and then add 5^{cc} of iodin solution (iodin 0.1 per cent. and potassium iodid 0.5 per cent.) and place a piece of ordinary filter paper, which usually contains starch, over the top of the flask, and then continue the heating until the solution is decolorized, which takes place at about 80° C., the filter paper will be colored blue, showing that some of the iodin has been volatilized. Furthermore, on cooling the solution, as already pointed out, the blue color begins to return at about 65° C. and increases in intensity until at about 40° C. it reaches the maximum; though it is less intense than the color produced when an iodin solution is added to a starch solution cooled to this temperature. These results may be interpreted as showing that iodin forms a compound with starch which is dissociated on the application of heat; that is, at a temperature between 60 and 80° C., part of the freed iodin is volatilized as such, and the amount remaining in solution depends upon the length of time the heat is applied. Also the loss of iodin in this way accounts for the decrease in color of the starch-iodin solution on cooling.

An attempt was made to remove the free iodin from the hot colorless starch-iodin solution by the addition of chloroform, but it was found difficult to handle the material, as chloroform boils at about 60° C. Subsequent experiments, however, showed that unaltered potato starch grains as well as a solution of potato starch would remove the iodin from a chloroformic solution at the ordinary temperature. These experiments were conducted as follows: 5^{cc} of an iodin solution, of the strength already stated, were shaken in a separatory funnel with 25^{cc} of chloroform, and most of the chloroform containing the iodin separated. To this was added 5^{gm} of dried starch. The latter, however, did not take up the iodin from the solution; but on the addition of a small quantity of water (about 10^{cc}) and after shaking the mixture, the starch and iodin combined, and almost all of the iodin in the chloroformic solution may be removed in this way. The addition of 2^{cc} of potassium iodid solution (5 per cent.), even with 0.5^{gm} of starch, causes the iodin to be taken up immediately. The starch in a soluble starch solution also combines immediately with the iodin in a chloroformic solution.

In summing up the observations on the behavior of iodin and starch, it seems to me that we are dealing with a chemical compound of iodin and soluble starch; but that the combination is a feeble one, being easily dissociated upon the application of heat, and the iodin being more or less volatilized. Also the facility with which soluble starch takes up the iodin in a chloroformic solution indicates that the affinity of starch for iodin is considerably greater than heretofore supposed.

STAINING OF THE GRAIN.

While I have obtained at times some beautiful results by the use of anilin stains, it has been impossible for me until now to duplicate some of my earlier results. I have succeeded, however, in developing a method in the staining of wheat starch which yields uniformly satisfactory results. It is as follows: to 0.500^{gm} of wheat starch add 2^{cc} of an aqueous iodin solution (containing 0.1 per cent. of iodin and 0.5 per cent. of potassium iodid); mix well and allow the mixture to stand from 20 to 30 minutes in a porcelain dish or watch crystal; then add 2^{cc} of a saturated aqueous solution of gentian-violet (1^{gm} of gentian violet to 100^{cc} of water); allow this to stand from 12 to 24 hours, examining the grains from time to time by mounting them in water. When the grains are satisfactorily stained, the mixture is transferred to a filter and the excess of stain is removed as quickly as possible by washing the magma with water. The material is then allowed to dry spontaneously or between pieces of bibulous paper.

For examination it is then mounted in Canada balsam, the preparation being permanent for years, as is also the case with the unmounted material.

Corn starch may also be stained by the use of this method, but in the staining of potato and maranta starches it is necessary to use weaker iodin solutions. I have not evolved entirely satisfactory methods, however, for uniformly staining these latter starches.

It may be of interest to state that the foregoing method has certain features which are similar to those of the gentian-violet method used in demonstrating the so-called continuity of protoplasm in the vegetable cell wall (**15**). In the study of the continuity of protoplasm a swelling reagent, such as sulfuric acid, is used and a comparatively short time is consumed in the whole operation; whereas in the method proposed for the staining of wheat starch the water used may be considered a swelling agent acting on the grain during a longer time. The analogy in the results are so striking that students who are interested in the study of the continuity of protoplasm will do well to compare their results on the cell wall with those obtained in the study of the wheat starch grain by the method just described.

The author acknowledges his indebtedness to Miss FLORENCE YAPLE for valuable assistance in the preparation of this paper.—HENRY KRAEMER, *Philadelphia College of Pharmacy.*

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CURRENT LITERATURE.

BOOK REVIEWS.

The water-lilies

The Carnegie Institution has published a sumptuous volume bearing the above title.[1] Mr. Conard, the author, is a Senior Fellow in Botany at the University of Pennsylvania, and has spent four years in the preparation of this monograph. The purpose seems to be to present water-lilies from every botanical standpoint; and so far as this can be done by one man making most diligent use of his time it has been well done. The conception that research is the exhaustive study of a single form, and that all observations should be reported whether pertinent to anything or not, is well exemplified in this volume. The diligence it has demanded is beyond praise; the ideas directing it are questionable. The following statement in the preface is significant: "had the learned doctor (Caspary) of Königsberg assembled his vast knowledge into one connected whole, the present work would be needed chiefly as a translation." As this implies, the volume is the assembling of a vast amount of information about water-lilies; and the scope of it is expressed by the following statement: "It has therefore seemed important to bring together the knowledge of the genus in all of its botanical relations and in its bearings on human life and history."

It is questionable whether any one man is equipped to do this as a contribution; he may do it as a compilation. Just here is the vital difference between research and collected information. It is unfortunate that many who are directing research do not make the distinction. It would reduce publications in bulk and save an immense amount of time consumed in discovering the contribution. In the present work, for example, there have doubtless been made some real and valuable contributions to botany, but there is no way of discovering them without looking through nearly three hundred large pages.

There are eight parts in the volume, each presenting water-lilies from a distinctly different point of view, as follows: (1) history, including oriental literature as well as pre-Linnaean literature; (2) structure, which is for the most part anatomy; (3) development, by which is meant what is usually considered under morphology; (4) physiology; (5) taxonomy; (6) distribution; (7) hybrids and garden varieties; and (8) culture and uses. The taxonomy must have been in a fairly good condition, except perhaps as to nomenclature, for of the thirty-four species recognized only one is described by the author as new.

The thirty plates are works of art, twelve of them being colored. It is a gratification to know that the Carnegie Institution has money enough to spend in this lavish way.—J. M. C.

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[1] Conard, Henry S., The water-lilies, a monograph of the genus Nymphaea. 4to. pp. xiii+279. *pls. 30. figs. 82.* The Carnegie Institution of Washington. 1905.

French instruction in botany

BONNIER and SABLON[2] have published the first volume of a text-book of botany for the use of classes in universities, and in schools of medicine, pharmacy, and agriculture. The first impression is that of great bulk, and it is almost beyond belief that such an amount of material can be absorbed by undergraduate students in a continuous course. The authors, however, are teachers of large experience, and must know what the French situation demands and how much the French student can endure. The illustrations are for the most part excellent, and are said to be published in this volume for the first time. This means a large stock of new illustrations of well-known structures; and this stock really constitutes the chief contribution of the volume.

The text is clear and well organized; and the distinct paragraphing is all that could be desired in a text for elementary students. The material is brought together from every direction, making the volume a compendium of information concerning the topics presented. However, it gives an impression of voluminousness and diffuseness rather than of logical and compact presentation.

The four parts of this first volume are very unequal. The first part (138 pp.) consists of a general introduction, beginning with the characteristics of living things and gradually approaching plants. The second part (602 pp.) presents the morphology of angiosperms, under the following topics: leaf, stem, root, flower, and development. In this part the emphasis is laid upon anatomy and what one may call for convenience the older morphology.

The third part (524 pp.) deals with the families of angiosperms, that dreariest of all wastes for the elementary student, but perhaps demanded by the French schools. Just what is done with this part of European text-books has always been a mystery to the majority of American teachers. The fourth part (62 pp.) presents the gymnosperms and closes the volume.

A noticeable feature of the presentation is the singular blindness to published work. In an elementary text this seems natural, and usually would occasion no remark; but this large compendium cites literature, and further dignifies the citations by collecting them in a list at the end of each part. The four lists include 108 titles; and when they are examined, it is evident that the selection has been at random, without reference to the importance of the papers or to the representative character of the lists. In fact, the impression upon students and colleagues would be far better if no citations had been attempted.

Taking the book as fairly representative of botanical instruction in French schools, one may conclude that the instruction includes more of the old botany than the new; presents a mass of details rather than general organizing ideas; and calls for diligence and a good memory rather than for initiative.—J. M. C.

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[2] BONNIER, GASTON, et SABLON, LECLERC DU, Cours de botanique. I. Phanérogames. 8vo. pp. iv+1328. *figs. 2389*. Paris: Librairie générale de l'enseignement. 1905.

MINOR NOTICES.

A SECOND REPORT to the Evolution Committee of the Royal Society has been made by BATESON, SAUNDERS, PUNNETT, and HURST,[3] under the subtitle "Experimental studies in the physiology of heredity." About two-thirds of this report deals with plants and the rest with poultry. The plants used were Datura, Matthiola, *Salvia Horminum*, *Ranunculus arvensis*, Pisum, and *Lathyrus odoratus*, the most attention being given to Matthiola, Pisum, and Lathyrus. The numerous experiments present too many important details to permit of adequate review, but several features deserve special mention. In Matthiola it is found that two races which are constantly glabrous when pure-bred may, on crossing, produce hoary canescent offspring, and that in certain combinations this hoariness is coupled with purple flower-color, both the hoariness and the purple color being recognizable as atavistic characters. These reversions occur invariably when cream or white-flowered glabrous stocks are crossed with those of any other color; but the various sap-colors (e. g., purple, flesh, red, copper, etc.) crossed with each other conform strictly to Mendelian expectation in regard to hoariness, though with respect to color there is a complication introduced by the presence of the atavistic purple in addition to the two parental types. Very similar reversions and half-reversions are also found regularly in sweet peas. Generally white was found recessive to all sap-colors, and cream recessive to both white and the sap-colors, so that cream-colored sweet peas are always homozygous and can produce nothing but cream-colored offspring. With one exception, white crossed with any sap-color gave reversion in the first generation to purple or to "painted lady" (red bicolor). This occurrence of two reversionary types gives rise to complications which have not yet been well worked out.

Perhaps the most novel result is seen in the different behavior of two white-flowered strains known to the trade as "Emily Henderson" and distinguishable from each other only by the form of the pollen which is either long or round. The long pollen is generally characteristic of the various strains of sweet peas, while the round appears to be limited to this one strain of "Emily Henderson," and to the various dwarf sweet peas or "Cupids" which are believed to have sprung from it. When any pure-bred white-flowered strain having long pollen was crossed with any colored strain the first-generation hybrids were always purple. When white with round pollen was crossed with blue sap-colored, it likewise produced F_1, but when crossed with red sap-colored the first generation was always painted lady. When pure-bred white "long" was crossed with pure-bred white "round," the first generation hybrids were sometimes purple, sometimes painted lady. If, on the other hand, *extracted* whites are used, whether they have long or round pollen, no reversion takes place when they are crossed together, and F are all white-flowered.

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[3] BATESON, W., SAUNDERS, Miss E. R., PUNNETT, R. C., and HURST, C. C., Reports to the Evolution Committee of the Royal Society. Report II. Experimental studies in the physiology of heredity. 8vo. pp. 154. London: Harrison & Sons. 1905.

This difference of behavior between pure-bred and extracted whites is suggestive of CASTLE'S[4] recently reported results with guinea-pigs, in which several white individuals showed the presence of latent black pigment by transmitting it to a certain proportion of their offspring. The whites extracted from the non-black members of these crosses proved to be pure albinos incapable of producing black offspring.—G. H. SHULL.

MACDOUGAL[5] has published, with the cooperation of A. M. VAIL, G. H. SHULL, and J. K. SMALL, some of the results of the study of Oenothera that have been made at the New York Botanical Garden. Thus far the attempt to find *O. Lamarckiana* in its native state has been unsuccessful, although herbarium and other records make it "fairly conclusive that it is a true and independent species, native to America." That this species has remained unchanged for over a hundred years is certain. *O. grandiflora*, *O. Lamarckiana*, and *O. argillicola* are more closely related to one another than any of them are to *O. biennis.* An expedition by S. M. TRACY undertaken for the purpose of the rediscovery of *O. grandiflora* was successful. *O. biennis*, as commonly understood, includes two or more elementary species, and *O. cruciata* embraces three such species. These facts make it evident that the resolution of a "species" into its elementary species is the first requisite for the study of mutation, casual field observations being almost worthless. Careful studies were made of hybrids of *O. Lamarckiana* with *O. cruciata* and *O. biennis.* The occurrence of known mutants, as *O. rubrinervis*, *O. albida*, *O. gigas*, etc., from a culture of *O. Lamarckiana* was observed, showing that the mutative period of the latter is still present, and that the same mutants may occur in diverse environments. Some hitherto unknown mutants were also observed. Results of statistical studies are set forth in some detail; while the mutants show great variability, there is yet a great gap between them and the parent form. A summary of this paper[6] is given in another place. —H. C. COWLES.

WHITE[7] has published a preliminary report on the Hymeniales of Connecticut, illustrated by half-tone reproductions of excellent photographs. The purpose of the report is to compile, so far as possible, a complete list of native species, with notes as to the characteristics of the genera.—J. M. C.

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[4] CASTLE, W. E., Heredity of coat characters in guinea-pigs and rabbits. Papers of the Station for Experimental Evolution at Cold Spring Harbor, New York, no. 1. pp. 78, *pls. 6.* Washington: Carnegie Institution of Washington.

[5] MACDOUGAL, D. T., VAIL, A. M., SHULL, G. H., and SMALL, J. K., Mutants and hybrids of the Oenotheras. Pp. 57. *figs. 13. pls. 22.* Carnegie Institution of Washington, Publication No. 24. Washington, 1905.

[6] MACDOUGAL, D. T., Studies in organic evolution. Jour. N. Y. Bot. Gard. **6**:27–36. 1905.

[7] WHITE, EDWARD ALBERT, A preliminary report on the Hymeniales of Connecticut. State Geol. and Nat. Hist. Survey, Bull. 3. pp. 81. *pls. 40.* 1905.

Clinton[8] has described the fifty species of smuts known to occur in Connecticut, introducing the descriptions by a general account of the characters of the group. Numerous drawings and reproductions of photographs illustrate the paper.—J. M. C.

Schaffner[9] and his associates have made an ecological study of a glacial lake near Columbus, Ohio. Many of the typical bog plants, such as sphagnum, are absent; but some, as Decodon, are present in abundance.—H. C. Cowles.

Osgood,[10] in an account of a reconnoissance in Alaska mainly concerned with birds and mammals, gives notes on the distribution of the more characteristic plants that will interest plant geographers.—H. C. Cowles.

NOTES FOR STUDENTS.

Faull[11] has made a cytological investigation of the ascus, studying the origin of the asci from the ascogenous hyphae, and their nuclear divisions and spore formations in a number of hitherto uninvestigated Ascomycetes, particularly *Hydnobolites* sp., *Neotiella albocincta*, and *Sordaria finicola*. He has examined thirty-six species in order to determine how the ascus originates from the ascogenous hyphae. He finds numerous cases in which the ascus does not arise from the penultimate cell of the recurved tip of an ascogenous hypha, as described for various Discomycetes but not for mildews. Maire and Guilliermond have fully described deviations from this type, and Faull in his examination finds that such is invariably the case in only eleven species. The ascus may bud out from the penultimate cell, although occasionally the septum between it and the terminal cell is lacking. The absence of this wall cutting off a uninucleate terminal cell at the tip seems to be the most frequent departure from the conventional type, being well illustrated by *Genea hispidula*, in which form the wall is always wanting. In some forms the asci arise from the terminal cell of the ascogenous hyphae and in others apparently from any cell. In every case definitely determined, the uninucleate stage of the ascus arises by fusion of two nuclei, which may be daughter nuclei or sister nuclei, either before or after entering the ascus. Extranuclear granules, staining like nucleoli and evidently nutritive in character, were observed in the neighborhood of nuclei in the asci. The constant appearance of these bodies is a characteristic feature at different stages. Similar bodies were also observed in ripe spores.

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[8] Clinton, George Perkins, The Ustilagineae, or smuts, of Connecticut. State Geol. and Nat. Hist. Survey, Bull. 5. pp. 45. *figs. 55.* 1905.

[9] Schaffner, J. H., Jennings, O. E., and Tyler, F. J., Ecological study of Brush Lake. Proc. Ohio State Acad. Sci. **4**:151–165. 1904.

[10] Osgood, W. H., A biological reconnoissance of the base of the Alaska Peninsula. Pp. 86. *pls. 5. maps 2.* North American Fauna No. 24. Washington. 1904.

[11] Faull, J. H., Development of ascus and spore formation in Ascomycetes. Proc. Bos. Soc. Nat. Hist. **32**:77–113. *pls. 7–11.* 1905.

This author believes that the spindles are of intranuclear origin, while the centrosomes and asters with which they are associated are of extranuclear origin. The nucleus occupies the dense cytoplasm which becomes differentiated about it. In Neotiella and Sordaria the protoplasm about the exceedingly large nucleus streams out irregularly into the foamy cytoplasm above and below; while the nucleus of Hydnobolites is surrounded by a hyaline area possessing a radiate structure. The fibers of the broad spindle taper in Neotiella and Sordaria to terminate in two very minute centrosomes, from which radiate very fine rays, often so fine as not to be easily demonstrable. The astral rays in Hydnobolites are long and coarse and easily observed. These rays stain differently from the centrosome, and there is no evidence that they are outgrowths from or that they are absorbed by the centrosome at the time of their disappearance. In Hydnobolites the chromosomes are very small, while those of Neotiella are large horseshoe-shaped bodies. The number of chromosomes may vary in different species, being four or five in Hydnobolites and six or seven in Neotiella. The method of spore formation is particularly interesting, as it does not at all correspond with that described by HARPER. A plasma membrane is organized about the sporeplasm before the nuclei pass into a resting condition. This membrane is formed entirely distinct from the astral rays, which do not appear to enter into its composition. The long thick astral rays of Hydnobolites change position, but so as to be thrown farther apart. A fusion is an impossibility. These rays may be seen distinctly even after the spores are delimited. The sporeplasm is delimited from the rest of the cytoplasm by the differentiation of a certain hyaline finely granular area. This specialized hyaline layer of protoplasm begins just outside the centrosome and proceeds progressively until it entirely encloses the sporeplasm. A plasma membrane is subsequently formed from or in this limiting area. Concurrently with this first membrane a second membrane is formed in contact with the first, which lines the cavity in which the spore is to lie. FAULL suggests that these membranes may arise by a cleavage in the limiting area, caused by its increased growth and differentiation and a pull on the part of the nucleus. Both plasma membranes are intimately concerned in laying down the spore walls between the opposed membranes. The time of the formation of the spore walls is variable in the different species and bears no relation to the delimitation of the sporeplasm. Multinucleate spores are usually septate, but those of Sordaria are unseptate. The multinucleate condition arises, at least in Sordaria, by karyokinetic division of the nucleus of the spore. Where a septum is formed cutting off an enucleated portion, as the tail of the Podosporas, its organization is due to the direct action of the nucleus on the cytoplasm, since septa are formed only in the immediate neighborhood of nuclei. The author favors the view that homologizes the ascus with a zoosporangium of the Oomycetes, as an argument in favor of the origin of the Ascomycetes from the Oomycetes. He does not believe that the difference between the method of spore formation in the ascus and sporangium is so great as to prevent an assumption of their homology.—J. B. OVERTON.

WASIELEWSKI[12] has undertaken by theory and by his own experimental data to dispel what he calls the "Mitosendogma" of HEGLER. This so-called dogma consists in a discrimination between mitosis and amitosis, in which the former is regarded as the only process by which nuclear division can be accom plished and the potential qualities retained. According to this view, fragmentation of the nucleus is held without exception to involve loss of regeneration capacity. According to the author this dogma ignores the fact that amitosis is just as normal for many lower organisms as mitosis is for the higher. Further, the idea that the nucleus is the bearer of the hereditary qualities is a theory only, though so widely accepted as to be regarded often as a fact. A study of the influence of chloral hydrate, especially, on nuclear and cell division leads the author to conclude that both may occur amitotically in higher plants. This tendency to amitosis apparently dormant may be aroused by stimulants. Degeneration as a consequence of amitosis was not observed, and cells so divided can resume mitotic divisions without loss of capacity for development. Two modes of amitotic nuclear divisions were observed: *Diatmese* (dissection) and *Diaspase* (distraction). Thus, the latter are regarded as members in a phylogenetic series which includes mitosis and from which amitosis does not fundamentally differ. In the second section the author goes so far as to state that a given nucleus may begin its division mitotically and complete it amitotically. The physiological equivalence of mitosis and amitosis is advocated. NĚMEC's paper, in which the author is believed to have confused amitosis with nuclear fusion, appeared after this second section had gone to press. The author promises a paper in which this matter will be considered.—RAYMOND H. POND.

A RECENT PAPER by LONGO[13] describes the nutrition of the embryo sac in the Cucurbitaceae, especially in *Cucurbita Pepo*. The principal point of interest is the behavior of the pollen tube, which, after discharging the usual function connected with fecundation, serves as an organ of food absorption. About the time the pollen tube reaches the embryo sac, an enlargement occurs in it a short distance from its extremity. After fertilization, slender branch-like outgrowths proceed from the enlargement and grow along the nucellus to enter a specialized region of the outer integument. This region is composed of cells containing food material, as starch, which is extracted by the haustorial prolongations of the pollen tube. In the meantime the epidermis of the nucellus, or its outermost layer of cells, becomes cuticularized and the cells near the chalaza become suberized. Thus it would seem that the path of the food material is through the vascular bundle of the outer integument to the nutritive tissue, and from thence to the embryo through the haustorial prolongations and the pollen tube. The remainder of the paper is occupied (1) with an account of the changes that occur

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[12] WASIELEWSKI, W. VON, Theoretische und experimentelle Beiträge zur Kenntniss der Amitose. Jahrb. Wiss. Bot. **38**:377–420; **39**:581–606. *figs. 10.* 1904.

[13] LONGO, BIAGIO, Osservazioni e ricerche sulla nutrizione dell'embrione vegetale. Annali Botanica **2**:373–396. 1905.

in the endosperm and integuments during seed development; and (2) with reviews of various papers dealing with different methods of embryo sac nutrition. While LONGO's paper was in press, that of KIRKWOOD[14] appeared. A footnote by LONGO states that his observations and KIRKWOOD's do not agree in respect to the presence of a micropyle and the passage of the pollen tube through it in *Cucurbito Pepo*. LONGO maintains that in this species no micropylar canal is present, but that the pollen tube grows between the cells of the nucellus. As a micropyle is present in other species, he thinks KIRKWOOD has made a mistake in determination.—F. H. BILLINGS.

TWO INVESTIGATORS have published preliminary announcements of the results of a study of fertilization and the associated structures in *Juniperus communis*. NORÉN[15] says that during the summer following pollination the pollen tube grows into the tissues of the nucellus, but fertilization does not occur until the following year. The two male cells are equal in size. A ventral canal nucleus is formed, but it is not separated from the egg by a wall. The male cell is still surrounded by its cytoplasm when it enters the egg, but slips out from it as the sex nuclei come into contact. There are eight free nuclei in the proembryo before walls begin to be formed.

SLUDSKY's[16] announcement was hastened by that of NORÉN. He reports that the entire development of the sexual generation, from pollen to fertilization, and from megaspore to embryo, lasts only one summer; the growth of the pollen tube lasting only two to six weeks. A ventral canal nucleus is formed, but disappears before fertilization. Centers with radiations are prominent in the egg; and are caused by the diminishing pressure which accompanies the formation of vacuoles. There are never more than two male cells in a pollen tube. The multicellular complex described for Cupressus by JUEL is regarded as due to abnormal material. Not more than two male cells ever enter the egg, and only one functions in fertilization. The nucleus of the male cell is still surrounded by its cytoplasm after it enters the egg. During fertilization there can be seen in the upper part of the egg the tube nucleus, neck cells, and even cells of the overlying tissue. In regard to the fusion of sex nuclei, the author agrees with NORÉN, and in regard to the embryo he agrees with STRASBURGER.—C. J. CHAMBERLAIN.

LILIENFELD[17] ascribes the indecisive results obtained by NEWCOMBE and RHODES in their study of the chemotropism of roots to inadequate methods. Among the sources of error unprovided for by them the author mentions (1)

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[14] KIRKWOOD, I. E., The comparative embryology of the Cucurbitaceae. Rev. in BOT. GAZETTE **39**: 73. 1905.

[15] NORÉN, C. O., Ueber Befruchtung bei *Juniperus communis*. Vorläufige Mitteilung. Arkiv. Bot. Svensk. Vetens. Akad. **3**: pp. 11. 1904.

[16] SLUDSKY, N., Ueber die Entwickelungsgeschichte des *Juniperus communis*. Vorläufige Mitteilung. Ber. Deutsch. Bot. Gesells. **23**: 212–216. *pl. 6.* 1905.

[17] LILIENFELD, M., Ueber den Chemotropismus der Wurzel. Ber. Deutsch. Bot. Gesells. **23**: 91–96. 1905.

traumatic disturbance due to resistance offered by gelatin surface to entering root; (2) positive aerotropism because of the stratum of air between the gelatin blocks; (3) diffusion of stimulating substances from one block to the other. In the author's improved method, only one large circular block of gelatin is used. After a cavity is made in the center of the block, the seedlings are planted in the gelatin at varying distances from the margin of the cavity, and into the latter the stimulating substance is then placed. By using this method negative responses were obtained in cases corresponding to which positive responses were obtained with the method of NEWCOMBE and RHODES. The former responses are regarded as chemotropic, while the latter are considered traumatropic.—RAYMOND H. POND.

THE GREATEST GAP in our knowledge of the morphology of Coniferales is in connection with the Araucarineae. THOMSON,[18] whose interesting work on the megaspore-membrane of gymnosperms has been noted, has published a preliminary statement of the results of his investigation of the tribe. The conspicuous features are the supernumerary nuclei found in the pollen tube, in one case reaching thirty in number; the failure of the pollen grains to reach the micropyle, lodging at the distal end of the scale and sending out their tubes from that point; the unusual freedom of the nucellus from the integument; and the peculiar arrangement and development of the archegonia, not described in this notice. The anatomical details also indicate a peculiar isolation of the tribe among Coniferales. The forthcoming monograph will be looked for with great interest. —J. M. C.

SCOTT[19] has discovered the sporangia of *Stauropteris Oldhamia*, a common plant of the English Coal-measures, which has been regarded as a much branched and naked rachis of a fern leaf. The ultimate branchlets are exceedingly numerous and slender, "occurring in dense, faggot-like groups." SCOTT now finds that these branchlets bore terminal sporangia of the ordinary fern type, except that there is a terminal stomium and no annulus. There is a suspicion that these may be the microsporangia of a pteridosperm, especially since the ovules of that group, so far as found attached, are also terminal upon ultimate branchlets. Another suggestion would be that such a position of sporangia attained among true ferns accounts for its occurrence among pteridosperms.—J. M. C.

IN A LIST of some unrecorded stations for New Zealand plants, COCKAYNE[20] includes *Carex Darwinii urolepis*, a plant hitherto recorded as occurring only in Patagonia, thus adding another form common to the floras of South America and New Zealand.—J. M. C.

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[18] THOMSON, R. B., Preliminary note on the Araucarineae. Science N. S. **22**:88. 1905.

[19] SCOTT, D. H., The sporangia of *Stauropteris Oldhamia* Binney. New Phytol. **4**:114–120. *figs. 2.* 1905.

[20] COCKAYNE, L., Some hitherto-unrecorded plant habitats. Trans. N. Z. Inst. **37**:361–367. 1905.

NEWS.

PROFESSOR EDUARD TANGL, University of Czernowitz, died recently at the age of fifty-seven years.

PROFESSOR LEO ERRERA, director of the Botanical Institute of the University of Brussels, died August 1 at the age of forty-seven years.

THE TOTAL APPROPRIATION for the U. S. Department of Agriculture for the year 1905 is $5,944,540. This includes $1,337,740 for the Weather Bureau.

DR. ROBERT BRAITHWAITE completed on his eighty-first birthday his monograph, the *British Moss Flora*, on which he has been engaged for twenty-five years.

EDWARD W. BERRY is studying the fossil flora of Maryland. His new address is in care of the Maryland Geological Survey, Johns Hopkins University, Baltimore.

THE NEW YORK Botanical Garden has purchased the entire mycological collections of Mr. GEORGE MASSEE, on which largely was based his work on *British Fungi*.

IT WOULD NOT be amiss for the editor of the *Zeitschrift für Pflanzenkrankheiten* to revise the list of collaborators on its title page. One at least has been dead these ten years.

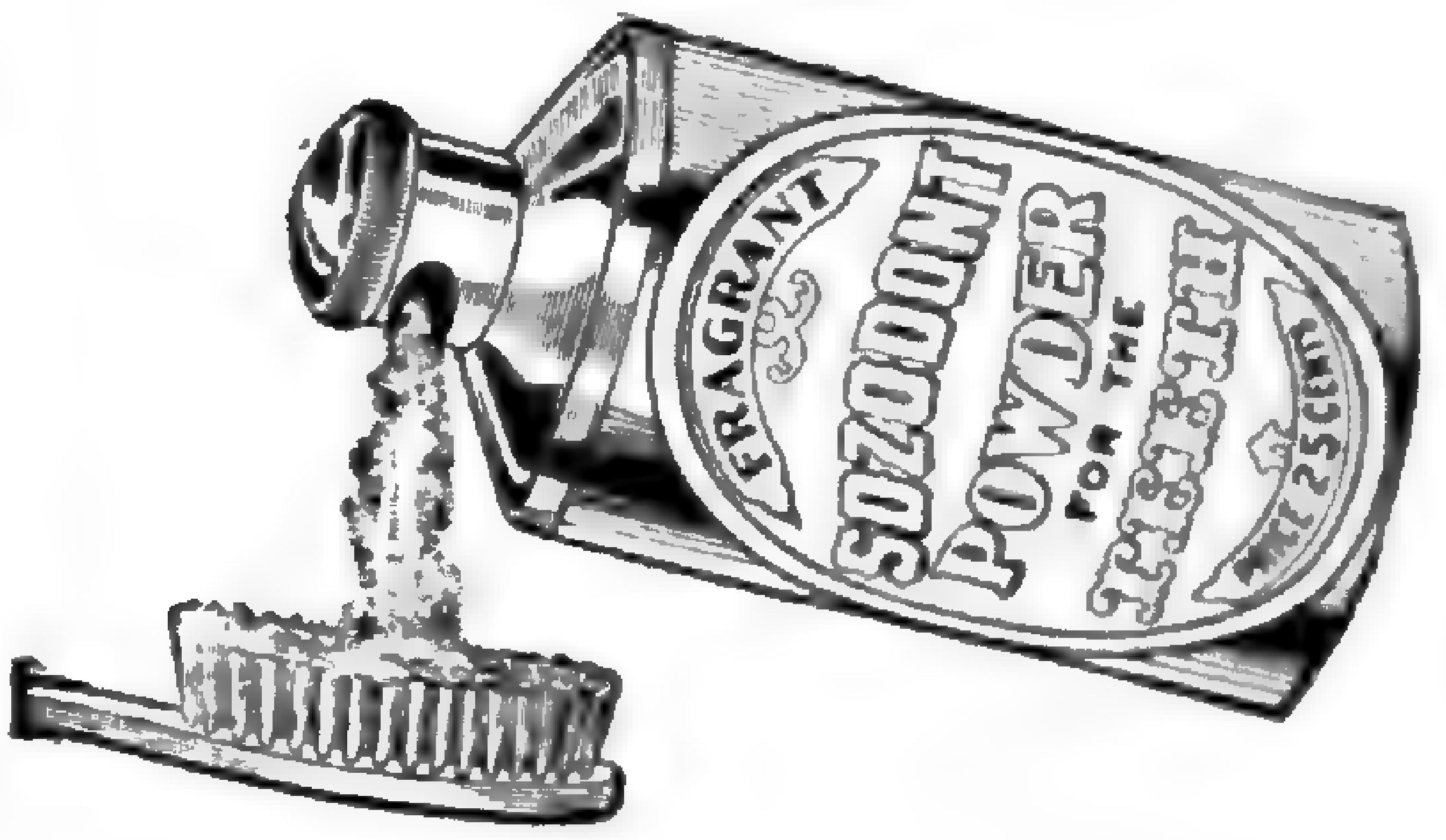
WE LEARN from the *Journal of Botany* that Mr. GEORGE MURRAY has been compelled by failing health to resign his curatorship in the department of botany of the British Museum.

AN ADMIRABLE SUMMARY of the relation of plant physiology to the development of agriculture is presented by ALBERT F. WOODS, pathologist and physiologist of the Bureau of Plant Industry, in the Yearbook of the U. S. Department of Agriculture for 1904 (pp. 119–132), just issued.

THE ITALIAN Botanical Society devoted a special session at its recent general meeting in September to the memory of Professor F. DELPINO, of Naples, who died last May. The meeting was held in Vallombrosa, where DELPINO was formerly professor. A eulogy was pronounced by Professor BORZI, who was earlier his pupil and then his assistant.

PAUL PAREY (Berlin) announces that the third edition of the *Handbuch der Pflanzenkrankheiten* is in preparation by Professor Dr. P. SORAUER, who has associated with him Professor Dr. G. LINDAU and Dr. L. REH. They will treat respectively the plant and animal parasites which occasion diseases in plants, the original author, Dr. SORAUER, confining himself in this edition to the diseases due to conditions of weather, position, soil, and cultivation. The new work will appear in three volumes.

[OCTOBER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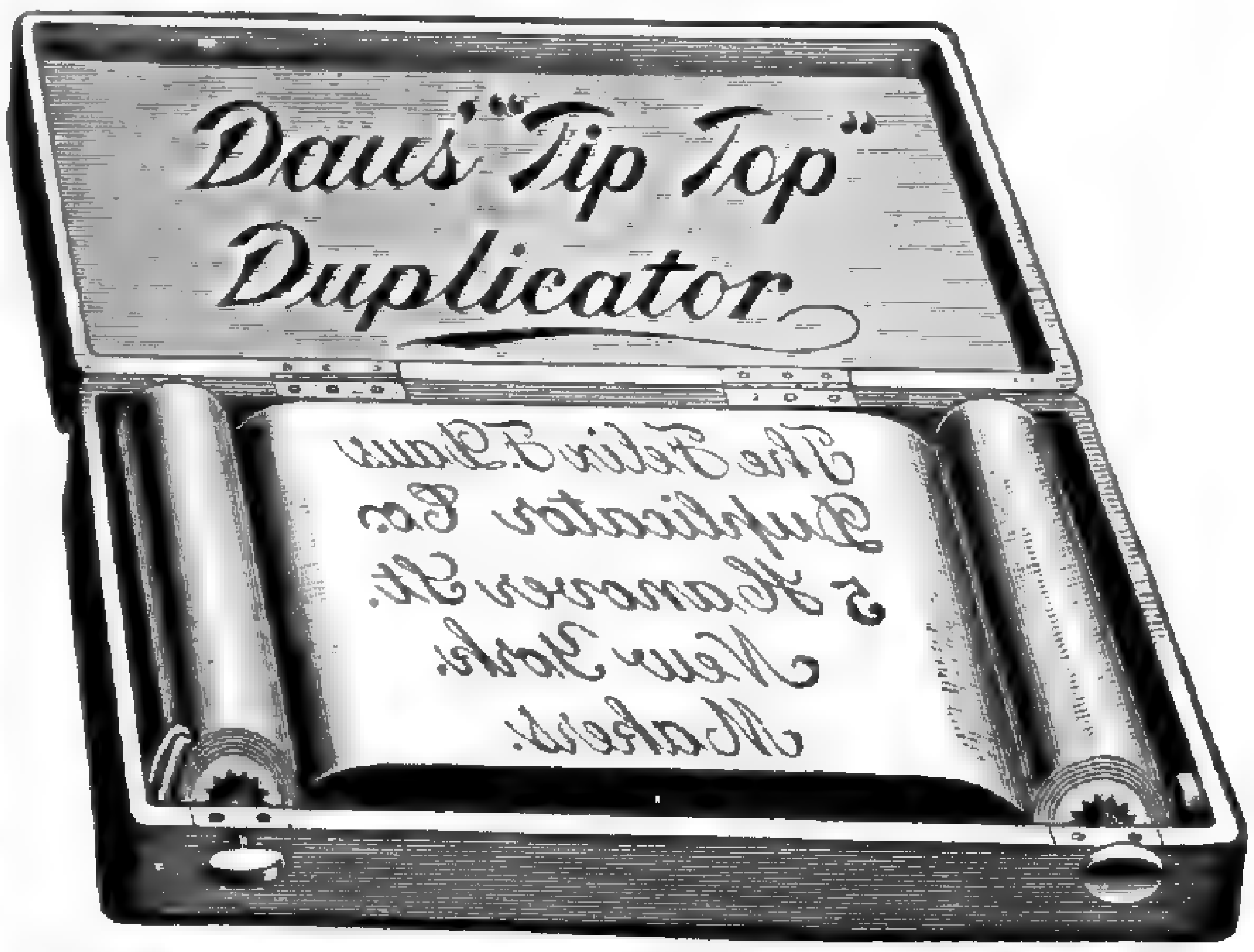

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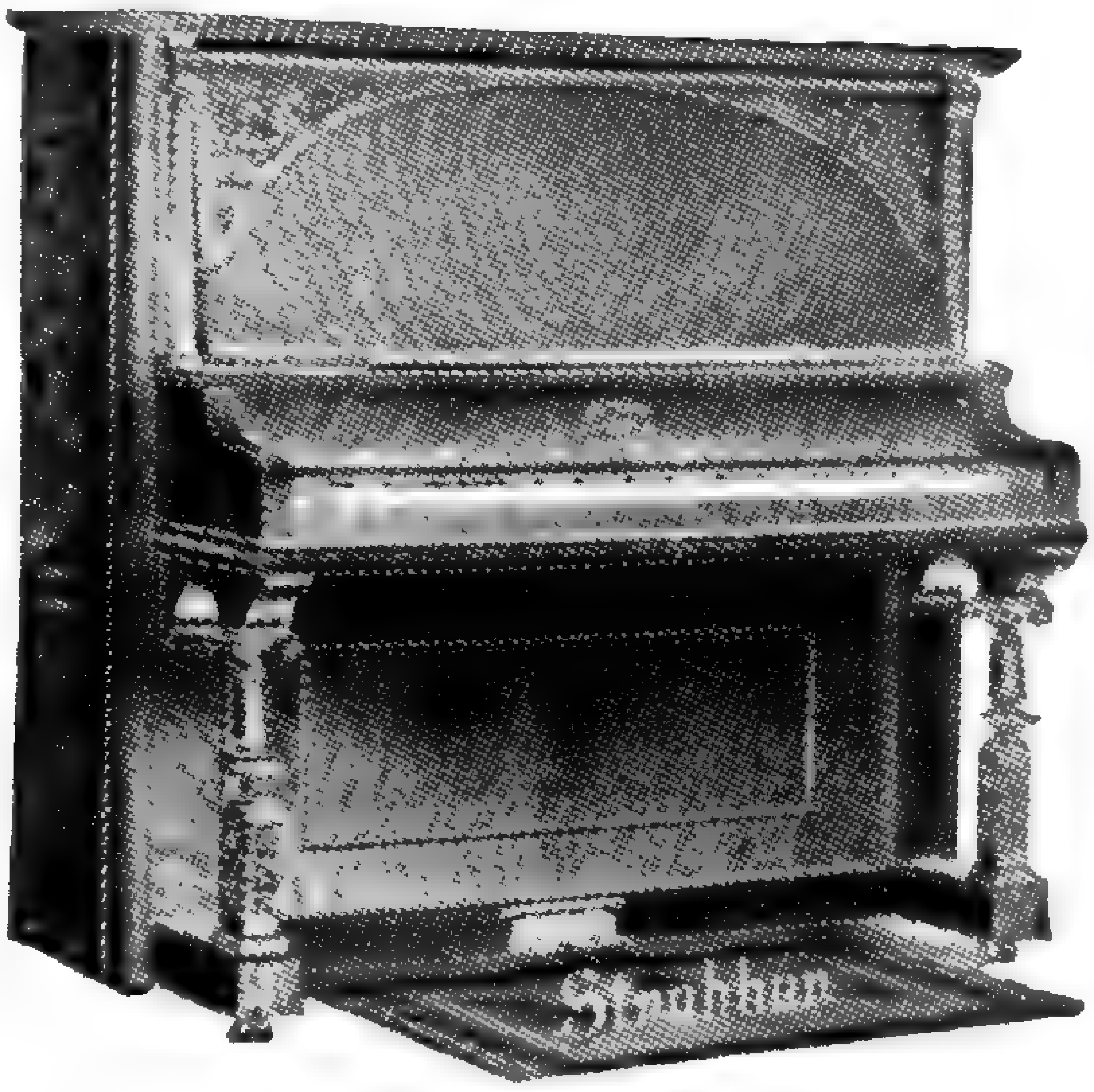

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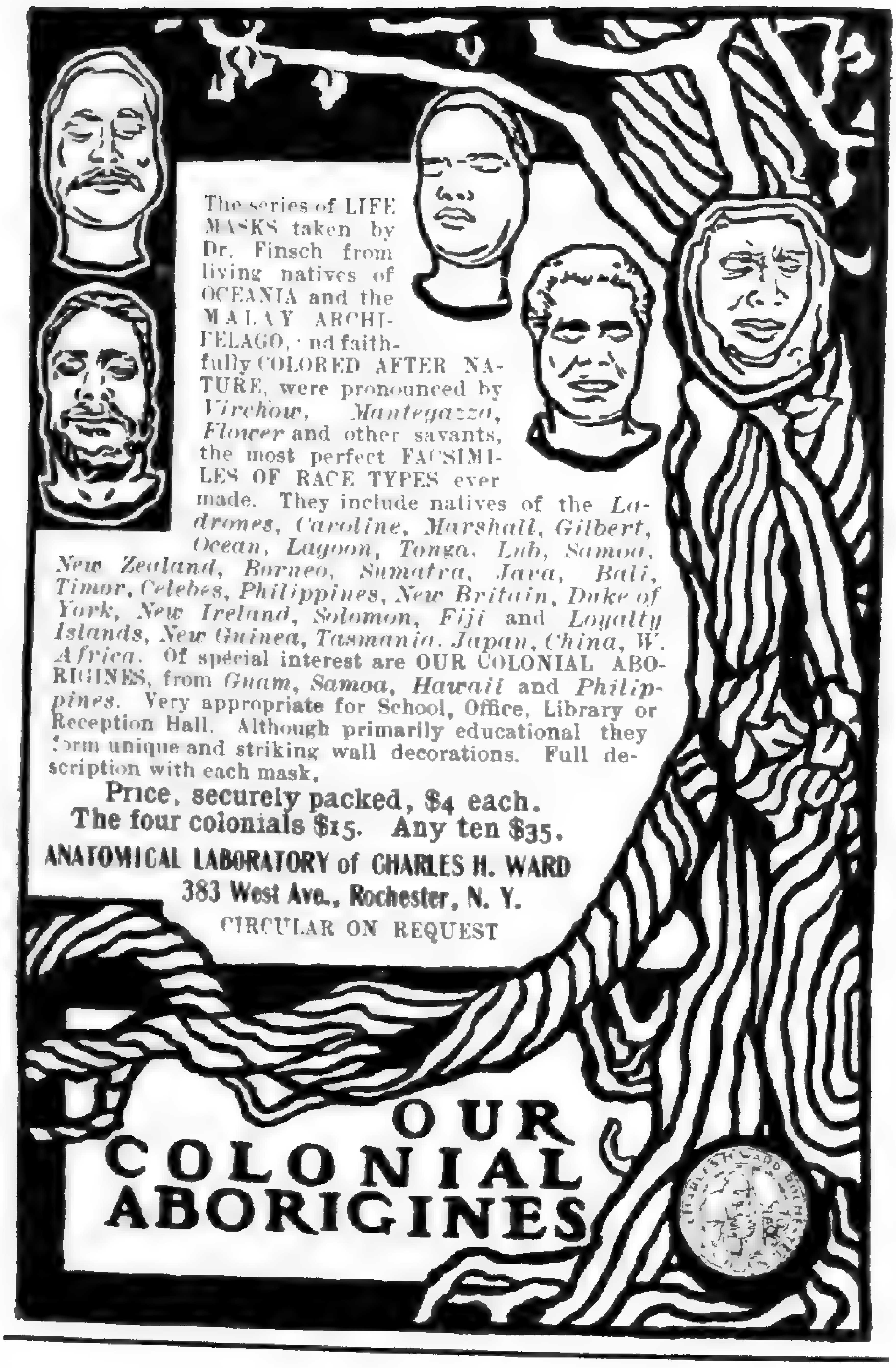
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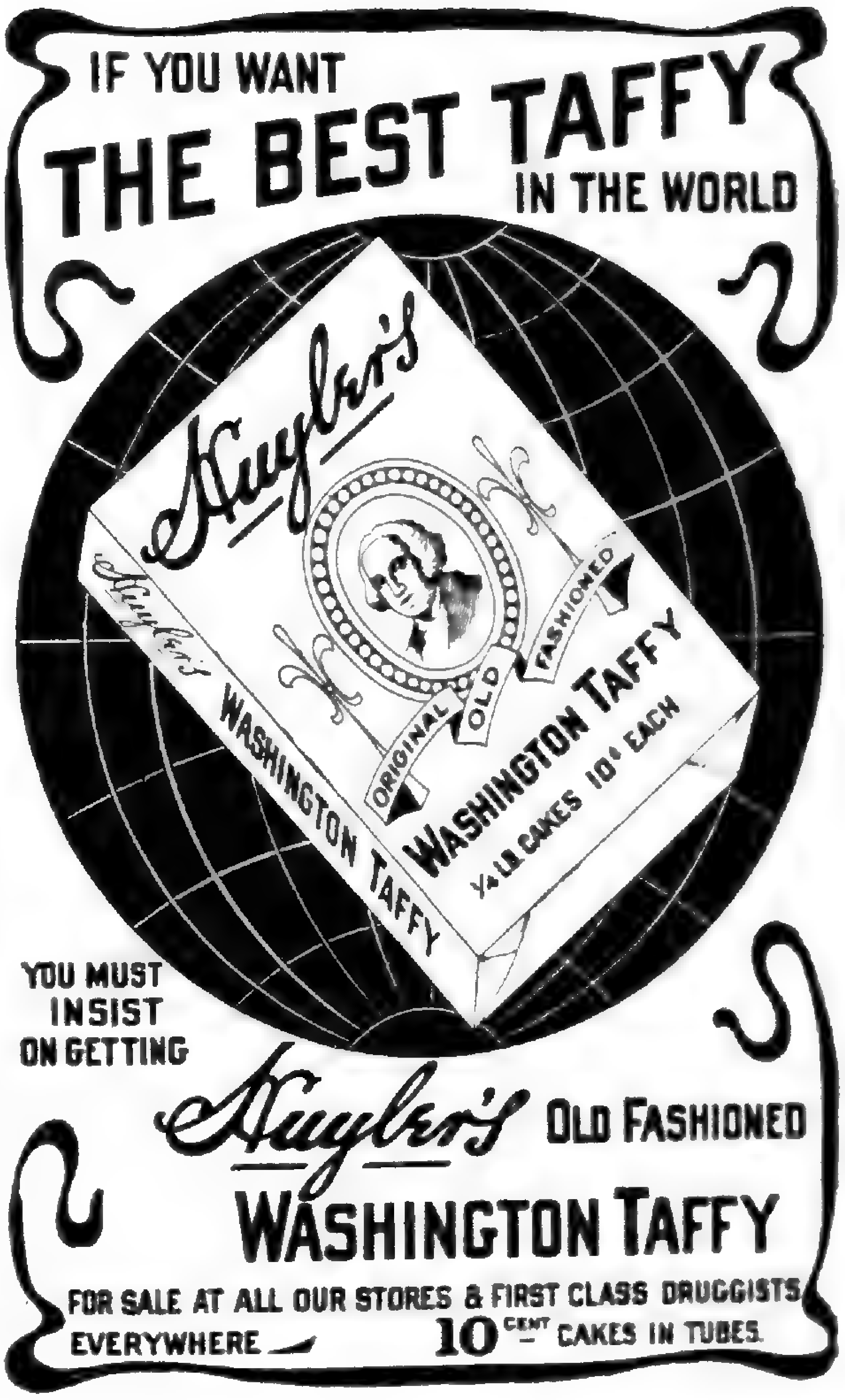
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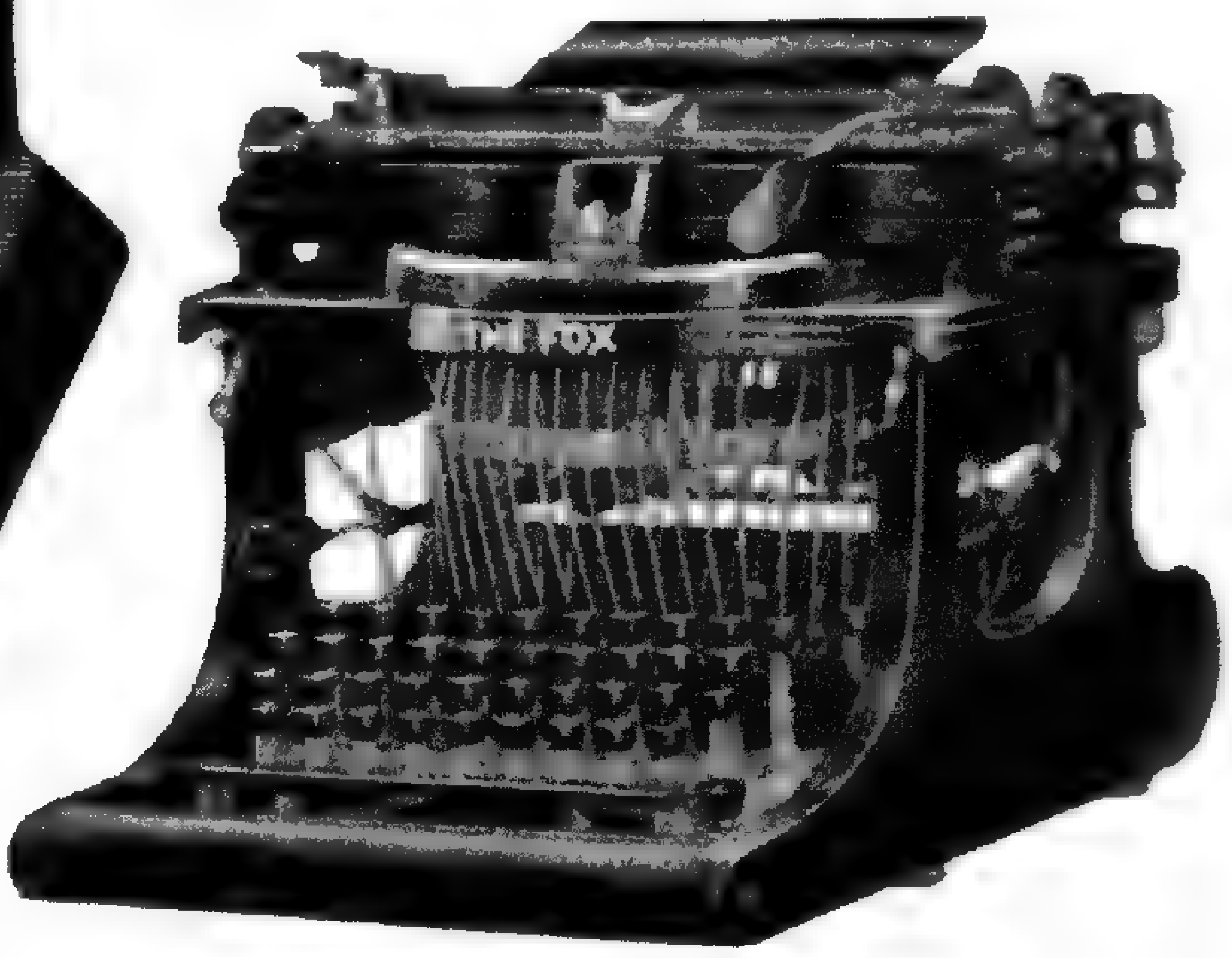

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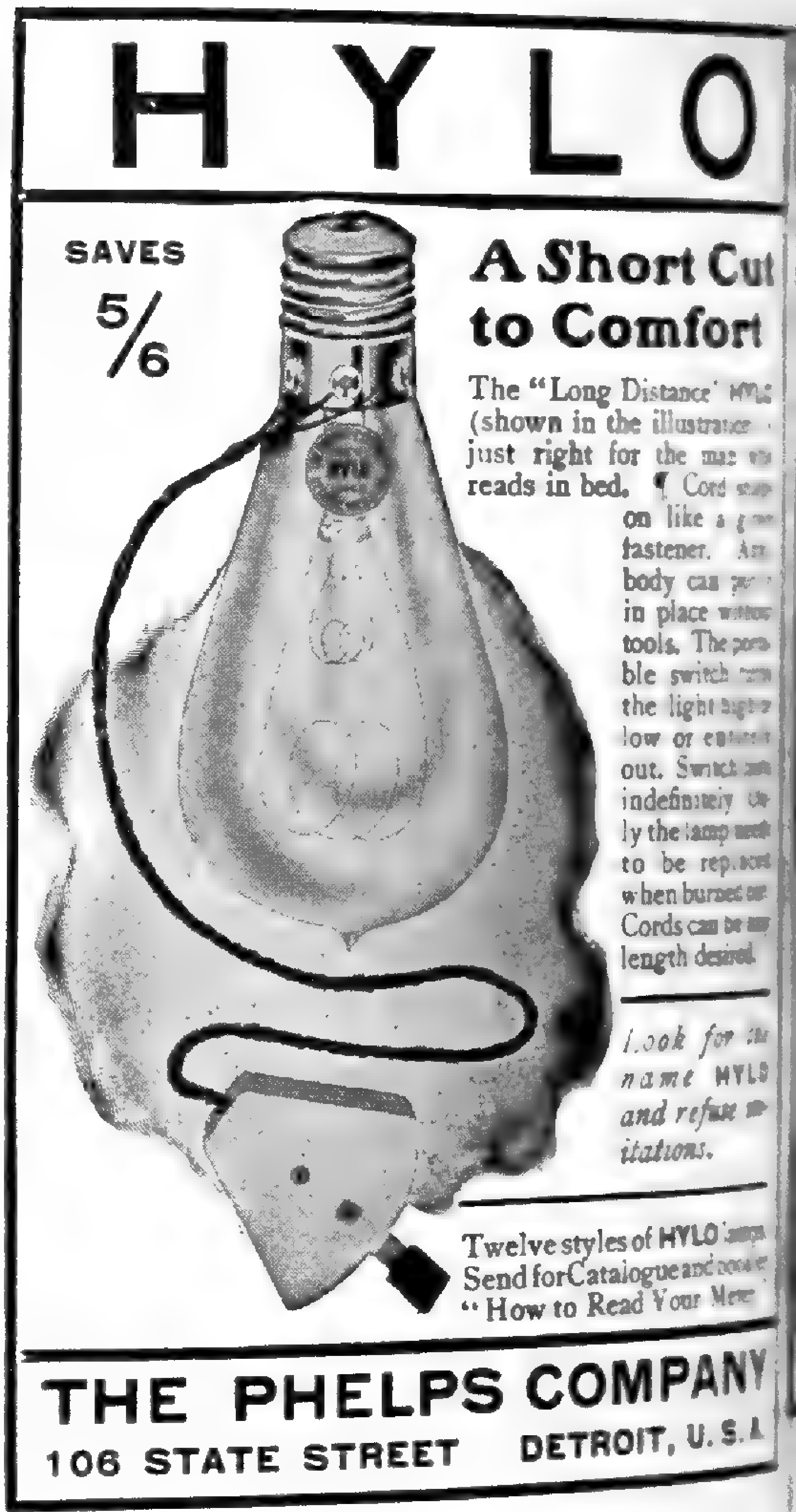

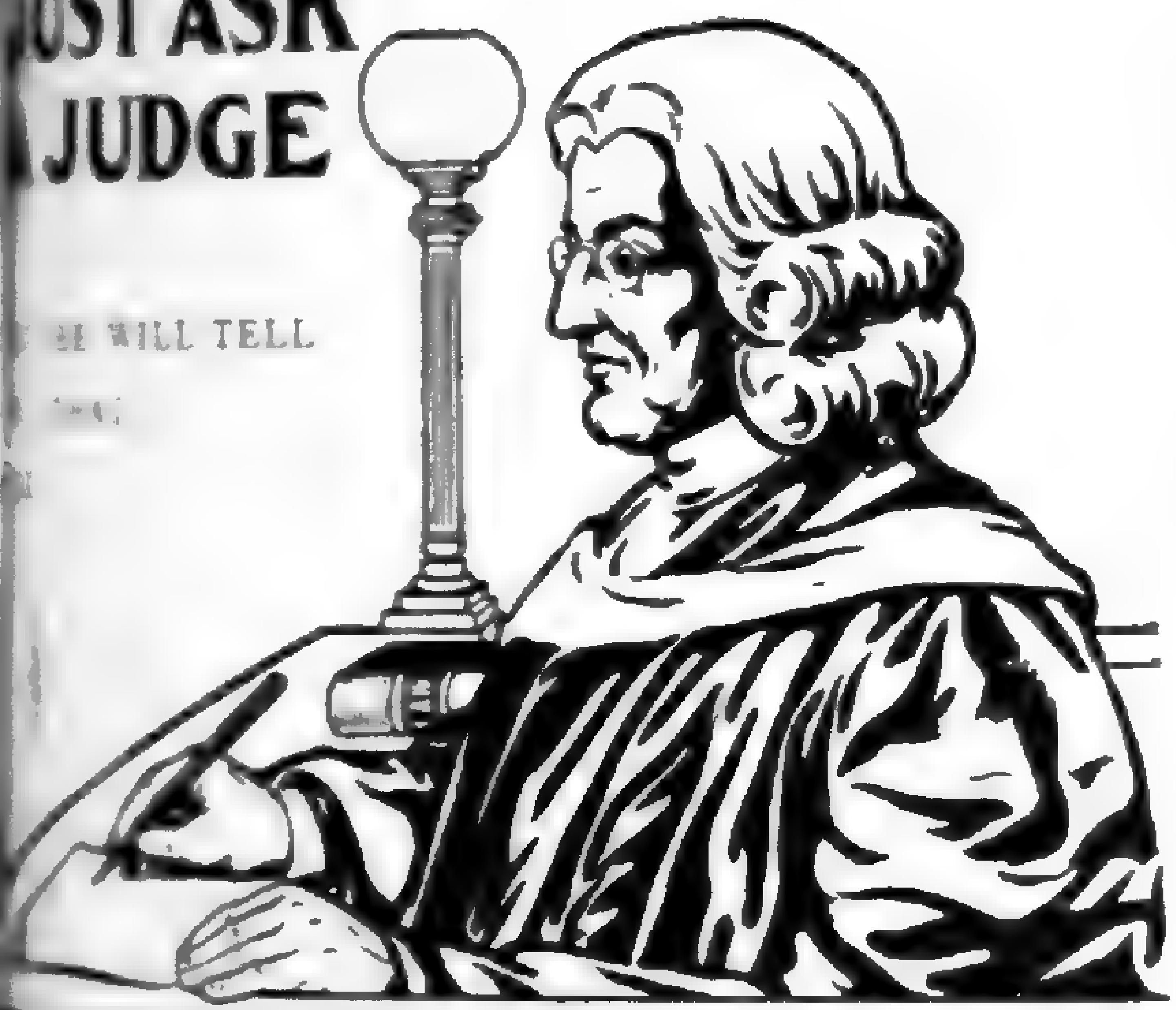

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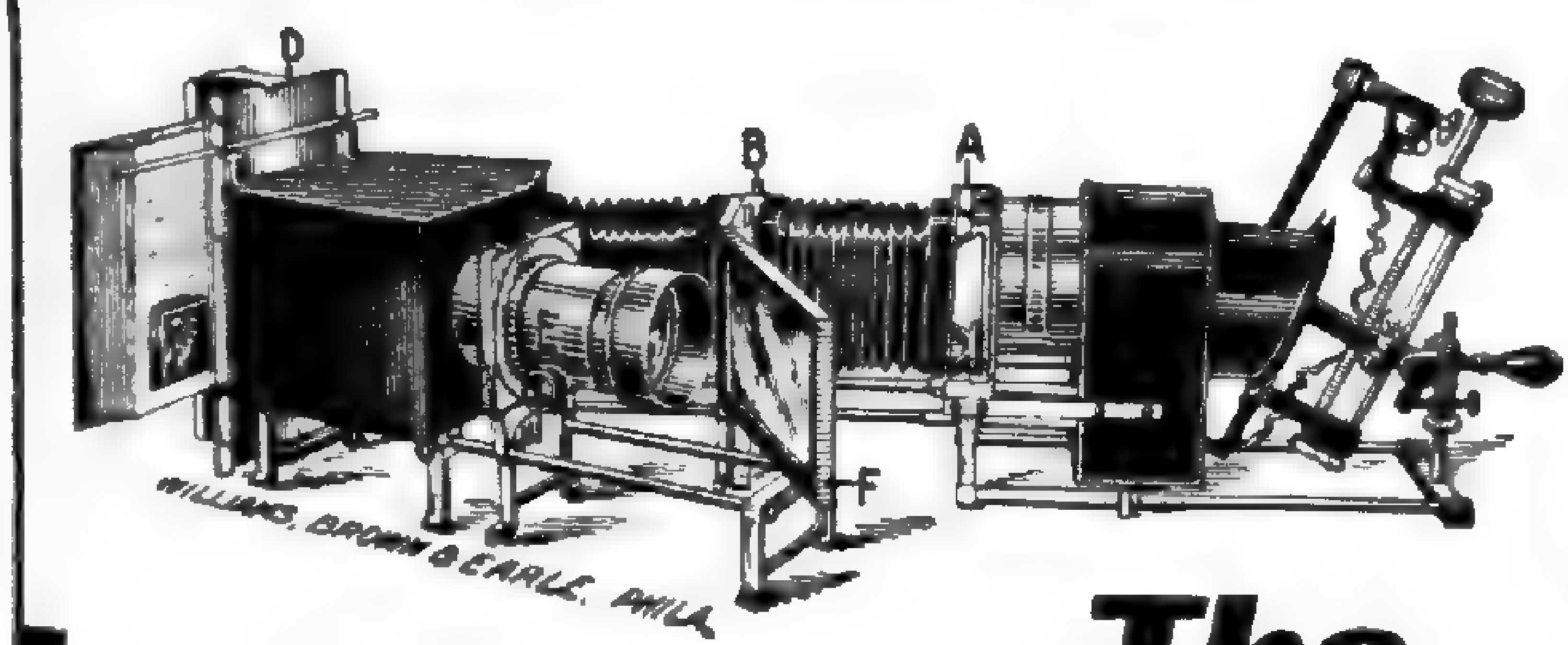
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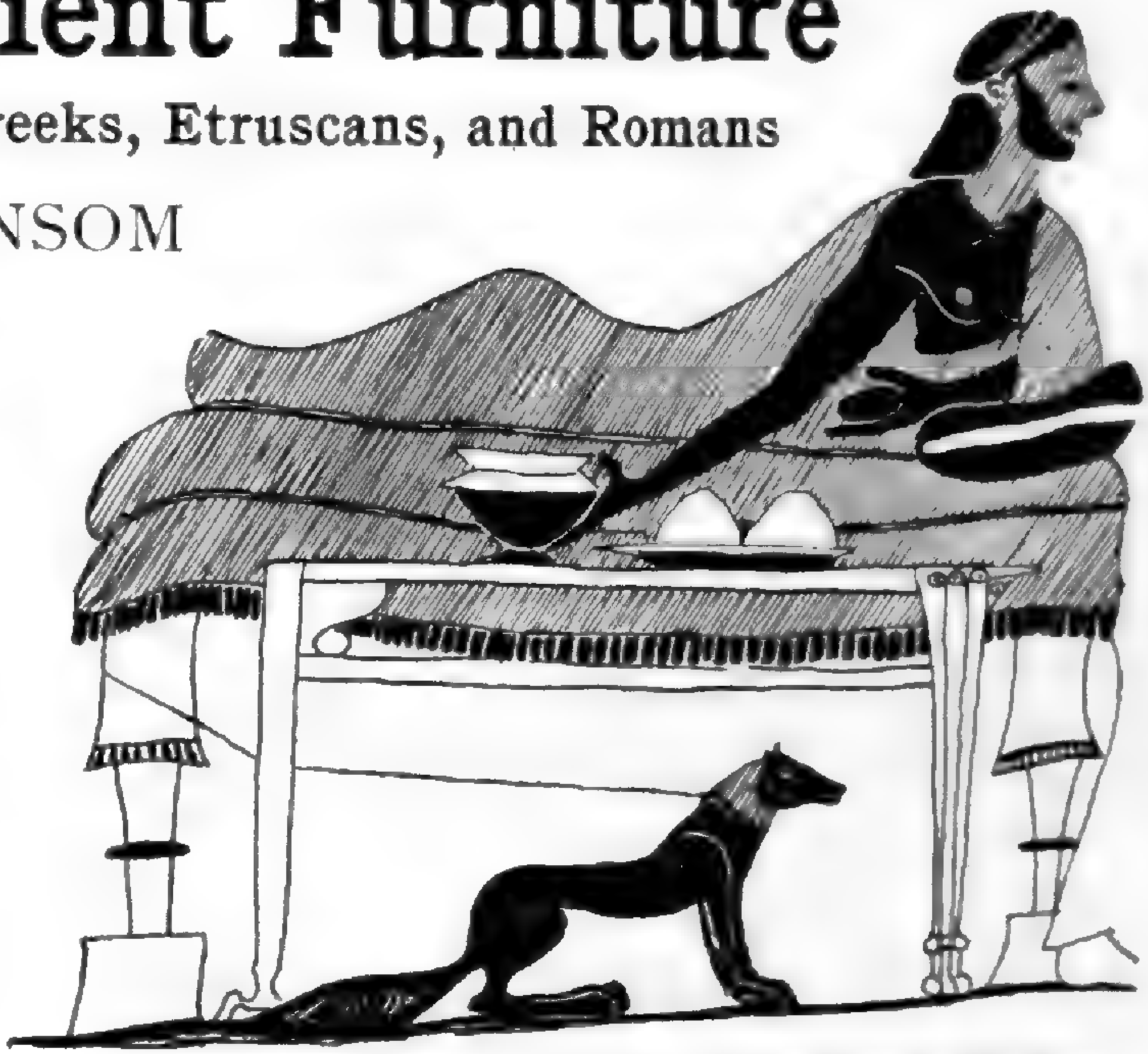

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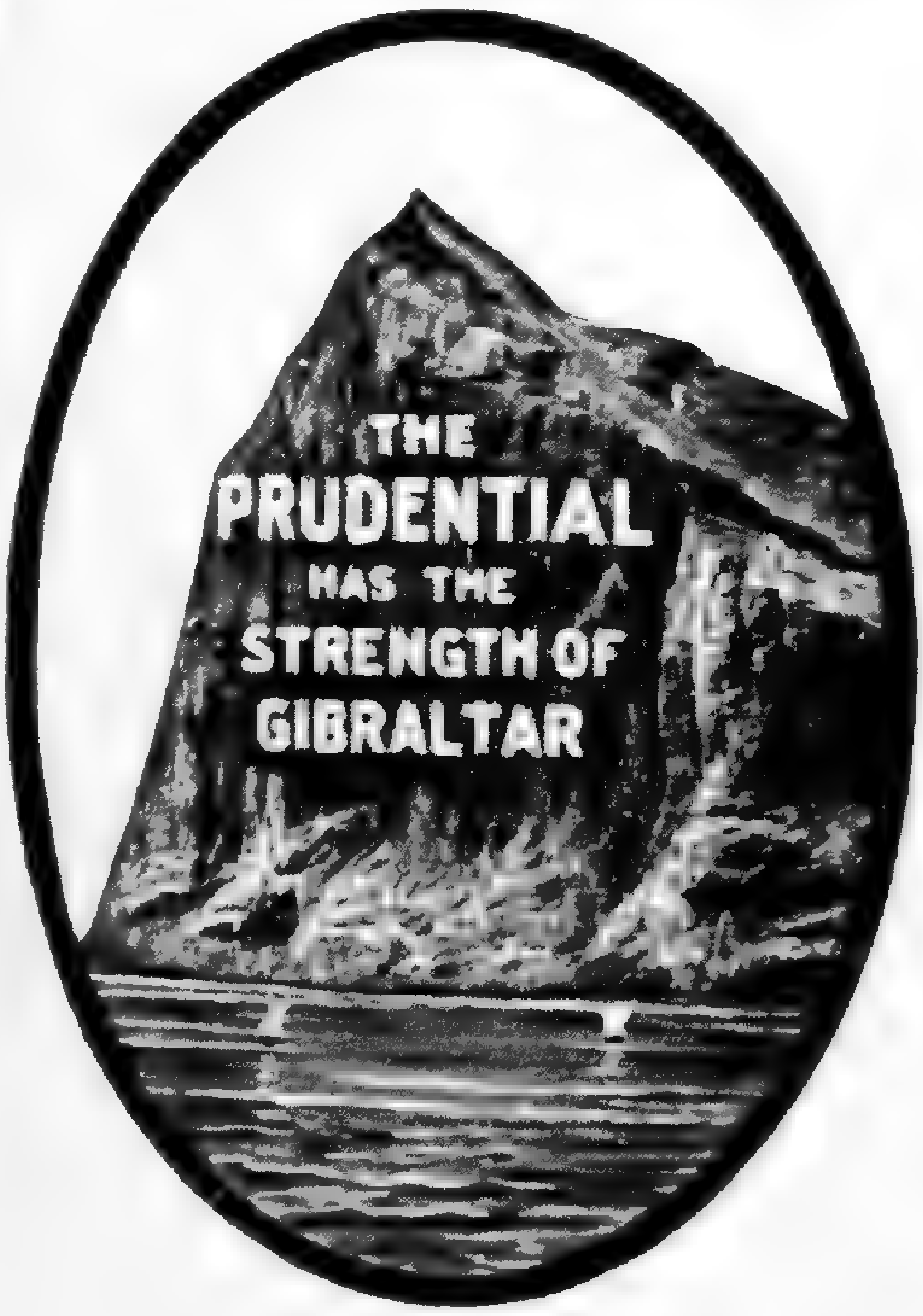

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VOLUME XL NUMBER 5

BOTANICAL GAZETTE

NOVEMBER, 1905

STUDIES OF IRRITABILITY IN ALGAE.

GEORGE J. PEIRCE and FLORA A. RANDOLPH.

(WITH TWENTY-SEVEN FIGURES)

INTRODUCTION.

IN a recent book on the physiology of plants (**13**) the statement is made that "when zoospores and other motile and floating spores of sessile plants come to rest, attaching themselves to the substratum, the attachment is effected through means not yet wholly clear. . . . It remains for experiment actually to show that the increased rate and the changed direction of growth in such cases among plants are due to contact, though it seems to be the case in animals" (**10**).

It was with a view to adding somewhat to our knowledge in this direction that the studies here reported were undertaken, first with fresh-water algae, and subsequently with marine. We worked together on the fresh-water algae; one of us worked alone on the sea-weeds;[1] we have gone over all the results together.

For the sake of clearness, we may briefly describe the series of events, a small part of which we wish to report in some detail. Zoospores of Oedogonium, Vaucheria, and other fresh-water algae, after escaping from the cells in which they form, may swim about for a considerable length of time. If they are in the light, the direction of their locomotion is influenced by the direction and intensity of the light which falls upon them. This has long been known, though

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[1] I take this opportunity to express my appreciation of the opportunity of studying, during October and November 1904, at one of the tables maintained at the Zoological Station in Naples by the Carnegie Institution, Washington. I wish also heartily to thank the officers of the Zoological Station for the courtesy which they showed me.—G. J. P.

even now far from perfectly understood (**7**). When the zoospores come to rest, they surround themselves with a cellulose wall. If they come to rest in contact with a solid object, their form changes as well; the part against the solid flattens and adheres to it. Thus a holdfast is formed. The young plant, now sessile, may pass rapidly by successive periods of cell-division and of growth through the subsequent stages of its development. The activities of zoospores, then, are greatly influenced at different times by various agents; the direction of their locomotion is determined by the intensity and direction of the light falling upon them, the formation of cell-wall immediately follows their coming to rest; the growth of the foot or holdfast is proportioned in form and extent to the roughness of the surface with which the zoospore is in contact; and the direction of the first cell-division is probably determined mainly by the light. These last three points we shall discuss in detail.

Turning for the moment to the behavior of the non-motile spores of marine algae, such as those of Fucus, Cystoseira, Dictyopteris (Halyseris), we see nearly the same phenomena exhibited. There is no independent locomotion, and hence the transport of the spores from their points of origin to where they are to germinate is not directed by the influence of light upon them, but by water currents. The formation of the cellulose wall, the growth of the foot, and the direction of the first cell-division (**20**) are, however, determined by the same influences as those controlling the similar phenomena among fresh-water algae. These we hope the following pages will make clear. We shall report first upon the fresh water algae, as it was upon these that we began our work.

I. FRESH-WATER ALGAE.

MATERIAL AND METHOD.

Vigorous plants of Oedogonium, somewhat crowded by diatoms and other low forms, were found in watering-troughs for horses in paddock or on pasture in the vicinity of Stanford University, California. Many of the plants were growing attached to the sides of the troughs, submersed but near the surface of the water, in some cases fully exposed to the light, in others partly shaded by trees. Other Oedogonium filaments were found attached to dead leaves floating near the surface of the water in the troughs. This water was quiet and fairly clear. The level of the water, tending to be lowered by evaporation or by the draughts of the few horses using the troughs, was automatically maintained by ball-valves, similar to those used in houses. A few other plants, apparently of the same species, were found in a quiet pool in the San Francisquito Creek, growing on stones in comparatively clear water.

The material was brought fresh into the laboratory from time to time from mid-September till mid-November, and again from early April till late in May. Since the material did not fruit in our cultures, and we found none fruiting out of doors, it was impossible to determine the species, though we tried to have this done for us. We regret this lack of definiteness in our work.

METHOD OF MANIPULATION.

Plants brought into the laboratory were placed in an abundance of tap-water in glass dishes covered with a glass plate or loose cap to prevent excessive evaporation and to exclude dust. Small Stender dishes were largely used, since these could easily be placed under the microscope, thereby avoiding such disturbance of the material as transfer from one dish to another would entail.

Fortunately for us the water from the tap was from the same source that supplied the horse-troughs, and the creek contains mainly the overflow from the artificial lake which is the general water-supply for the region. When, therefore, our plants were brought in and put into tap-water in the laboratory, they were put into water of the same composition and approximately of the same temperature and degree of aeration as the water of the troughs and the pool from which they had been removed. The behavior of our plants was immediately affected only by those factors changed by the transfer to the laboratory, not by the water, though it goes without saying that the temperatures of the cultures in the laboratory never fell quite so low at night during the winter and spring as that of the water outside in troughs and pools.

Cultures were also made in Knop's solution,[2] 1 per cent. and 0.5 per cent. In certain cases we added 10 per cent. gelatine or 0.25 per cent. agar-agar to the Knop's solution, in order to obtain a

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[2] 4 parts calcium nitrate, 1 part potassium nitrate, 1 part magnesium sulphate, 1 part potassium phosphate.

solid culture medium. These solid cultures were made in Petri dishes. Although such dishes have the same advantage as Stender dishes in that they can be put under the microscope and the cultures studied without disturbance, they cannot safely be employed in an ordinary laboratory for more than very brief periods at a time. The air of the ordinary laboratory is excessively dry (**2**). In consequence, there will be a quite too rapid and altogether excessive concentration of the culture medium in Petri dishes, even if covered, in all cases in which experiments last for more than a few days. In our climate, the air in the laboratory in which we worked is more humid during the winter (the rainy season) than in most laboratories. We therefore ventured to continue these cultures for some time. In summer and autumn here, and at all seasons in most laboratories elsewhere, Petri dishes are unsuitable for the culture of algae. They should be replaced by flasks holding a much larger volume of the moist culture medium and furnished with narrow necks closed by very tightly rolled cotton plugs. At certain seasons it would be well to cover the plugs with the rubber caps made for that purpose.

All dishes and solutions were carefully sterilized before the algae were sown in them. Instruments were sterilized immediately before use. In this way few if any organisms were added from outside when fresh cultures were made; but as, in order to save time, we started with small masses of material rather than with single cells or single filaments, our cultures were not pure. We experienced considerable annoyance in a few instances from the growth of bacteria or of algae other than the ones especially sought. Nevertheless, for such experiments as we had in mind, the extreme pains and the long time required to obtain pure cultures would hardly be justified by results. Furthermore, the behavior of living organisms in pure cultures may be due in part to two unnatural, that is to say unusual, factors, namely, the artificial culture medium and the vessel in which it is contained, and the freedom from the competition with other kinds of organisms and their products. Our aim was, therefore, to grow our algae under as nearly as possible natural conditions, though we realize that the degree of naturalness which we attained is only one stage in advance of the frank artificiality of pure culture.

One of the greatest difficulties encountered in the culture of green plants of any grade of complexity in a laboratory not provided with a greenhouse is in securing proper illumination, a difficulty all the greater when one realizes that not only is normal growth dependent upon adequate illumination, but many of the other phenomena of life are greatly influenced by it. As KLEBS (**8, 9**) and VÖCHTING (**19**) go far toward proving, the reproductive processes, as well as the behavior of the reproductive elements, are profoundly sensitive to light. Therefore, in any series of experiments involving irritability—that is to say, in every series of experiments on living organisms—the illumination must be carefully considered. Not having any greenhouses connected with our laboratory, our difficulties were increased. Furthermore, in our climate, there is a great contrast between the light of the rainy and of the bright days in winter, while in spring and summer, the direct sunlight is quite too intense for algae except in running water or in large bodies of still water. Between too little light at a short distance from a window and too much light near it, the right illumination is difficult to find. We attempted to attain this by placing our culture dishes on glass shelves in a window looking southeast, screening the dishes at times of bright sunshine by a sheet of white tissue paper pasted across the lower part of the window.

BEHAVIOR OF THE ZOOSPORES.

Locomotion.—While motile, the zoospores are evidently sensitive to light, moving toward the more strongly illuminated side of a slide, or coming to rest, when possible, on the light side of the dish in which they escape. This is a general statement of a result of our observation; but, as has been known since STRASBURGER'S classical study (**18**) of the behavior of swarmspores, they move toward light of a certain intensity rather than light of greater intensity, turning away from spots too intensely illuminated toward comparative darkness, just as they turn from comparatively dark spots to more suitably illuminated ones. Since there are still no means of accurately measuring either the intensity or the quantity of light falling upon a given spot, it is out of the question to determine what the minimal, optimal, and maximal illuminations are for motile zoospores, for their production, or for the parent plant. We must, therefore, content ourselves with reporting such general observations as we were able to make.

The duration of swarming has been reported by various authors (**15,** p. 768), among them STRASBURGER, who found active swarm spores of *Ulothrix zonata* after three days, of *Haematococcus lacustris* after two weeks, during which the material had been kept continuously in darkness. These figures have little significance beyond the fact that the plants produced motile zoospores during this time. The duration of swarming of the individual spores is quite unknown. On this point we can give little information. We found, however, that in our Oedogonium the zoospores came to rest and attached themselves within fifteen to eighteen hours, *i. e.*, zoospores which had escaped and were active in daylight came to rest and attached themselves during the succeeding night.

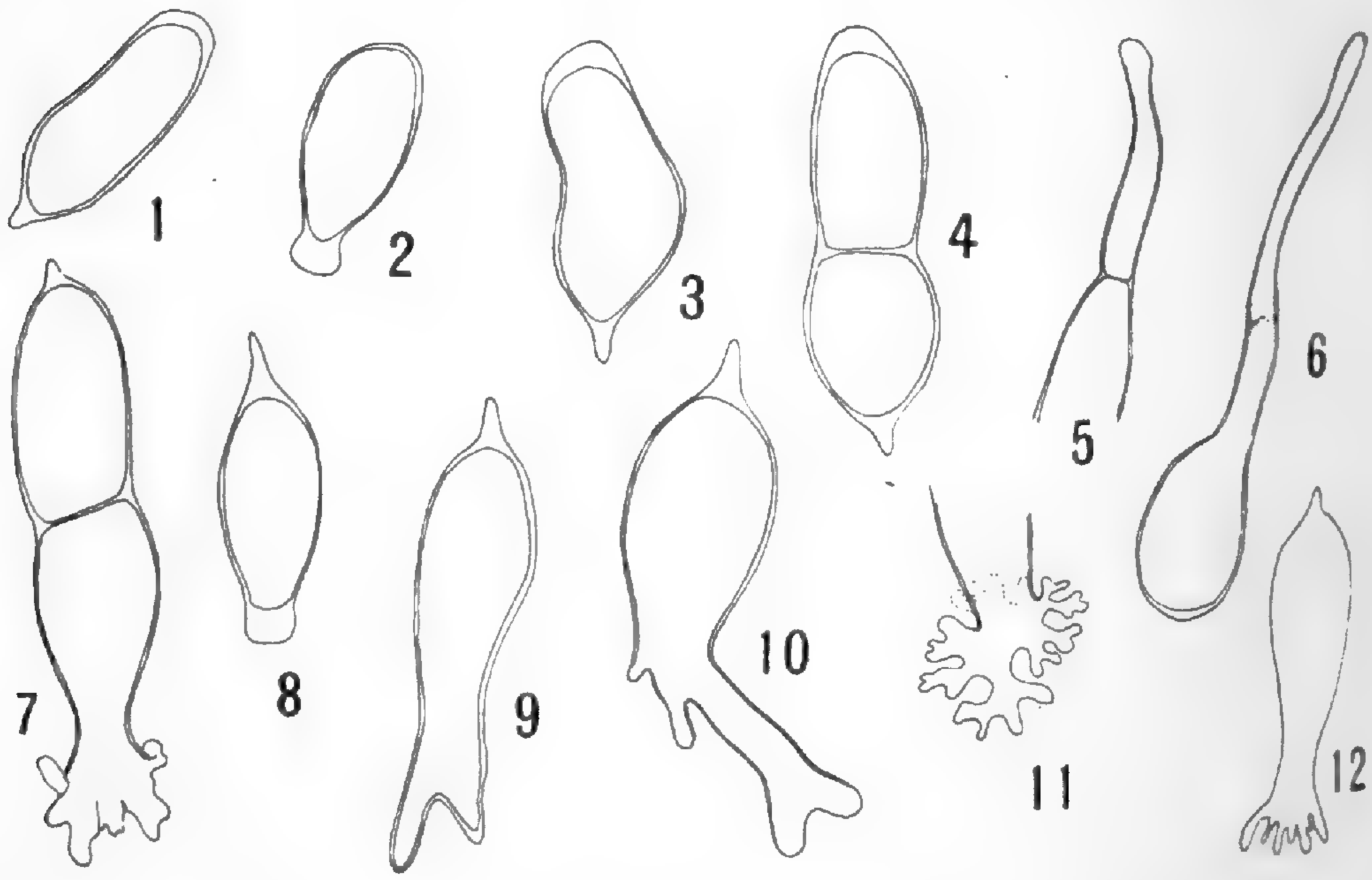
The spot to which zoospores formed in water attach themselves is largely determined by the direction and intensity of the light, if there be any, which falls upon the culture. If light of not too great intensity fall upon a dish horizontally or nearly so, the zoospores will collect and come to rest mainly upon the more strongly illuminated side. If on the other hand the light fall vertically or only somewhat obliquely from above, the zoospores will collect at the surface of the water. It is frequently observed, when the light falls obliquely upon a culture of algae, that the zoospores collect in greatest numbers at the surface of the water on the more brightly lighted side. From this the attractive influence of the oxygen of the air might be inferred. That such an inference is not always justified is proved by the fact that when the light falls horizontally, or is reflected obliquely from below upon a culture, the zoospores still tend to collect at the point best lighted, regardless of the greater oxygen supply near the surface of the water. As to the directive influence of oxygen upon the locomotion of zoospores, we made no experiments, but it is clear from this observation that in general the directive influence of light is stronger than that of oxygen. When, therefore, zoospores come to the surface of the water, they do so mainly under the influence of light. Their behavior on reaching the surface, which is decidedly different from that of the zoospores coming to rest elsewhere, we shall presently describe.

Germination.—When zoospores come to rest, the cilia are absorbed, the naked masses of protoplasm surround themselves by cell-walls, the forward end of each zoospore develops a holdfast attaching it to the surface with which it has come into contact. As light evidently directs the locomotion of the spore, it is reasonable to suppose that it also determines its polarity on germination. It is hardly probable that light influences the growth of the holdfast; nor has gravity any effect, for the spores attach themselves in various positions and may even be suspended from the surface of the water. Chemical stimulus can hardly have any part in the matter, except perhaps in relation to the bacteria. The growth of the holdfast would appear, then, to result from contact with a solid body, as an irritable response to contact stimulus. This matter we wish to report upon at length.

The influence of contact upon growing plants and their parts has been studied from various points of view by many investigators and upon a great variety of plants. It is now clear that contact with a solid object may influence growth in three ways: first, as to its direction, as shown by sensitive tendrils (**16**); second, as to its rate, also as shown by tendrils (**5**); and third, as to its kind, as shown by the formation of haustoria in dodder (**14**). Contact similarly influences the direction, rate, and kind of growth in germinating zoospores.

If it is true that contact influences the direction, rate, and kind of growth in germinating zoospores, the character of the surface with which the contact is effected should be reflected in the germinated zoospores, a rough surface producing a different and more pronounced effect than a smooth surface. To test this hypothesis, we used a variety of substances for the purpose of catching the zoospores, viz. wisps of cotton, clean cover glasses, glass roughened by corrosion and deposit, strips of gelatine, freshly split mica, and the surface of the water itself. These we interposed between the swarming spores and the light. The spores came to rest and attached themselves within eighteen hours.

Zoospores germinating on the surface of the water in contact with dust particles, diatoms, and masses of bacteria developed long slender processes, sometimes forked, but always hypha-like in appearance (*figs. 5, 6*). Others on the surface, and in contact with no solid matter whatever of visible amount, formed the most rudimentary hold-fasts, knob-like processes of very small size (*figs. 1, 2, 3, 4*). Those on gelatine, the acid reaction of which had been duly neutralized, formed knob-like or filamentous processes in lieu of holdfasts on clean spots on the gelatine (*fig. 8*), whereas those in contact with particles of dirt were more or less branched (*figs. 9, 10*). On roughened glass many zoospores developed disks (*fig. 12*). On clean glass the regularity of these disks was very striking (*fig. 11*). Irregularity of surface evidently induces irregularity of growth and form. This appears even more plainly from the experiments on marine algae (p. 343).



FIGS. 1–12.—Germinating zoospores of *Oedogonium sp.*? ×780.

1, 2, 3, Germinated on the surface of water (1, 2 filtered, 3 unfiltered) showing extremely rudimentary holdfast.—4. Same somewhat older, divided into two cells.—5, 6. Same but with hypha or rhizoid-like outgrowths at the basal end of each spore. Bacteria surround these filamentous processes.—7. Germinated on freshly split mica. Note well-developed holdfast.—8. Germinated on clean wet gelatine.—9. Germinated on a spot of dirt on wet gelatine.—10. Germinated on spots of dirt and bacteria on wet gelatine.—11. Germinated on clean cover glass. Note extremely regular holdfast.—12. Germinated on side of roughened glass dish. Note irregular holdfast.

Even clean glass and freshly split mica are not absolutely smooth. The dustless upper surface of clean water is smooth. So also is clean wet gelatine, as PFFEFER'S work on tendrils showed (**16**). On these two no holdfasts are formed by germinating zoospores. In place of holdfasts longer or shorter hypha-like filaments appear, often very short indeed, and branched only where the surface is roughened by dust or dirt. On carefully polished clean cover glasses, holdfasts of remarkably regular form were developed. As will be shown later (p. 344), uniformly ground cover glasses used in experiments with the less irritable germinating spores of marine algae induced the formation of very regular holdfasts. We may say then that the form, size, and even the development of holdfasts by sessile fresh-water algae depends upon the character, the degree of roughness, of the surface with which the zoospores come into contact. A uniform though slightly rough surface, like that of clean polished glass, will induce the formation of very symmetrical holdfasts. Coarsely or irregularly roughened surfaces induce the formation of irregular holdfasts. Extremely smooth surfaces fail to induce the formation of holdfasts, unless perhaps of the most rudimentary sort. It would seem clear then, that so far as the direction and kind of growth are concerned, contact acts as a stimulus; for the holdfast grows parallel with the surface, no matter how irregular this may be, and the organ produced corresponds to the surface on which it is formed, being simple or branched, symmetrical or irregular, according to the character of the surface. As to the effect of contact upon the rate of growth, we can say nothing so far as fresh-water algae are concerned. The measurements of growth rates among marine algae are given subsequently (p. 347).

From the observations thus reported, it is obvious that contact acts as a very important stimulus in the germination of the zoospores of sessile algae. The value of this to the plant is evident enough. If, however, we could induce algae ordinarily not sessile to form rhizoids or other holdfasts by bringing them into contact with suitably roughened surfaces, and if we could find, in nature,[3] algae ordinarily not attached fastening themselves to rough surfaces occasionally, we should add materially to the significance of our observations. Both of these things one of us has done. Though reserving the subject for further study, we may report now that plants of a species of Spirogyra which did not fruit and hence could not be determined while we were working upon them, formed rhizoids in our cultures, and were found to have formed rhizoids out of doors, wherever the filaments were in contact with sufficiently rough material, clean cover glasses, trough-scrapings containing lime, diatoms, etc., and similar

[3] Since this part of our work was ended, at least for the time, COLLINS's paper in Rhodora (**6**:230. 1904) records the formation of holdfasts by Zygnema filaments growing against rock in a swiftly running stream.

material. We have never seen rhizoids on floating filaments or on the free floating parts of attached filaments. The size, form and direction of growth of the rhizoids were greatly influenced by the nature of the surface which the cells of Spirogyra touched, clean glass inducing the formation of strikingly regular crenate disks on the ends of the rhizoids like those formed on the same material by *Oedogonium*. Dirty glass, on the other hand, induced the formation of proportionally irregularly branching holdfasts. Thus our observations confirm the generally unknown observations of BORGE (**3**), who in 1894 reported his studies of a species of Spirogyra which formed rhizoids. BORGE'S paper contains a list of earlier authors who mention having seen rhizoid-bearing Spirogyra.[4]

From the fact that on extremely smooth surfaces like the surface film of clean water or of wet neutral gelatine, no true holdfasts form, and that on sufficiently rough surfaces even such a plant as Spirogyra may form organs of attachment, it is clear that the growth of rhizoids or holdfasts represents the reaction of a plant to the stimulus of contact. The germination of a zoospore of a sessile alga is influenced by contact; but contact, though it stimulate the zoospore to form an organ of attachment, is not needed to cause the zoospore to germinate. The zoospore may remain in motion for a long, but at present unknown, period of time. So long as it continues to move about, it does not germinate. When its locomotion is stopped, germination begins. When a zoospore reaches a very smooth but impenetrable sheet of gelatine interposed between it and the source of light falling upon a culture-vessel, it loses its cilia, ceases to move, and surrounds itself by a cellulose wall — it germinates; but unless it has stopped upon a particle of dirt on the surface of the gelatine, it puts out at best only a rudimentary hypha-like process, a rhizoid, not a holdfast, and this it does after germination has begun. Similarly, if the further progress of a zoospore toward the light be opposed by its having reached the top of the water in which it was found, the zoospore will cease to move, will lose its cilia, will surround itself with a cellulose wall, will germinate; but it will not form a holdfast or even a rhizoid

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[4] Subsequent papers by BORGE figure other species of Spirogyra with rhizoidal holdfasts (Die Algen der ersten Regnelschen Expedition. Archiv för Botanik 1:— 1903).

unless it has happened to land upon particles of dirt or other solid. Germination, then, follows enforced cessation of locomotion; growth, so far at least as the formation of a holdfast is concerned, follows and is dependent upon contact irritation.

Let us turn now to the marine algae.

II. MARINE ALGAE.

MATERIAL AND METHOD.

The material consisted of fresh fruiting plants brought in almost daily from the Bay of Naples. These plants, when not used immediately, were put into well-lighted aquaria, supplied with running sea-water, where they remained healthy for days after they had ceased to be used. The plants were *Dictyopteris* (*Halyseris*) *polypodioides*, *Dictyota dichotoma* (two varieties at least of this extremely variable form), *Cystoseira barbata*, *C. erica marina*, among brown algae; and *Laurentia obtusa*, *Polysiphonia* (sp.?) among the red. I tried to get zoospores of Ulva, Cladophora, and other green algae, for the sake of comparison with the behavior of the zoospores of fresh-water algae; but whether owing to the season of the year (October, November) or to other causes, I do not know—at all events, I failed to get sufficient numbers to justify any conclusions. The spores used were of two sorts, the fertilized eggs of the two species of Cystoseira, and the non-sexual spores and tetraspores of Dictyopteris, Dictyota, Polysiphonia, and Laurentia. Their behavior is essentially similar.

BEHAVIOR OF THE SPORES.

Influence of light upon their escape.—I began my work with *Dictyopteris* (*Halyseris*) *polypodioides* and the two species of Cystoseira. Clean fruiting branches, as free as possible from diatoms and other organisms, were put in small dishes about 4^{cm} diameter and 2^{cm} depth, filled with fresh sea-water. To reduce evaporation the dishes were covered either with glass caps or clear glass plates. The dishes were set on a broad shelf inside a northwest window about 13^{cm} below the lower edge of the glass. The light fell therefore somewhat obliquely upon the cultures. At noon on sunny days I closed the screens, made of sheeting, in order to prevent the sun shining directly upon the dishes during the afternoon. I found this illumination satisfactory. If the fruiting branches are put in the dishes late in the afternoon, enough spores will escape by nine o'clock next morning to justify removing the branches. In this way the age of the escaped spores may be confined within fairly narrow limits. If it were desirable to limit the age of the spores still more, as was sometimes the case, I made the cultures as soon as the fresh material was brought in, in the forenoon, and left them for four hours on the window shelf. In this time many spores escaped from good material, and I removed the fruiting branches. The dishes were left otherwise undisturbed for 22 or 24 hours after the cultures were made, in order to allow as many spores as possible to stick closely by their slimy coverings to the bottoms of the glass dishes. At the expiration of this time, the water in the dishes was carefully decanted, and fresh sea-water poured in. A considerable number of spores may wash out in this first change, but presumably they are the youngest, the ones last escaped from the fruiting branches, and there is the advantage in losing them that the material left in the dishes is still more nearly of the same age. Within these 24 hours the spores of Dictyopteris will have begun to germinate, putting out a short blunt process which is to form the holdfast, and having divided into two or three cells. Cell-division, so far as the formation of a dividing wall is concerned, does not seem always to precede the appearance of the process which is to become the holdfast; but there seems to a be slight difference in this regard between spores germinating under the ordinary conditions of alternating daylight and darkness and those kept constantly in darkness. The latter generally form the division wall before putting out the process, but to this rule there are many exceptions. In Dictyota and Cystoseira, however, the division wall is always plainly visible before the rhizoid appears.

The escape of the spores of Dictyopteris is much less abundant if the dishes are left in the dark than if they are normally lighted. Thus, on November 11, at 12 o'clock, I put as nearly as possible equal quantities of fruiting Dictyopteris in eight dishes, two of which I set on the window shelf and six in the dark. At 10 o'clock the next morning I counted the spores in all the dishes. There were 444 and 75 spores in the dishes set on the window shelf. In the six dishes kept in the dark for these 22 hours there were 59, 134, 287, 135, 219, 218 spores. The first three of these dishes I then set on the window shelf, putting into each the same pieces of Dictyopteris that had been in them. The other three I set back in the dark, putting into them the same branches which they had previously contained. All the dishes had fresh sea-water put into them. At 5 o'clock that afternoon so many spores had come out in the dishes in the light that I removed the pieces of Dictyopteris from all six and left them undisturbed until November 14 in the morning. Then I counted the spores, practically if not quite all of which had become fastened to the bottom of the dishes. There were now in the dishes in the light 1565, 2046, and 2245 spores; in the dishes in the dark 866, 1716, and 596 spores. In the dishes put into the light after darkness there were now 5856 spores where there had been only 480 before, a gain of 5376 or 11.2 times as many. In the dishes kept in the dark there were now 3178 spores, a gain of 2606 or 4.5 times as many. Nearly two and a half times as many, therefore, had come out in the light as in darkness in the same length of time.

The counting of such large numbers of small spores, especially where they lie very close together, is not easy. To facilitate counting and to bring the count to an approach to accuracy, I ruled lines about 2.5^{mm} apart with India ink on the bottoms of the dishes. The counting was done over a white surface with a hand-lens magnifying about fourteen times.

To ascertain whether the amount of light has any effect on the discharge of spores, I put fruiting branches of Dictyopteris in dishes in the dark, in the full diffused light on the window shelf, and under black hoods which had a vertical slit on one side about 3^{mm} wide and 15^{mm} long. I did not count the spores, but it was evident that most had escaped in the dishes in full light, fewest in the dishes in the dark, and a quantity between these two in the diminished light.

Similar experiments with *Dictyota dichotoma* yielded results similar in every respect.

As indicating the relation of light to the process of extrusion of the gametes I may report some of my experiments on Cystoseira. On November 8, at 11 o'clock, I put fruiting branches of *Cystoseira barbata* in four small dishes, two of which I set in the dark, two on a shelf by a window, taking pains to have as nearly as possible equal numbers of fruiting tips in the different dishes. At the same time I similarly prepared four dishes of *Cystoseira erica marina.* In two hours and three quarters there were evidently many more spores (eggs) in the lighted dishes of *C. erica marina* than in those in the dark, but apparently about equal numbers in the two sets of dishes of *C. barbata.* At about 10 o'clock the next morning I removed the branches of *C. erica marina* from the dishes, throwing away those that had been kept in the light, and poured off the water from the four dishes. I counted 99 and 50 eggs in the two dishes which had been kept in the dark, 454 and 420 in the dishes kept in the light. The latter two had of course been dark for nearly or quite twelve hours, from sunset to sunrise. The branches which had been in the darkened dishes I put back in these dishes, with fresh sea-water, and set them on the window shelf. Four hours later many eggs had come out and I therefore removed the branches, but left the dishes quiet till the morning of the 10th, so that the eggs might settle and become fastened to the bottom of the dishes. On the morning of the 10th, I poured off the water, preparatory to counting the spores. Many spores were carried away by this means, but those attached to the bottoms of the dishes now numbered 270 and 241 respectively.

I made similar counts of the number of eggs of *C. barbata* escaped and attached in the dishes darkened for twenty-three and one-half hours. There were 426 and 348 in the two darkened dishes. There were so many spores in the dishes which had been exposed to the daylight till sunset and after sunrise that I contented myself with counting those in the first three spaces from one side of one dish. In this space there were 376 spores. This area equals about one quarter the area of the bottom of the dish. The spores were not equally distributed over the bottom, but there were at least four times as many over the whole area. There were therefore about four times as many spores in the dishes which had been in the daylight as in the constantly darkened dishes. As with *C. erica marina,* I put back the fruiting branches which had been in the darkened dishes, filled them with fresh sea-water, and set them on the shelf by the window. Three hours and a half later I took out the branches, leaving the spores which had escaped to settle in the dishes and to become attached. The next morning I counted the spores attached to the bottom of the dish, in which 426 spores had escaped and attached themselves in the dark. There were now 1574 spores. In three hours and a half, therefore, after putting the dishes in the light, 948 spores had escaped and become fastened to the bottom, more than twice as many as had escaped in twenty-three and one half hours of darkness.

That the number of spores which had escaped was far greater than the number which had attached themselves is shown by the other dish. From this dish I carefully decanted rather more than half the water and shook as many as possible of the loose spores into a space about 6^{mm} square. In this space a single layer of spores covered the whole area of $36^{sq\ mm}$. Half the area had two layers of spores, and one quarter had three layers. If these spores had been spread out in a single layer, they would have covered an area of $63^{sq\ mm}$. The average diameter of the spore is 0.09^{mm}. Calculating the area of a spore and dividing this into $63^{sq\ mm}$ we find that there were about 2623 loose spores in this area. There were many more loose spores than I could collect in one spot by shaking, so that the calculated number of practically spherical spores is none too large, though they could not occupy the whole of any quadrangular area. There must have escaped therefore at least 3400 spores during three hours and a half of daylight in the dish in which I had counted 348 spores, twenty-three and a half hours after the dish had been put in the dark. At least eight times as many spores had come out, therefore, in three and a half hours of daylight after darkness as in nearly seven times as long a period of darkness.

It is to be noted that this very large number of spores (egg-cells, probably fertilized) was obtained only after an abrupt change from protracted darkness to full daylight. In nature, except in polar regions, the darkness is never so prolonged; and nowhere in nature is the change from darkness to daylight so abrupt. Whatever effect darkness and light have upon the discharge of the gametes must be exhibited in maximum degree in such an experiment as I have just described.

We see, then, that light has a decided influence on the time and the rate of discharge of gametes (in Cystoseira) and of non-sexual spores (in Dictyopteris and Dictyota). In Fucus it has long been known that the majority of the gametes escape and fertilization takes place soon after sunrise. OLTMANNS (**12**, p. 523) speaks of a periodicity in the discharge of the gametes of the constantly submersed Fucaceæ (Halidrys, Cystoseira, etc.) as well as in Fucus. Fucus does not occur in the Bay of Naples, though abundant enough in most other parts of the ocean. It is ordinarily twice daily exposed at low tide, but as various authors[5] have shown such uncovering is not necessary to the discharge of the gametes. The mechanism of the discharge of the gametes consists, in part, in the swelling of the gelatinous material in the conceptacles and the compression of the walls of the conceptacles by the surrounding tissues when the sexual elements are ripe. OLTMANNS expresses doubt whether these two factors alone furnish an adequate explanation of the process. As the matter now stands, these mechanical means do not account for the periodicity, unless we assume the relation of light to the processes connected with the growth of the gametes and with the formation of gelatinous matters within the conceptacles.

The periodicity coincides with the sequence of light after darkness, and is as evident, as my experiments have shown, in forms having no conceptacles as in those that do have them. In Dictyopteris, the aplanospores (tetraspores) form on both surfaces of the flat thallus, near the midrib, and project more or less from the surfaces as they grow. Finally they escape through a slit in the wall of the mother-cell. They may even germinate (**12**, p. 486) before escaping. It is difficult to see where mechanical pressure can effectively develop here except in the sporangium itself, that is, by the growth of the spores and the gelatinization of the wall and residual contents (if any) of the spore mother-cell. I shall subsequently show that light favors the germination of the spores and the growth of the young plant, though they will germinate and grow in darkness. It is probable, therefore, that light favors the growth of the spores before they escape from the sporangium as well as after. In this we have a partial explanation of the connection of the periodic discharge of the spores in Dictyopteris and of the gametes in Fucus and Cystoseira with the mechanical means of discharge above discussed. The influence of light is favorable to the growth of the spores, therefore to the development of mechanical pressure by them, but as the rapid discharge of

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[5] Cited by OLTMANNS, *l. c.*

spores occurs within a few hours after the fruiting material has been put into the light after being in darkness, it may be objected that there is not time for sufficient growth to take place to develop the necessary mechanical pressure, if mechanical pressure has anything to do with the matter in such plants as Dictyopteris. In reply to this possible objection, I may say that, though the spores are rapidly discharged within a few hours, there was no evident increase in the accumulation of spores in my dishes until at least two hours had elapsed after they were put in the light. There is therefore time for growth.

To make this point clear I will report one experiment. Three small dishes of fresh fruiting Dictyopteris branches were kept in the dark for twenty-two hours. Early in the morning, the material was removed from these dishes, in which a considerable number of spores had been discharged, and placed in three clean dishes of fresh sea-water on the window shelf in the light. From these dishes the fruiting branches were removed after the lapse of one hour and put in another set of three dishes, the first set being left otherwise undisturbed to allow the spores which had escaped to settle and become attached. The same was done at the end of each of the two hours following. At the end of another hour and forty minutes, I repeated the process, and again after the lapse of two hours more. I therefore had five sets of three dishes each, in which spores had escaped. The number of spores at the time of exposure to light are as follows:

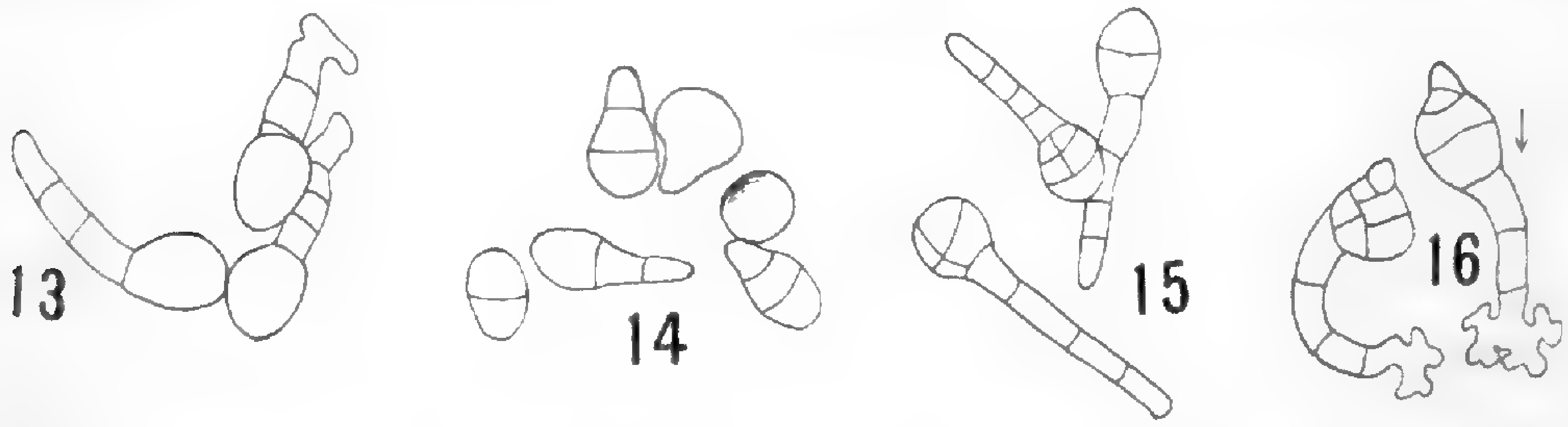
After 1 hour's exposure to light	36	spores in	3	dishes
“ 2 hours' “ “	26	“	3	“
“ 3 “ “ “	170	“	3	“
“ 4⅔ “ “ “	1671	“	3	“
“ 6⅔ “ “ “	597	“	3	“
Total number of spores in 15 dishes	2500			
Total number of spores in escaped last 3⅔ hours	2268			
Percentage of spores escaped in last 3⅔ hours	90			
Percentage total time in which these spores escaped	55			

From these figures it is clear that the discharge of the spores in the light is not an immediate one, but that a certain length of time must elapse after the plants are brought into light after darkness before they begin to discharge their spores rapidly. What changes take place under illumination which result in the discharge of the spores, I do not venture even to guess. On this interesting point I have no data.

It may be that in addition to the influence of light on the processes of food manufacture and growth in the spores and in cells adjacent to the sporangia, there are irritable responses which contribute to the development of the mechanical pressure which causes the spores to be discharged. Information on this point might add to our meager knowledge of the phenomena of irritability in the marine algae.

I am by no means satisfied that the plant does not irritably respond to the light by more immediate means than growth. The light may also favor gelatinization, but the connection with this process, the details of which are unknown, is not sufficiently clear to justify discussion now.

The influence of light upon the germination of the spores.—The germination of the spores of Dictyopteris has been adequately described by REINKE (**17**), but he naturally made no attempt to ascertain the influence of the different factors of the environment upon the course of germination and upon the form of the young plants. In order to learn something about these matters I compared spores which had escaped during twenty-four hours in different dishes as to their rate of germination and the development of the young plants in the light and in darkness. In *fig. 13* we have young plants shown which had developed thus far in a dish completely covered by black paper except for a vertical slit $17 \times 6^{\mathrm{mm}}$ on the side of the dish toward the window. The time since sowing was three and three-quarters days. In *fig. 14* are shown young plants from spores escaped at the same time, but in dishes kept completely darkened. It may be objected that the conditions of the two experiments were not the same, and therefore the results may not be comparable. I have shown above that light favors the escape of the spores, probably because it favors their growth. For this reason, therefore, the results are exactly comparable, because the point is made still clearer that the germination of the spores is more rapid under the normal daily alternation of light and darkness than in continuous darkness. For the germination of the spores of ferns (**4**, p. 423–4), the seeds of Viscum, and for various other plants it is claimed that light is necessary. This is not generally the case with higher plants. As *fig. 15* shows, the young plants grown in the dark for five days were only as far along as those grown for three and three-quarters days under the black cap with a slit in the side. *Fig. 16* shows plants five days old grown under the black hoods with a side slit. This difference in growth rate may be due to two factors at least. In the first place, no manufacture of non-nitrogenous food can take place in the dark, though some such food may be manufactured even in the dim light under the black cover. If such food were manufactured, it could be used at once to nourish the organism, which is supplied in the spore with only a comparatively small amount of food. In the second place, if the manufacture and assimilation of nitrogenous food is more rapid in the light than in darkness, as is now claimed,[6] those spores in the light would be better off than those in darkness.



FIGS. 13–16.—*Dictyopteris* (*Halyseris*) *polypodioides*. ×123.

13. Germinating spores sowed $3\frac{3}{4}$ days earlier on ground glass in dish receiving light only through vertical slit on one side, $17\times6^{\mathrm{mm}}$; direction of light indicated by arrow. Note that all rhizoids point away from light, whereas the nearly erect plantlets are inclined toward the light.—14. Same in every respect, except that it was kept constantly in darkness. Note smaller size of plantlets. 15. Same, five days old, constantly in dark. Size about same as lighted plantlets $3\frac{3}{4}$ days old.—16. Same as 15 but in dish lighted through vertical slit, $17\times6^{\mathrm{mm}}$. Plantlets strikingly further advanced, erect but inclined toward light; direction of source of light indicated by arrow.

Whatever the reason may be, the young plants grow and develop faster in normally alternating light and darkness than in continuous darkness. This fact, not altogether in harmony with certain current views of the influence of light and darkness upon growth (**11**), deserves much more extended study. It seems to us probable that the opinions of plant physiologists, based too exclusively on studies of land plants, will be modified when the algae, especially the marine algae, have become as familiar to them as aquatic animals now are to other physiologists.

Having seen that light favors germination and growth, we may now inquire what other effects it has. If spores sown in dishes in the

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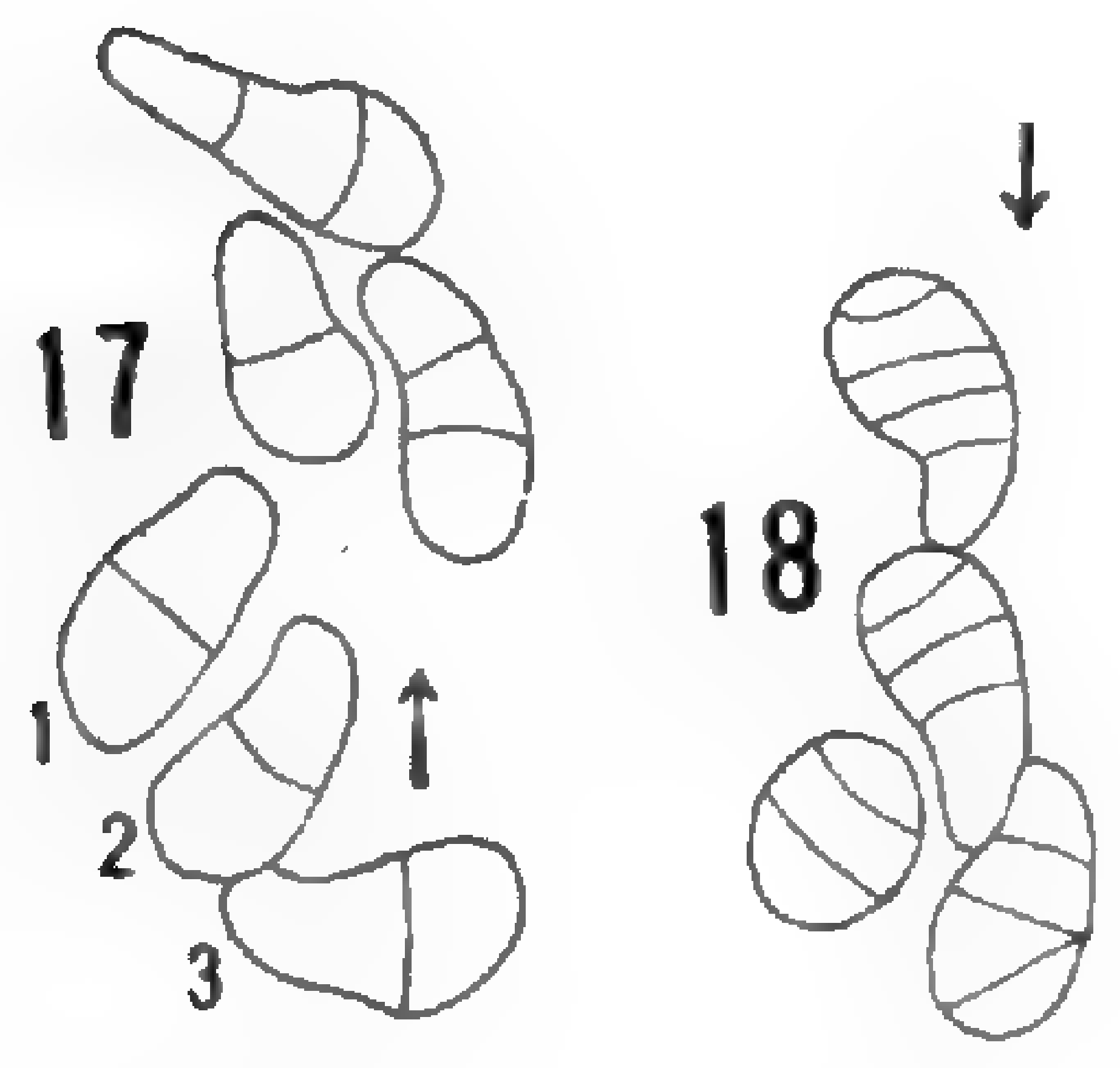
[6] GODLEWSKI'S papers in Bull. Acad. Sciences Cracow, 1903, and earlier and later.

manner previously described are exposed to one-sided illumination, the holdfasts will appear always on the side away from the light. If spores germinate in darkness, the holdfast will be put out in all possible directions from different spores. This result I have repeatedly obtained in Dictyota, Dictyopteris, and Laurentia, as well as in two species of Cystoseira, thus confirming and extending WINKLER'S (**20**) interesting experiments on *C. barbata*. The gelatine method which WINKLER used for part of his experiments is apparently more exact than mine, but what it gains in apparent exactness it loses in naturalness. The spores in a layer of sea-water not too thin (as it may be on a slide, especially if this is covered) quickly adhere to the surface of clean smooth glass, and if the dish remain undisturbed for several hours they are not likely to be dislodged by ordinary movements afterwards. The use of gelatine, or of any other similar material even in dilute solution, such as WINKLER describes, is open to suspicion by reason of the facts reported in the foregoing part on fresh water algae, and also because of the results of BORGE (**3**) already referred to, although WINKLER reports the germination as perfectly normal. Naturally, for his gravitation experiments, a solid medium was necessary, but not for those on light.

To escape the legitimate objection that the spores may behave differently in darkness and in light, I put upon the horizontal plate of a clinostat a dish in which Dictyopteris spores had escaped during twenty-four hours in darkness, covering the dish with a black sheet of cardboard so that all the light came from the side. The plate of the clinostat was also covered with dull black paper to avoid possible reflection from below. The dish was therefore revolved in a horizontal plane and received light not only from the side, but on all sides successively. The clinostat was very simple — an alarm clock from which face and hands were removed, a sleeve carrying a thin zinc plate being soldered to the minute hand spindle. The dish was therefore revolved once an hour. The result was that the germinating spores sent out holdfasts in all possible directions, some of the rhizoids growing upwards, others downwards, the majority horizontal until their increasing weight tipped the spores sufficiently to bring the ends of the rhizoids into contact with the glass.

It appears, then, that the side of the spore which is to give rise to the holdfast is ordinarily determined by light, which in nature falls from above, vertically or more less obliquely. The direction of growth of the rhizoid is also determined by the light, other things being equal, and this frequently brings it into a more or less vertical position until it comes into contact with a solid object.

Although under natural conditions the cell which is to form a rhizoid, and the direction of growth of the rhizoid, appear to be determined by light and by the direction from which it comes, the fact that spores will divide and form rhizoids both in the dark and under supposedly equal illumination from all sides successively, leaves us with a doubt whether, after all, the point of formation of the rhizoid may not depend on other factors also. Keeping the spores continuously in the dark for forty-eight hours or more is extremely unnatural. The results of such procedure may also be unnatural; they may mislead us as to the natural course of events. Again, cultivating the spores in a dish on a clinostat is an unnatural proceeding, for in nature the illumination is not even approximately equal on all sides in one plane, but is unequal and in many planes successively. And finally, though darkness follows light and light follows darkness only gradually, on the clinostat as well as in nature, it is obvious that a spore in a dish on the clinostat receives the stimulus of light on one side, and as darkness comes on, there can be only weaker and weaker stimuli, and finally none at all on the other sides of the spore. The direction of division of the spore may or may not be determined by this last stimulus of light. According to WINKLER (**20**, p. 302), a three or four-hour exposure to one-sided illumination is necessary to determine the direction of the first division wall in the eggs of Cystoseira. He suggests that perhaps by changing the direction of illumination 90° or 180° about every three hours, we might stop the germination altogether. This I have not tried with Cystoseira, but as the foregoing shows, such is not the case with Dictyopteris spores, for they germinate in darkness, and also on the clinostat, at once, although perhaps not as rapidly as under ordinary illumination. It may take three or four hours under ordinary conditions to determine the line of division of an egg or spore. It may take much less time, much less of a stimulus by light, to determine which of the two cells thus formed shall send out the rhizoid. In cultures of *Dictyota dichotoma* under one-sided illumination, but with the ordinary alternation of daylight and darkness, I noticed that both the direction of divisions that took place at night and also the cell which put out the rhizoid did not conform to the rule to which those spores which germinated in the daytime evidently pointed. This is clear from *figs. 17* and *18*. Rhizoids, formed during the night on the side which did and will receive more light during the day, bendaway from the light when the daylight comes. In such cultures as these we have much more nearly normal conditions than in continuous darkness or on the clinostat. Divisions often occur and the rhizoids often grow out in darkness, and though the spores were lighted only from one side during the day, the direction of these divisions and the side from which the rhizoid springs follow no rule. This fact at least suggests, but without proof, that influences preceding illumination also affect the direction of division of the spores, and the point of origin of the rhizoids.



FIGS. 17, 18.—*Dictyota dichotoma*. ×123.

17. Germinating spores 1¾ days since sowing on ground glass in dish lighted only through vertical slit, direction of light indicated by arrow. Note that spores 1, 2, 3 divided during the night (in darkness), and that the rhizoids of 2 and 3 are curving away from the light.—18. Somewhat older.

It does not seem to me necessary to assume a polarity in the spore. There is no evidence in the form of the undivided spore that there is such a polarity, for the undivided spore is spherical or spheroidal. After the first division the spore becomes ellipsoidal by the growth of the daughter cells at right angles to the division wall. The rhizoids grow from one or the other end—sometimes from both ends—of these ellipses, not from the side; but beyond this there is no indication of the point of origin of the rhizoid. So far as I can see, then, all one is justified in saying is that, in the light, the direction of division of the spore and the point of origin of the rhizoid are determined mainly by the direction from which the light falls upon them, but that the spore has the impulse both to divide and to form a rhizoid, and will do both even in the absence of any directive influence. In the latter case the direction of division and the point of origin of the rhizoid are determined by conditions preceding the escape of the spore from the mother cells, conditions which may have induced a polarity in the spore, but a polarity which is not so fixed that subsequent influences cannot alter it.

Influence of contact on germinating spores.—From the work in fresh-water algae reported in the foregoing pages, one is led to suspect that the character of the surface with which the rhizoids of germinating spores of marine algae come into contact will largely determine the shape and completeness of attachment of the holdfasts. The strength of the holdfasts as the plants mature is determined not merely by the surface but by other factors. Among these may be mentioned the movement of the water in currents and waves, the size and shape of the plants, and all other factors which affect the strain which the holdfast must withstand.[7] But the first attachment of sessile algae, whether marine or fresh water, is greatly influenced by the roughness of surface. I was first led to suspect this by the extraordinary freedom of Spirogyra and Iridea—the smoothest, most slippery fresh and salt water algae, respectively, which I know—from diatoms and other sessile plants growing upon them. Cladophora and Microcladia, comparatively rough forms, show the direct opposite.

To test this hypothesis with marine algae, I put in the bottoms of the glass dishes used for cultures cover glasses 18×18^{mm} square, which had been carefully ground on one side on a stone. One half of the cover glasses were put smooth side up, the other half rough side up. At first I used the cover glasses only rough side up, letting the smooth glass of the dishes furnish the other surface. This plan seemed open to objection, as the glass of the dishes might not have the same composition as the material of the cover glasses, and the light would not be the same on a ground surface as on a smooth. This latter objection is not wholly eliminated even by using thin cover glasses, but it is as nearly eliminated as at present possible.[8] The

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[7] PFEFFER (1, p. 305) has felt obliged to retract his published conclusions, based on the work done in his laboratory by the late R. HEGLER (6), that an increased strain acts as a stimulus to the development of increased strength, as shown in part by anatomical changes in the tissues; but I may venture to express the belief that time will show that PFEFFER and HEGLER and not PFEFFER and BALL (1) were right.

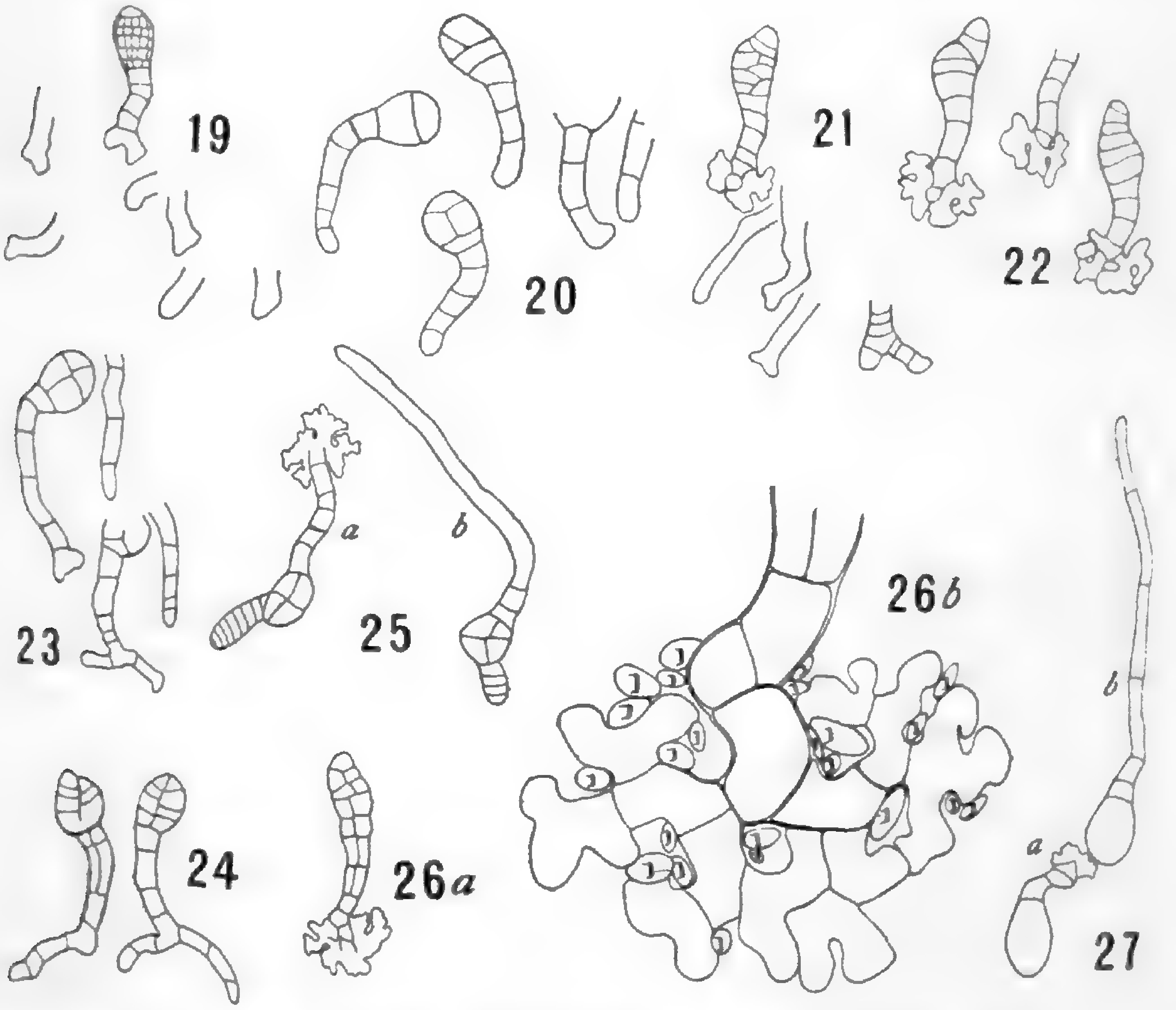
[8] The objection can be and was eliminated in certain cultures by keeping them in the dark. The results were similar to those in the light, but darkness necessarily introduces other effects if prolonged.

cover glasses ground on one side only, some with the ground surface upward, others with the ground surface downward, served as the bottom on which the spores settled.

In these experiments I used the same species previously enumerated, but those which form a single rhizoid at first give more immediately recognizable results than those which, like Cystoseira, form several rhizoids. For this reason Dictyota, Dictyopteris, and Laurentia are preferable. I shall describe first Dictyopteris, as it was the marine alga with which I first obtained satisfactory results. The results obtained with Laurentia are so similar that I shall not speak of them further.

In *fig. 19* we have sketches of Dictyopteris plantlets two and five-sixths days after sowing on ground glass. *Fig. 20* shows plantlets sowed at the same time on smooth glass. In the first set the rhizoids are beginning to enlarge, and one to branch, at the tips. In the latter there is no such appearance. The idea that this difference in appearance might be due to a difference in age suggests itself. But the difference in age could be only slight, for the fertile branches were removed at the same time from both dishes, and both dishes were emptied and filled with fresh sea water at the same time. Emptying the dishes generally removes the youngest spores, those still unattached or only slightly so, leaving those which are equally firmly attached. I am nevertheless inclined to think that not merely is growth in the part of the rhizoid in contact with a rough surface stimulated by that contact, but also the growth and development of the other parts of the plantlet also. There seems to be a transfer from cell to cell of the stimulus produced by contact, a stimulus the greater the rougher the surface. If this be true, there is every reason for the younger appearance of the plantlets on the smooth glass, for their growth was less stimulated than that of the other plantlets. This is in accord with the observations previously referred to (**10**) which Loeb made upon animals.

Fig. 21 shows the same group of plantlets nearly twenty hours later. Here holdfasts are evidently begun. Twenty hours later than this we have the condition shown in *fig. 22*, where the rhizoids have almost completely lost their filamentous appearance and have become holdfasts, circular in general outline, but with elaborately crenated margins. Comparing these two figures with *figs. 23, 24*, showing plantlets of the same age on smooth glass, we see that the plantlets have not changed in character from day to day, though they have grown; that the rhizoids are still filamentous; and that no holdfasts are yet begun.



FIGS. 19–26.—*Dictyopteris polypodioides.* ×123, except 26 *b*, ×900.

19. Germinating spores $2\frac{3}{8}$ days since sowing on ground glass.—20. Same in every respect except sown on unground glass. Note that plantlets appear younger than those of same age on ground glass.—21. Same as *fig. 19*, but $3\frac{3}{4}$ days since sowing.—22. Same as *fig. 21*, but 24 hours later, $4\frac{3}{4}$ days since sowing.—23. Same as *fig. 20*, $3\frac{3}{4}$ days since sowing.—24. Same as *fig. 23*, 24 hours later, $4\frac{3}{4}$ days since sowing.—25. Ten days since sowing, *a* on ground side of cover glass, *b* on unground side, in sea water.—26*a*. On unground cover glass.—26*b*. Same showing diatoms and diatom-shells, *D*, in almost every lobe of the well-developed holdfast.

FIG. 27.—Two *Dictyota* plantlets on smooth glass. ×123.

a has formed a holdfast on coming into contact with dirt; *b* finding no such obstacle has grown out into a long rhizoid; *a* erect, *b* erect at tip but rhizoid creeping.

In *fig. 25* we see the condition of two plantlets of Dictyopteris ten days after sowing, the one on ground glass, the other on smooth. These are not the extremes of two series of plants, but are the average. On unground glass, however, under certain conditions, as elaborate holdfasts may develop as on ground glass. When I saw the plant shown in *fig. 26a,* I thought my hypothesis was disproved, for here we have as elaborate a holdfast as on ground glass. On examining the plant with a stronger magnification, I found, as *fig. 26b* shows, that diatoms or diatom-shells were very numerous on the glass at this point, making it rough, or rather covering it with obstructions to the growth of the base of the plantlet. This plant and the many others like it confirm my belief that roughness of surface stimulates the sessile algae firmly to attach themselves.

It must be noted, however, that ground cover glasses kept in cultures for a week or so become slimy; their roughness is reduced or concealed by a thin, very smooth coat, which must be dissolved off before one can use the cover glasses again with the maximum effect. Even when all "dirt" and diatoms are washed off, the cover glasses are not clean as they are when new; they must have the slimy coat removed too. This is easily done by boiling in fresh water for a few moments. On the other hand, diatoms, animal excrement, and fine dirt generally, often so roughen the unground surface of glass as to induce holdfast formation of marked character.

When for any reason, such as the extreme smoothness of the glass, or the absence of any contact whatever, the elongation of the rhizoids is not stopped, they may attain surprising lengths and often in a very short time. *Fig. 25* shows such an extraordinarily long rhizoid of Dictyopteris. *Fig. 27* shows us two plantlets of *Dictyota dichotoma* growing on the same smooth side of a cover glass. In the one case, the rhizoid soon came into contact with small particles of dirt sticking to the glass, and thereupon ceasing to grow in length, formed a typical holdfast. In the other case, no dirt caught the rhizoid, which continued to grow over the smooth slime-covered glass.

I may here say something about the amount and the rate of growth of these germinating spores. On November 5th, at a quarter past twelve, I made a camera drawing of a spore of *Dictyota dichotoma.* Four hours later I similarly drew the same spore. And the next morning at a quarter to eleven o'clock I made another drawing. This third drawing is 107 per cent. longer than the first and 85 per cent. longer than the second. Another spore was 0.089^{mm} long when the first drawing was made. In four hours it grew 0.016^{mm}; in twenty-two hours and a half it grew 0.089^{mm}; and in forty-five hours and a quarter it grew 0.2195^{mm}. These figures converted into rates of growth per hour show that the plantlet increased in length at the rate of 4.23 per cent. per hour for the first four hours, 4.4 per cent. per hour for the next eighteen hours, and 5.82 per cent. per hour for the following twenty-three hours. These figures, however, distribute the growth over the whole length of the young plant, whereas it is mostly at the tip. Since this is the case, the rate of growth in the growing part must be much higher. I was not able at the time to make measurements to ascertain this rate in Dictyota. Similarly a spore of *Dictyopteris polypodioides* increased in length 360 per cent. in three days, or an actual increase in length of 0.292^{mm}.

All of these cases of growth are unusual. The plantlets sent out their rhizoids either horizontally or somewhat obliquely upwards, at all events without contact with the surface of the glass. Where contact occurs, there is no such extraordinary growth unless the contact be with an exceedingly smooth slippery object. There, as in water, the rhizoid will continue to elongate.

In a spore of Dictyopteris I attempted to measure the length of the growing region, the total increase in length, and the distribution of this increase among the cells of the rhizoid; but the growth rate in this instance has little value, because of the extraordinarily cold weather prevailing at the time. As the laboratory is cold at night, the growth rate for twelve hours of the twenty-four must have been much below normal. However, I will give the figures. The increase in length of the tip cell of the rhizoid was 150 per cent. or 0.078^{mm} in twenty-four hours. The increase in length of the cell next behind was 40 per cent. or 0.020^{mm}. The other cells of the rhizoid did not lengthen at all. Of the total increase in length 79 per cent. was made by the tip cell. This cell had at the outset only 41 per cent. of the length of the growing region. The actual zone of growth, however, is only the tip of the cell. Hence these percentages give only a vague and quite inadequate idea of how rapid the growth is in the actually growing part.

SUMMARY.

1. The zoospores of Oedogonium, as has long been known, are sensitive to light, the direction of locomotion and the place at which they come to rest being determined much more by the direction and

the intensity of the light falling upon a body of water than by other influences, such as unequal distribution of oxygen, etc.

2. Apparently the germination of the zoospores of sessile algae is induced primarily by interference with their locomotion. When this is blocked, germination begins; conversely, when nothing prevents locomotion, they do not germinate.

3. The nature of the attachment formed by the germinating zoospores of sessile algae is dependent upon the roughness of the surface of the object with which they come into contact. Upon extremely smooth surfaces—such as the surface of clean water and clean wet gelatine—the spores form either only the shortest most rudimentary holdfasts or merely rhizoids; whereas, on relatively rough surfaces, the holdfasts are large and conform in their lobing to the contour of the surface. Furthermore, ordinarily floating algae may sometimes be induced to form rhizoids or other organs of attachment if brought into contact with sufficiently rough surfaces.

4. The discharge of the spores or gametes of Dictyopteris, Dictyota, and Cystoseira is strongly influenced by light, the discharge being much more rapid within a few hours after exposure to light than before or than in continuous darkness. For this reason the time of the discharge as well as the rate is strongly influenced by light, and a periodicity of discharge is established which follows approximately the periodicity of daylight and darkness.

5. The spores of the sessile marine algae studied germinate better in normally alternating daylight and darkness than in continuous darkness; and subsequent growth and development follow the same rule.

6. As shown by WINKLER to be the case with *Cystoseira barbata*, we have found that the direction in which the light falls determines the plane of the first division in the germinating spores of *Cystoseira erica marina*, Dictyopteris, and of Dictyota, the new cell wall being formed at right angles to the incident rays.

7. Similarly, the rhizoids or holdfasts formed by germinating spores ordinarily issue from the daughter cells away from the light. In darkness the rhizoids arise in all possible directions, sometimes even from both cells of a germinating spore.

8. The direction of growth of rhizoid and of plantlet is determined

mainly by the direction from which the light comes: the rhizoids are negatively phototropic, the plants positively.

9. As in fresh-water algae, so also in sessile marine algae, the nature of the surface with which the spores come into contact very largely controls the nature of the attachment formed, a rough surface inducing the growth of a large and well-developed holdfast, a smooth surface causing proportionately less growth.

10. Though the direction toward which the rhizoids ordinarily grow is determined at first by light, the character of the surface with which the rhizoid comes into contact still more strongly influences the direction of its growth.

11. The direction, rate, and kind of growth of these germinating spores is strongly influenced by contact irritation.

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THE BOGS AND BOG FLORA OF THE HURON RIVER VALLEY.

EDGAR NELSON TRANSEAU.

(WITH SIXTEEN FIGURES)

I. The Huron River valley.

PHYSIOGRAPHIC FEATURES.

THE Huron River valley, to the botanical survey of which the present paper forms the sixth contribution, is located in the southeastern part of Michigan. As indicated in *fig. 1*, the valley embraces parts of five counties.

Throughout, its surface forms are of glacial origin and, with the exception of the immediate borders of the river, have undergone but slight modification since glacial times. Perhaps its most striking topographic features are the rough morainic hills of its upper and middle courses, and the gently undulating plain of its lower course.

The river has its source in west-central Oakland County in Big Lake, 9 miles (14.5^{km}) southeast of Holly and approximately 40 miles (64^{km}) northwest of Detroit. Starting with an elevation of 950 feet (290^{m}), after a course, extending for 50 miles (80^{km}) generally southwestward and then for another 50 miles (80^{km}) southeastward, it empties into Lake Erie at an altitude of 573 feet (175^{m}) above tide. As is common in areas of glacial deposition, the topography of the drainage basin of the Huron has little of the appearance usually suggested by the term "valley." The upper two-thirds of its course is a winding depression among morainic knobs, lake basins, abandoned glacial drainage channels, and sand plains. Here the river is characterized by long reaches and occasional slight riffles. At intervals it broadens into stretches of lake-like character, as is illustrated by such bodies of water as Commerce, Taylor, Strawberry, Whitewood, and Bass Lakes, each with an area of one-fourth to one-half a square mile (65–130 hectares). The river margin is usually low and swampy.

Its tributaries enter it at every angle, and bring to it the drainage of hundreds of lakes and swamps. Most of these lakes are small, occupying areas of an acre (half a hectare) or more, but there are several of considerable size. Portage and Whitmore[1] Lakes occupy one and one-fourth to one and one-half square miles (325–390 hectares), while Union, Straits, Four-Mile, Ore, Independence, etc., cover a fourth to half a square mile (65–130 hectares). A very large percentage of the tributaries lie in flat-bottomed depressions whose surface approximates the ground-water level, consequently producing thousands of acres of swamp and marsh land. Everywhere occur small undrained depressions, some well above the average ground-water level, others containing lakes and bogs. It is also worthy of

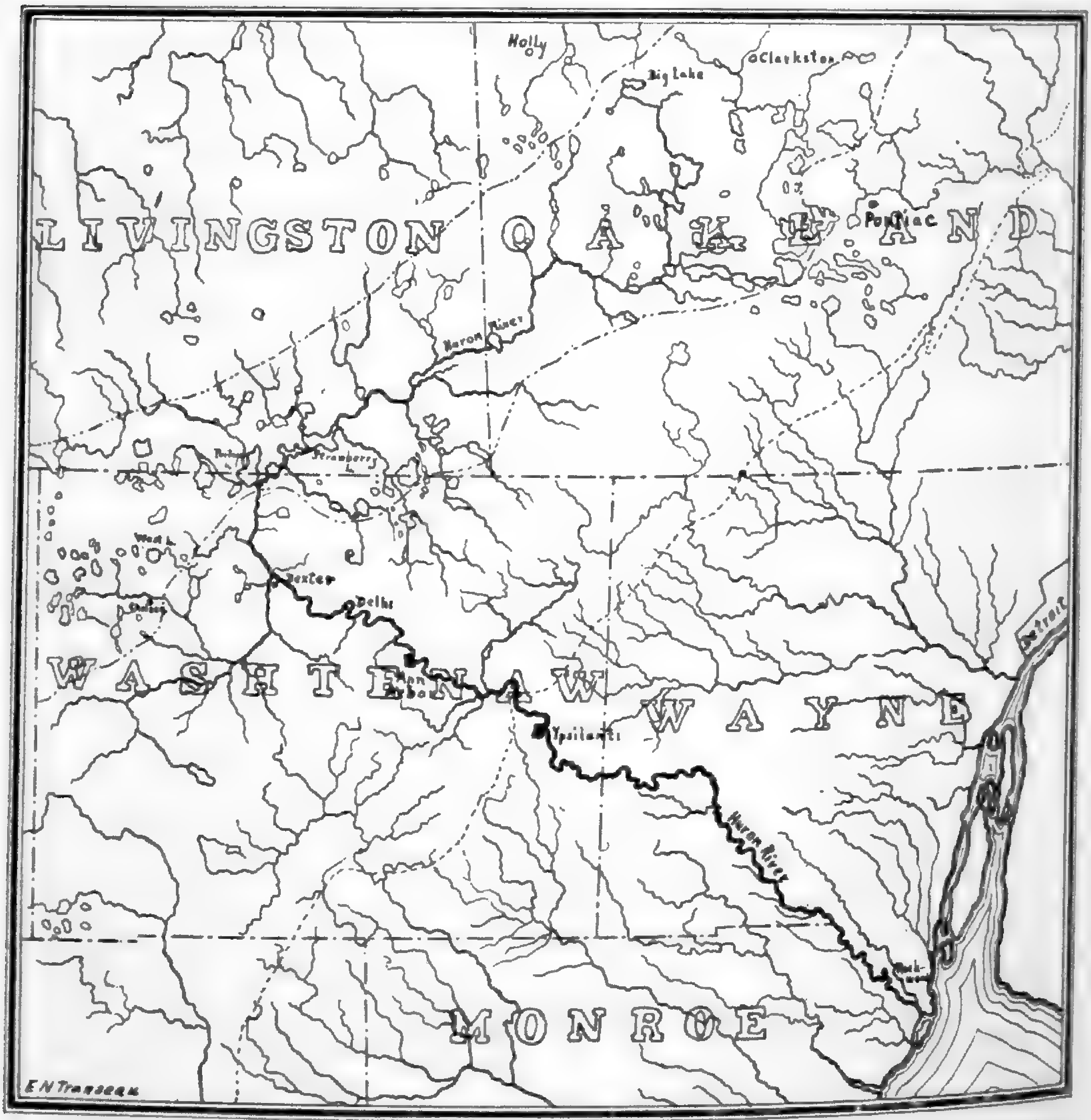

FIG. 1.—Map of the Huron drainage basin. The boundaries of the interlobate moraine are shown by the lines —·—. The boundary between the clay morainic belt and the lake plain is marked by the line - - - - -.

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[1] Not connected with the Huron River by surface drainage.

note that a large part of the surface drained by the Huron and its tributaries, before it makes the great bend to the southeast below Portage lake, is made up of sand and gravel, composing and accompanying the Saginaw-Erie interlobate moraine. It is a region of steep hills, with occasional dry plains, everywhere penetrated by lakes and swamps.

The country which the river next crosses, beyond the great bend, for a distance of 20 miles (32^{km}) is composed of glacial till plains and clay moraines—a belt extending NE–SW, approximately parallel to the interlobate moraine. Here, although the hills are well marked, the slopes are more gradual and the basins broader. The river is bordered by banks several feet in height, and seldom attains a width of 150 feet (50^{m}).

The last 30 miles (50^{km}) of the Huron River traverses a meandering course sunken from 50 feet (15^{m}) at Ypsilanti to 25 feet (7.5^{m}) at Rockwood below the surface of a glacial lake plain sloping gently southeastward from the morainic belt just described, to the western shore of Lake Erie. The soil is here composed of sand, sandy loam, and—in the vicinity of the lake—clay; the only topographic features aside from the sunken water courses being the several beach ridges and dunes marking the successive stages in the lowering of the glacial lakes, forerunners of the present Lake Erie.

There are, then, three natural divisions of the Huron drainage basin: (1) the loose-textured rough interlobate moraine; (2) the clay morainic belt lying to the southeast of it; (3) and the low-lying plain extending to Lake Erie. Each implies important differences in the way of bog formation and provides edaphic factors which determine to a large extent the nature of the dominant forest covering.

PHYSIOGRAPHIC HISTORY.

The history of these topographic features is for the most part bound up with the retreat of the ice at the close of the last (Wisconsin) glacial epoch. A topographic map of the region lying between Lakes Michigan and Erie shows that the morainic hills so characteristic of the Huron basin are part of a belt of similar physiography extending from northern Indiana well up into the "thumb" of lower Michigan (*fig. 2*). This belt of glacial deposits is directly connected with the development of reentrant angles along its crest, as the great continental ice sheet[2] became more and more differentiated into lobes during its retreat (**52, 13**). In northern Indiana it marks the first areas uncovered, as the mass of ice, pushed forward from the basin of Lake Michigan, separated from that originating in the Lake Huron and Lake Erie basins.

When the Huron River basin was reached, the Saginaw lobe had been developed and lay over the northwestern part, while the Huron-Erie lobe covered all of the territory southeast of the interlobate moraine. The first portion of our area to be uncovered is the triangular gravel outwash apron extending southwestward from Sugarloaf Knob. This was the beginning of the Huron River. Kavanaugh Lake then lay just under the edge of the Erie ice, and Crooked Lake occupied a similar position on the southern border of the Saginaw lobe. As has been recently determined by Mr. FRANK LEVERETT, of the U. S. Geological Survey, the subsequent history of the Huron drainage is most remarkable.

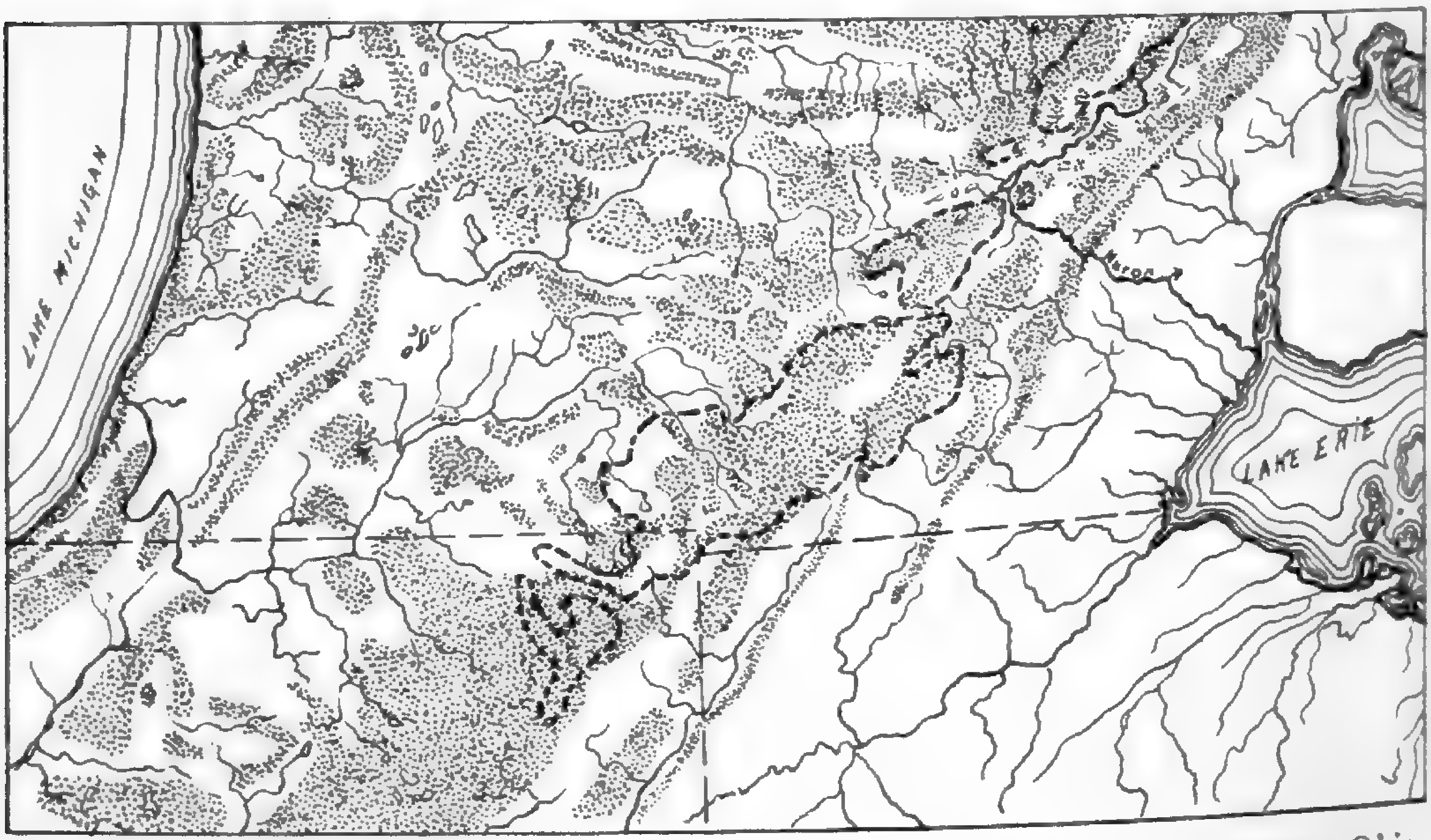

FIG. 2.—Map of southern Michigan, northern Indiana, and northern Ohio, showing "moraines with strong expression." After LEVERETT, U. S. Geol. Surv. Mon. 41, *plate 2*. The irregular dotted lines mark the 1000-foot (300m) contour.

The waters from the glacial drainage at first flowed generally westward, reaching the Kalamazoo River near Albion, thence to the St. Joseph at Three Rivers. At South Bend, Indiana, it crossed

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[2] For general map see no. **55**, p. 411. (Bibliography at close of this paper.)

to the Kankakee River, and reached the Mississippi by way of the Illinois.

As the reentrant extended itself further to the northeast, another channel was opened for the Huron drainage westward past Pinckney into the Grand River, and from there to Battle Creek and the Kalamazoo River. Below the city of Kalamazoo it cut across to the Paw Paw River, and reached the Mississippi by way of Lake Chicago.

When the ice of the Erie lobe had retreated as far eastward as Ann Arbor, and all of the interlobate moraine had been uncovered, a third outlet for the waters of the Huron was opened by way of Clinton and the Raisin River, which at that time emptied into glacial Lake Maumee at Adrian (**32**, *pl. 20*). This lake was drained by the Wabash River into the Mississippi.

As soon as the ice margin passed the clay morainic belt already described, the Huron reached Lake Maumee at Ypsilanti by way of its present channel. But Lake Maumee had meanwhile changed its outlet to the northward, its drainage going by way of Imlay (**53**) to the Grand River, Lake Chicago, and the Mississippi (**32**, *pls. 21, 23, 26*).

Later the Erie basin was entirely freed of ice, and its water for the first time flowed eastward into the Ontario basin (glacial Lake Iroquois), and thence by way of the Mohawk to the Hudson. With the clearing of the St. Lawrence channel the present system was inaugurated.

Aside from the physiographic interest connected with their early history, these glacial drainage channels are of distinct biological interest. They furnish continuous lowland habitats extending in all directions. In so far as they are represented by broad, open valleys, and connect with tributaries of the northern Ohio valley, they provide important highways for the dispersal of southern river-valley species.

FORESTS.

The three topographic divisions already described exhibit marked differences in their forest aspect. On the lake plain we find the richest and most mesophytic of the forest types. This lowland habitat is a continuation of the northern Wabash valley, and it is not surprising that its flora should be of much the same character. Here we find the greatest variety of tree species, among which are *Fagus atropurpureus*, *Quercus rubra*, *Ulmus americana*, *Platanus occidentalis*, *Acer saccharum*, *Tilia americana*, *Acer saccharinum*, *Fraxinus americana*, *Gleditsia triacanthos*, *Liriodendron tulipifera*, *Gymnocladus dioica*, *Cercis canadensis*, *Asimina triloba*, and *Celtis occidentalis*.

The clay morainic area is dominated by *Quercus rubra*, *Q. alba*, *Q. velutina*, *Hicoria ovata*, *H. glabra*, *Acer rubrum*, *Ulmus americana*, and *Quercus macrocarpa*.

In the region of the interlobate moraine the disappearance of the more mesophytic forms is quite marked. The forest is there largely composed of *Quercus coccinea*, *Q. macrocarpa*, *Q. velutina*, *Q. alba;* and as we go northeastward these become associated with *Pinus strobus*. *Quercus prinoides* forms a characteristic shrubby growth along the roadsides and in waste places.

Such is the forest background in which are set the thousands of acres of bog and swamp, and to which the groves of *Larix laricina* exhibit a marked contrast. These tamarack areas are to be seen on all sides in the region of the interlobate moraine; they are quite common in the clay morainic belt, but are practically wanting on the lake plain.

As one follows along the morainic country from northern Indiana into the "thumb"of Michigan, he passes from a region dominated by a rich mesophytic broad-leaved forest to one of conifer and xerophytic broad-leaved ascendency; from a region whose low grounds are characterized by a swamp flora to one in whose depressions the bog flora reaches a high state of development. In this connection it is interesting to note that one finds this gradual change epitomized in the Huron valley as he goes from its mouth to its source.

METEOROLOGICAL CONDITIONS.

Under this head we shall consider the general meteorological conditions of the Huron basin, and compare them with the meteorological conditions found about the center of the distribution of bog plants (**55**, p. 406). In general, this center extends from Lake Winnipeg through the upper Great Lake region down the valley of the St. Lawrence to the Atlantic coast. It is in the coast provinces, however, that the bogs reach their highest development, in the form of the "raised bog." Certain temperature phenomena associated with the bog habitat will be discussed in connection with the analysis of the life conditions obtaining in bogs.

Rainfall.—In the following table is given the mean monthly and annual precipitation for seven stations located within or near the Huron basin. As their individual variation is but small, it is probable that the average for the stations gives a fair estimate of the rainfall and its distribution. Appended are the corresponding records for the maritime region of eastern Canada:

MEAN PRECIPITATION IN INCHES.

Station	Alt. feet a.t.	Record for Yrs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor.	930	23	1.99	2.19	2.12	2.88	3.72	3.39	2.82	2.45	2.58	2.82	2.77	2.35	32.08
Ypsilanti. .	736	18	1.97	2.61	2.48	2.24	3.98	4.02	3.09	2.24	2.63	2.70	3.29	2.32	33.60
Jackson. . .	927	6	2.06	2.21	3.14	1.26	3.22	3.02	2.47	1.76	1.74	3.61	2.87	1.56	28.92
Annpere. . .	924	11	1.98	2.19	2.42	2.60	3.38	2.44	2.66	2.85	1.93	2.04	2.64	1.77	26.05
Ball Mt. . . .	932	13	1.73	1.76	2.07	2.12	3.52	3.13	2.47	2.59	2.62	2.69	2.71	2.30	29.72
Birm'gham	860	15	1.91	2.00	2.32	2.53	3.36	3.15	2.56	2.38	2.33	2.51	3.02	1.88	29.95
Average.			1.94	2.16	2.42	2.27	3.53	3.19	2.68	2.38	2.30	2.73	2.88	2.03	30.22
St. John, N. B.(18)		?	5.55	3.93	3.80	2.50	3.66	2.72	3.29	4.64	3.08	4.13	4.71	5.16	47.17
Halifax, N. S.(51)		22	5.63	4.94	5.15	4.00	4.43	3.68	3.43	3.96	3.53	5.21	5.26	5.52	57.74

It will be noticed from the above data that the precipitation is quite evenly distributed throughout the year. It reaches its maximum during the months of May and June, when the vegetative processes of the bog plants are most active. It approaches its summer minimum during July and August, when the temperature commonly attains its greatest height. The former implies that the water level in the bogs is kept at or above the surface of the substratum for weeks at a time. The latter involves strong transpiration on the part of the vegetation, when the water supply must be drawn for the most part from the substratum. The average number of rainy days during the past five years is one hundred per annum.

The average snowfall in this region during the five years, 1898 to 1902, amounts to 38.4 inches (975 ^{mm}). In the case of the bogs this thickness is usually increased by the drifting of snow from the surrounding hills. Observations during the past two winters show that the bogs are covered by ice to a thickness of a foot (30 ^{cm}) or more.

Consequently, low shrubs, and herbs which pass the winter by means of underground stems, are well protected from low temperatures and sudden temperature changes. The ice further results in lowering the temperature in spring and in retarding the beginning of favorable growth conditions.

The percentage of sunshine is not published by the several stations, but the number of clear and partly cloudy days is stated. The numbers from the various stations show marked differences, due to different standards established by the observers; but perhaps these are largely eliminated in the average. If we take the average number of clear days, add to it one-half the number of partly cloudy days, and divide by the number of days in a year, we obtain a percentage of forty-six. This probably approximates the percentage of sunshine.

In comparison with the rainfall data for Halifax and St. John, it is notable that in the latter localities the mean rainfall, both monthly and annual, is considerably larger. The annual precipitation exceeds that of the Huron valley by fully 20 inches (50 ^{cm}), or about 40 per cent. Finally, the sunshine percentage is slightly lower, being 39 for Halifax and 42 for St. John.

Temperature.—The following table exhibits the monthly and annual means for the several stations already cited:

MEAN TEMPERATURE IN °F.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor..........	22.2	23.1	30.6	45.4	53.2	67.3	72.0	69.3	62.5	49.9	36.4	27.1	46.6
Ypsilanti............	25.9	24.2	32.3	46.7	58.1	63.5	71.1	69.7	61.8	49.9	36.7	27.6	47.3
Jackson.............	26.1	20.3	32.7	47.5	59.4	69.4	74.8	71.8	64.8	54.7	37.7	26.5	48.8
Annpere.	24.7	21.7	31.3	50.2	56.5	68.4	71.8	67.6	63.0	49.8	35.9	26.7	47.4
Ball Mt..............	22.6	21.4	27.6	45.3	56.0	66.9	70.0	68.1	62.2	49.5	35.9	27.1	46.0
Birmingham.........	23.1	22.8	30.4	46.5	57.3	69.1	72.2	68.4	61.5	49.7	36.7	27.0	47.1
Average..........	24.1	22.2	30.8	46.9	56.7	67.1	71.9	69.1	62.6	50.6	36.5	27.0	47.2
St. John, N. B.......	18.6	18.7	26.3	38.6	48.8	56.3	61.0	61.3	55.6	44.7	36.1	23.7	40.8
Halifax, N. S........	22.0	22.7	28.7	38.2	48.7	57.6	64.2	64.8	58.2	48.0	38.2	27.0	43.2

The table shows that the temperature conditions are comparatively uniform throughout the basin. The maximum average temperatures occur in July and August. But the significance of the data becomes more apparent, in so far as the bog vegetation is concerned, when they are compared with those of St. John and Halifax (*fig. 3*). It is to be noted that, although the average temperature for June, July, and August of the Huron basin is 8.6° F. (4.8° C.) higher, its rainfall during the same period is less by 2.6 inches (66 mm). There can be little doubt as to the effect of such differences upon the growth of the bog species, especially the sphagnum whose moisture supply is more directly dependent upon atmospheric water than upon the soil solution. Again, the occurrence of high temperature with decreased precipitation means the production of conditions impossible for the development of the "raised bog," if not unfavorable to the highest development of the "flat bog."

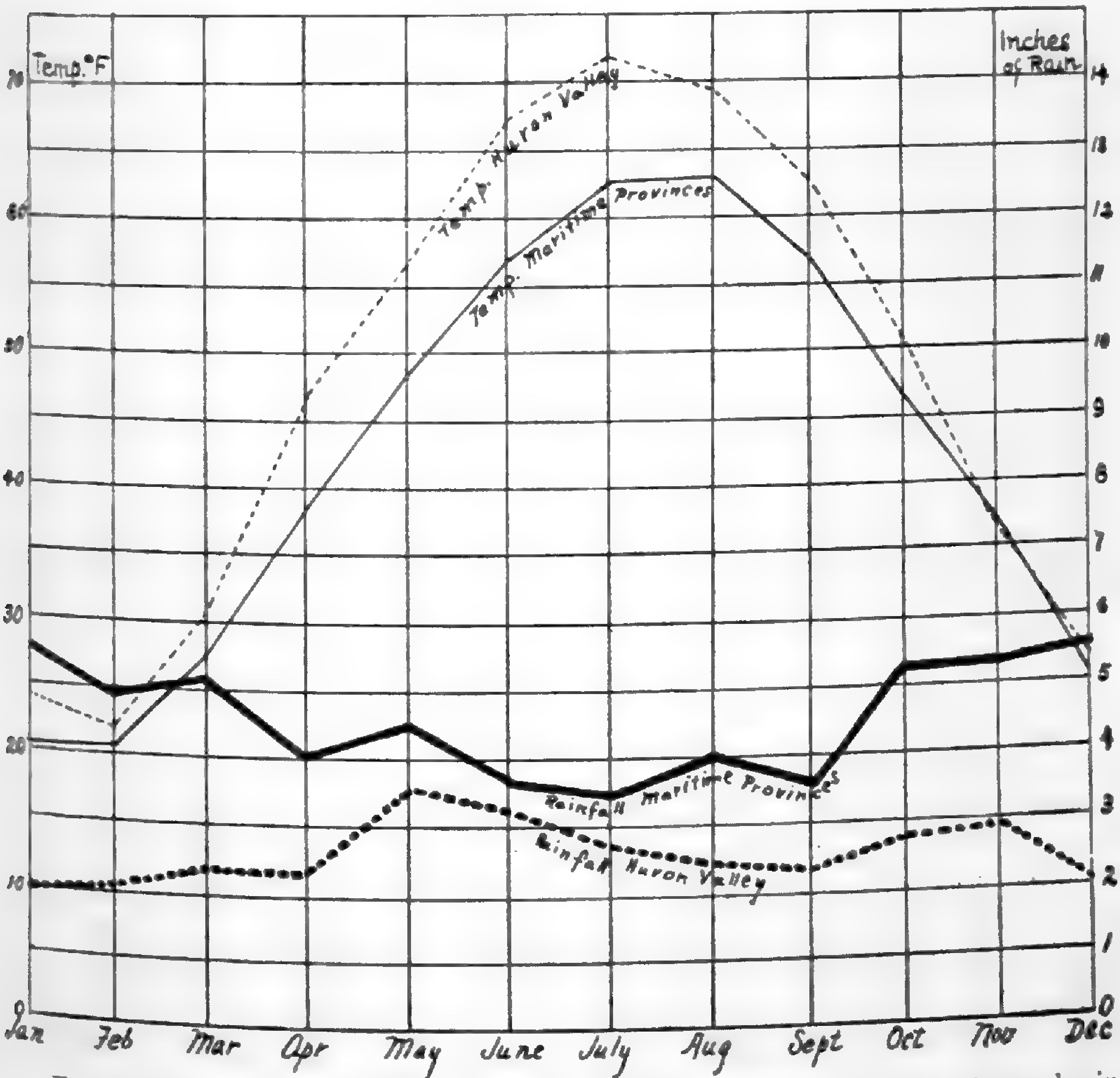


FIG. 3.—Curves of rainfall and temperature conditions in the Huron basin compared with those of the maritime region of Canada.

Since bogs attain their maximum development in a region of great rainfall and comparatively low temperatures, it is reasonable to infer that the extremes of summer heat become peculiarly significant in this region. Examination of the weather records shows that temperatures of 97–100° F. (36–38° C.) are likely to occur every year, and that temperatures approximating these may be prevalent for several days in succession each season. When these extremes coincide with periods of drought, they must act as important checks on the growth of the bog plants, especially the sphagnum. As we pass from northern Indiana along the moraine into Michigan, the gradual increase of bog development, of the variety of bog species, and of the areas covered by sphagnum is very marked. Although other factors are involved, this increase may be correlated with a decrease in summer temperature extremes.

II. The bogs: their development and ecological conditions.

PHYSIOGRAPHIC ORIGIN OF THE LAKE AND BOG BASINS.

In connection with the special consideration of the bog flora, it is of interest to note the origin of the depressions in which this flora has developed and flourished. Indeed, in the morainic belt of the Huron basin it would seem that among the agencies which have produced important topographic changes since glacial times, the bog plants stand near the head of the list. Stream erosion and deposition have been slight, while lake basins have been filled and the level of depressions generally raised by the deposition of plant débris.

As no attempt has as yet been made at the mapping of peat deposits and muck soils, no reliable estimate of the total amount of aggradation accomplished by plant agencies can be made. Yet the frequency with which in field work one encounters peat soils, in various stages of making or decay, suggests that in the aggregate such deposition has been most effective in this region. The northwest quarter of the Ann Arbor topographic map, which embraces an area of about 215 square miles (55,700 hectares), located in the morainic portion of this basin, indicates approximately 43 square miles (11,500 hectares)—20 per cent.—as swamp land. It is probable that at an early time this area was very much larger, but with the settlement of the land many extensive areas have been drained and only the dark humous soil remains to suggest its past history.

The most frequent source of lake and bog basins is here found in connection with the deposits made by glacial drainage. Among the vicissitudes attending the retreat of a glacier are the occasional detachment of blocks and masses of ice through differential melting (**19**). If these detached masses happened to be in the line of the overloaded glacial drainage, they became covered to a greater or less extent by sand and gravel. Owing to the poor conduction of heat by such deposits, they melted with extreme slowness. Where this latter process was prolonged until the drainage line had been abandoned or the stream had ceased depositing, subsequent melting brought about a settling of the deposits and the production of basins. Sister, Kavanaugh, and Crooked Lakes are examples of this type.

In the case of the chain of lakes which form a part of the Huron River in northwestern Washtenaw County, and such lakes as Portage, Tamarack, Ore, and Bass, according to LEVERETT, there was an additional settling of the fluvio-glacial deposit itself. This latter process has been of the greatest importance in the development of extensive bog areas. In the Portage Lake region this settling has amounted to as much as 40 feet (12^{m}) in certain places, and has resulted in reducing many hundreds of acres of land to the ground water level.

Throughout the belt of till plains occur shallow marshes, sometimes drained, but usually by a sluggish meandering stream, itself impeded by the growth of swamp plants. These basins are the natural expression of the unequal deposition of glacial material. Till plains result from a comparatively rapid retreat of the ice; hence the depressions are usually shallow, and have been mostly filled with peat to the level of the present drainage. The several small lakes lying to the west of Dexter are examples of basins not yet obliterated.

Where the retreat of the glacier is slow and deposits are made to a great thickness about the edge of the ice, kame or "knob and kettle" topography results. The basins of such areas are characterized usually by high margins and comparatively steep slopes. West, Silver, North, Island, and South Lakes may be cited as examples.

As we know from remains discovered in peat deposits, among the animals inhabiting this region in early postglacial times were the mammoth, mastodon, bison, peccary (*Platygonus compressus* LeConte) (**57**), elk, and "big beaver" (*Castoroides ohioensis* Foster). The last named is not a beaver (**34**, p. 256), but is more nearly related to the Coypu rat of South America. The common beaver

(*Castor canadensis* Kuhl) has been an important factor in the creation of bog areas (**37**), and in the extension of areas already existing, by the building of dams. The beaver was found in this section when it was first settled, but the last known specimen was killed sixty-nine years ago. The occurrence of peat deposits several feet in thickness and covering quite large areas, bordering streams, whose channels lie deeply sunken in the deposits, seems to find its best explanation in this manner. But little field work has been done on the relation of beavers to the peat deposits, and examples are still too hypothetical to cite in this connection.

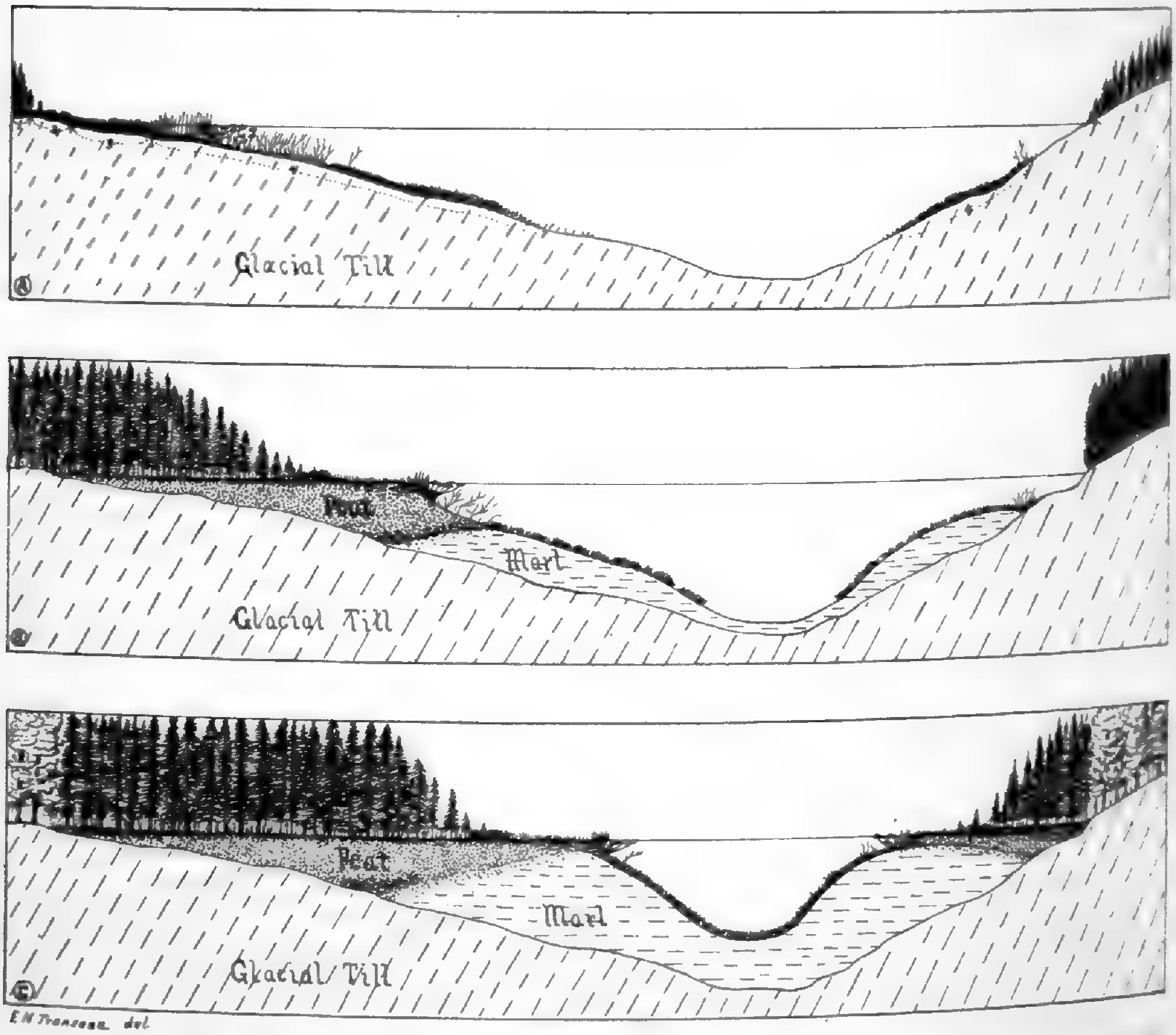
BOG AND LAKE VEGETATION.

Of the plants which might come into a new land area containing basins, such as was laid bare on the retreat of the glaciers, none is better adapted to rapid migration than the group of aquatic plants. Whether we have in mind the smaller submerged varieties or the partially submerged littoral species, their wide geographic distribution and uniform associations bespeak their evident solution of the problems of dispersal. The fact that deposits of peat and marl have been found in northern Indiana and lower Michigan to a thickness of 40 feet (12^{m}) would indicate that in these particular basins the vegetation must have obtained an early foothold.

Concerning the deposition of marl, it is of interest to us only in so far as it becomes an agent of aggradation in the basins. In the reports (**5, 42, 21**) on the marl deposits of Indiana and Michigan, many examples are cited where the marl forms the underlying substratum of peat deposits. That its deposition to a large extent is due to plant life has been shown by DAVIS (**9, 10**). The plants most concerned with this process are the Characeae and Cyanophyceae (Schizothrix, Zonotrichia). They are probably aided by certain mollusks, and perhaps also by chemical precipitation. As for the Characeae and Cyanophyceae, they have a wide range of habitat in different lakes, and may occur in deep or shallow water and on various rock substrata. Where they come into competition with shore species, the rank growth of the latter usually precludes their existence in sufficient amount to be of importance in marl formation. Where wave action is strong, the chara is confined to deeper water, but the blue-green algae may be present up to the water's edge, in such situations frequently forming marl pebbles. The lower limit of existence is largely determined by the transparency of the water, and may lie between 20 and 30 feet ($6–9^m$). Of the littoral plant associations there are commonly two quite distinct divisions, the outer made up largely of submerged or floating pondweeds and water-lilies, the inner of half-submerged rushes and sedges. Both are concerned in the process of peat formation. Under such conditions there naturally develop, in regions of calcareous underground waters, an outer zone of chara dominance and marl deposition, and an inner zone of pondweed-sedge dominance and peat deposition. Variations in the slope of the bottom, in the amount of wave action, in the presence of shore currents, and in the color of the water, determine whether one or both of these processes shall go on, and to what extent these activities are kept distinct or grade into one another.

In the case of the peat, however, the process is not dependent upon water species alone. They act merely as forerunners of a denser and more luxuriant vegetation which frequently is of greater quantitative importance. Briefly, we may note here that in the case of the bogs, unlike that of the swamps, the plants which develop on the margin, especially *Carex filiformis* and forms of Eriophorum, are able to secure all of their food materials from the water and air and build their own substratum. This tangle of roots and rhizomes usually attains a thickness of several inches, and on account of its low specific gravity floats on the surface of the water. Upon this foundation the sphagnum and bog shrubs advance, adding their quota to the débris. Later, these are followed by such tree forms as the tamarack. Coincident with this increased weight and augmented rate of deposition, comes the progressive submergence of the floating substratum, and its gradual disintegration and humification. The accompanying *fig. 4* will serve to illustrate this process.

Within the last two years much has been promised toward the utilization of the peat deposits in this region for fuel purposes. Companies have been organized, and the machinery necessary for the drying and consolidating of the peat has been much improved. At Capac and Chelsea, factories have been erected, and attempts are being made to place the industry on an economic basis. If these ventures prove successful, we may hope for an interesting body of scientific information to come from the study of bog sections. The work of ANDERSON, LAGERHEIM, SERNANDER, WEBER, and others in Sweden and Germany, gives indication of the data concerning postglacial migrations of plants and animals, and climatic changes, which will be obtainable when our bog deposits become of economic importance.



E N Transeau del.

FIG. 4.—Diagrams illustrating three stages in the development of peat and mar deposits in lake basins. In drawing the figures it has been assumed that the rates of marl and peat deposition are approximately equal. The peat accumulates most rapidly on the western side of the basin. On the east side a common effect of wave action is illustrated. The process of peat formation is hindered, while that of marl deposition goes on until the aggradation of the bottom reduces the force of the waves sufficiently to allow the bog plants a foothold. *A* represents conditions in early postglacial times when these basins acquired their first flora. The several plant societies represented are (1) conifer (2) bog shrub, (3) bog sedge, (4) aquatic, the outermost division of which is the chara association. In *B* the conditions for the growth of plants belonging to the northeastern conifer forest formation have reached their optimum. *C* represents present conditions in southern Michigan. The plants belonging to the southeastern broad-leaved forest formation, being climatically favored, occupy the areas of mineral soils, while the conifers are almost restricted to bog areas.

THE GEOGRAPHIC DISTRIBUTION OF PEAT DEPOSITS.

In North America the distribution of recent peat deposits may be conveniently summarized under two heads, genetically unrelated: (1) those of glaciated regions; (2) those of the coastal plain.

The peat of the glaciated area constitutes the great bulk of these American deposits. The southern boundary of this region is marked by a line passing westward from central New Jersey through northern Pennsylvania and Ohio, central Indiana and Illinois, thence northward through southern Wisconsin, northwestward to the Minnesota valley and the Red River of the North in Manitoba, westward through northern Assiniboia and southern Alberta to the Rockies. Here the boundary is deflected southward into Montana, but in crossing toward the coast it is again carried northward into British Columbia, and finally southward among the Cascades of Washington to the Pacific Ocean.

Along this southern border the peat deposits are exceedingly scattered and make up a small fraction of the total land surface. They have accumulated under water in depressions among the recessional moraines. As we go northward, the relative proportion of peat bogs and peat deposits regularly increases, and there is a notable tendency toward the accumulation of pure humus in situations other than depressions containing water. When the tundra or "barren ground" is reached, the accumulation of humus is almost universal. The contrast with our own region is well brought out in RUSSELL'S account of the tundra (**43**, p. 129). The vegetation

> grows rapidly during the long, hot, summer days, dies below and partially decays, but becomes frozen and has its complete destruction arrested, while the dense mat of roots and stems continues to thrive. In this way an accumulation of partially decayed vegetable matter is formed, which increases in thickness from year to year by additions to its surface. The process is similar to that by which peat bogs are formed in temperate latitudes, except that the partially decomposed vegetation becomes solidly frozen. It is in reality an example of cold storage on a grand scale.
>
> Under existing climatic conditions there does not seem to be any limit to the depth such deposits may attain. The amount of carbonaceous material already accumulated in the tundras of America and Asia must equal that of the most extensive coal field known.

South of the boundary above described, peat deposits of considerable extent are occasionally met with. In the region of the great plains they are sometimes found beneath a surface covering of sand and wind-blown deposits. TODD (**54**, p. 121) has mentioned the occurrence of such peat deposits in eastern South Dakota. BARBOUR also reports such deposits from central and eastern Nebraska (**2**). On the basis of their field relations and certain fossils which they contain, they are believed to be of Glacial and early Pleistocene age. If the plant materials of these deposits could be carefully worked over with reference to their successive floras, we might hope for some new light on glacial climate, since a part of the deposits are beyond the margin of the Wisconsin ice sheet. But even their location and existence give evidence of climatic change, and plant and animal migration. Although now widely separated from the region of active bog formation, they are historically connected with this division.

Among the mountains of both the eastern and western United States, bogs and swamps are to be found in association with mountain lakes. More frequently than otherwise these depressions are connected with former local glaciation, perhaps the most frequent situations being those afforded by the damming back of water by terminal and lateral moraines. Basins for peat accumulation are also found in solid rock made by glacial erosion. The conditions here are quite similar to those of the north, the altitude bringing about the same general effect as the latitude. The analogy is still further shown on mountains in moist regions where alpine meadows are strongly developed. Not only are the plants related to those of the tundra, but the deposition of peat or humus is again irrespective of basins.

In many places east of the great plains there is another type of situation not directly connected with glaciation, but in which vegetable débris may accumulate to considerable thickness, viz., about the débouchure of cold springs. Toward the north these springs may bring about humus accumulation on slopes, but further south peat is usually associated with pools and small lakes.

The second group of situations in which peat accumulation takes place on a grand scale, are those associated with coastal plain phenomena, such as the rising and sinking of the land, the irregular deposition of alluvial materials in deltas, and the extension of the land through reef building. These swamps have been described by SHALER, KEARNEY, JULIEN, and others (**46, 26, 24, 7**). They reach their greatest development in eastern Virginia, North Carolina, Florida, and the Mississippi floodplain. They may contain either salt or fresh water, and their vegetation is noted for its density and luxuriance.

The geographical distribution of peat deposits is of interest in this connection because it points to certain factors which contribute to the preservation of humus materials. Certainly in arctic latitudes the most significant factor is the low temperature, for humus accumulates to great thickness even with a scant vegetation. In the northern states and southern provinces of Canada, peat is associated with basins containing stagnant water or cold springs. The annual increment from the vegetation is greatly increased over that of the tundra. Mild temperatures and stagnant waters combine to preserve the plant débris. When we come to the coastal plain swamps of the southern states, this process takes place only where a luxuriant vegetation is combined with areas of stagnant water of considerable depth.

To put it sharply, we may say that, in spite of the scant vegetation, the cold of the tundra results in peat accumulation. In temperate latitudes, mild temperatures and stagnant water combine to prevent the complete disintegration of a vigorous vegetation. In the south, in spite of the high temperature, the luxuriance of the vegetation and stagnant water unite to make peat formation possible.

THE PROCESSES INVOLVED IN PEAT FORMATION.

When for any reason the living protoplasm in a plant or any of its organs is brought to the condition of death rigor, the continuance of this state for a prolonged period inaugurates certain chemical and physical processes which result in the breaking down of the exceedingly complex structures and compounds making up the living plasma. Among the first outward signs of such disorganization is the loss of water. The cells of soft tissues lose their normal form, and in any case the tissue becomes more or less filled with gases. The protoplasts as such disappear, and in their place granular carbohydrate and proteid bodies are to be found.

Aside from the mineral substances composing the ash of such bodies, the organic compounds are made up for the most part of carbon, hydrogen, and oxygen. In the case of the proteids, there are added to these nitrogen, sulfur, and phosphorus. As to the exact nature of the compounds existing in the dead material, aside from the carbohydrates, very little is known. The same statement holds as to the nature of the decomposition which goes on without the intervention of saprophytic organisms. But it seems probable that oxidation does occur. This action, then, is the beginning of the more comprehensive process known as peat formation.

When plants or their organs die, under ordinary circumstances they are at once attacked by fungi and bacteria. The progress of dissolution is then greatly hastened, and the final disintegration is more complete. According to the operation of certain external factors, the destruction may involve two very different groups of organisms and result in bodies of very different chemical and physical properties. These two processes are known as eremacausis and putrefaction **(61, 39)**.

Where access to oxygen is accompanied by favorable temperature and moisture conditions, the first of these processes, eremacausis, takes place. The formation of ordinary soil humus may be cited as an example. That oxygen plays the important rôle has been demonstrated both by experiment, and by the analysis of the gaseous and solid products. It has been shown, for example, that soils in which eremacausis is in progress contain CO_2 and O in inverse proportion to one another. Under constant volume, as the one increases the other decreases. It has been also shown by experiment that the process is wholly dependent upon the activities of certain lower plants. Among these members of the genera Mucor, Aspergillus, Penicillium, Saccharomyces, Micrococcus, Bacterium, Spirillum, Crenothrix, and Beggiatoa are most important.

The carbohydrates are by this means broken down to CO_2 and H_2O. The albuminoids and amides constitute the principal forms of the nitrogenous materials. Under the influence of these organisms, especially their katabolic processes, the oxygen unites with the carbon to form CO_2, the S is oxidized to H_2SO_4, the P to H_3PO_4, and the H to H_2O. The first form in which the nitrogen reappears is that of ammonia. This is at once attacked by the nitrifying bacteria, and changed successively to the form of a nitrite and a nitrate. The two latter changes again involve the addition of oxygen.

If we consider only the temperatures occurring in nature, we may say that these activities increase regularly with the temperature. As to water conditions, it has been shown that in air-dry soil eremacausis is practically wanting, and that when the soil is filled with water it is reduced to a minimum. Between these two extremes lies an optimum at which there is sufficient moisture for the life of the organisms, and yet not enough to interfere with the diffusion of oxygen. An acid condition impedes, and a slight alkalinity favors, the production of both the carbon and the nitrogen compounds.

Eremacausis is then essentially a process of oxidation, brought about by lower organisms, whose activities are favored by a high temperature, a slightly alkaline medium, and free access to the air. Its products are simple compounds which may furnish food materials for the higher plants living on the substratum in which they are formed.

By putrefaction is meant that process of disintegration which occurs when organic matter decays in the absence of oxygen. Here again organisms are involved, but they belong for the most part to the anaerobes, and are wholly forms of bacteria. The process is essentially one of reduction.

Carbon dioxid is again the principal gaseous product, but its relative amount is greatly reduced. Along with it CH_4, H, H_2S, H_3P, N_2O, and N are produced in small quantities. In the manufacture of the carbon dioxid the oxygen is not only derived from the organic matter, but also from nitrous oxid, nitrites and nitrates which may be present. In the decomposition of cellulose, carbon dioxid and methane result from the hydrolysis of the cellulose molecule. Albumins at first break up into amido-acids, nitrogenous compounds of the aromatic series, and other little-known bodies. If the decomposition continues, the amido-acids in turn form ammonia and compounds of the fatty-acid series. The latter substances may still further disintegrate to carbon dioxid, hydrogen, and methane. Depending upon the stage in the progress of decomposition, we may find complex organic compounds, organic acids, and their salts, or comparatively simple substances.

As to the influence of external factors, high temperatures increase the rate of disintegration, while the presence of acids prevents its continuance, due to the killing of the bacteria involved. It is to be noted that the products of putrefaction, both intermediate and final, can be of little use in furnishing food materials for the higher plants.

With these two processes in mind, we may now consider the matter of peat formation as it occurs in this region. We have already seen how the substratum is being extended at the edge and renewed at the surface by the plants forming the outer zone of the bog vegetation. It consists of sedges, especially forms of Carex and Eriophorum. Each year these plants send up stems and leaves from the matted rhizomes. At the approach of winter these are killed, and the snow later on aids in bringing them down to the water level. In the spring the water covers almost the whole of this zone to the depth of several inches. With the gradual lowering of the water level and the coming of warmer temperatures, the conditions for eremacausis are made favorable. If the water is approximately neutral in its chemical reaction, the fungi and bacteria begin the work of disintegration, which if continued would result in the complete destruction of the vegetable débris. However, on account of the great demand for oxygen, the process can be carried on only near the surface of the water. Even at a depth of a few centimeters the rate of oxygen diffusion is so small, as compared with the demand for it, that practically all aerobic bacterial action is prevented. All of the surface waters which I have examined have been found to be teeming with bacteria.

Close upon the extension of the bog-sedge zone comes the sphagnum-heath zone. Here the surface is characterized by hollows and elevations, the latter frequently due to the upward growth of the sphagnum beneath the shade of the heath plants, but in some cases due to the building of mounds by ants. In the hollows the water stands above the substratum throughout a large part of the year and even during dry periods lies just at the surface. Unlike the sedges, the principal plants of this zone are evergreen. The sphagnum forms a continuous mat of living plants several centimeters in thickness, through which all of the oxygen must diffuse before it can be available for the eremacausis of the dead plant-material beneath. The cassandra, cranberry, and andromeda which compose the bulk of the shrubby vegetation add to the débris largely by their leaves and underground stems. The former fall to the substratum as they die, but not at the close of each vegetative period. Consequently they are soon lost among the sphagnum, and there is no distinct annual layer added.

But beneath this layer of possible aerobic activity, the material would seem to be subject to putrefactive agencies. And there can be no doubt that such destructive processes are carried on in those situations in which the acidity of the soil solution does not preclude the existence of the anaerobic bacteria.

Among the taller shrubs and trees, such as *Vaccinium corymbosum*, *Aronia nigra*, and *Larix laricina*, the defoliation takes place each autumn. As these plants are of relatively large size, the bulk of the material forms a noteworthy annual addition to the substratum. When to this is added the twigs and small branches which fall each season, we can understand the fact that the substratum is almost entirely free of surface water. Usually the ground-water level lies 5–10 ^{cm} below. But the substratum has a high water-capacity and is kept constantly moist. Where the sphagnum covering is wanting for one reason or another, the dark color of the surface peat shows how much more complete is its disintegration as compared with that of the other zones. This condition is made possible by its position relative to the ground water. On the other hand, as will be shown later, the temperature conditions are more favorable in the zones of herbaceous and shrubby vegetation.

Most of the basins in which peat formation is going on actively, are subject to considerable variation in water level, both seasonal and annual. During the last two years the rainfall has been considerably above the normal in lower Michigan, and many of these bog areas were flooded. At West Lake, for example, a large part of the tamarack area was covered with water to a height of several inches above the level of the roots. Most of the basins are also subject to higher water level in the spring and during prolonged rainy periods. Accompanying such changes there are great differences in the rate and manner of decay. High water, in so far as it excludes oxygen, favors putrefaction; if it comes as a result of heavy rains, it decreases the acidity of the soil solution, increases its oxygen content, and at least for a short time favors the growth of the saprophytes causing eremacausis. Low water level exposes a much greater bulk of the substratum to disintegration, and favors the carrying away of the products of decomposition; in general, it favors eremacausis. In the samples of water which I have examined at various times from the same depressions, there have been marked variations within short periods of time in the color of the water and in the presence of such animals as Daphnia and Cyclops. No attempt has been made to count or even separate the bacteria present, but it is probable that they too vary with the color of the water and the animal life.

When the bog land has been cleared and ditched, the marked increase in the rate of decay is apparent. Eremacausis becomes exceedingly active, and in the course of a few years the substratum is reduced to a brownish-black, pulp-like mass. If continued, this goes to form "muck," a substance which when dry is powdery and somewhat resembles soot. During these processes of decay there occurs a succession among the organisms present. The accumulation of disintegration products makes the medium unfavorable for the continued existence of the organism involved in their production. At the same time it may furnish optimum conditions for the development of other forms. An acid medium favors the growth of the Phycomycetes, while alkalinity favors the bacteria. In such regions as this, where the underground waters are alkaline, the latter fact, together with fluctuations in the ground-water level, may have an important bearing upon the presence of more thoroughly decayed peat and of a distinct depression about the margins of many of the bogs.

If to the factors of relative scarcity of oxygen and the acidity of the soil solution is added the occurrence of temperatures considerably lower than those of the surrounding uplands, it is not difficult to understand why a large part of each year's vegetative products should escape complete destruction. In our estimate of the bog substratum as a habitat for higher plants, the strong competition with the microscopic plants to which the former are subject in the acquisition of oxygen for their underground parts, must be emphasized.

THE PHYSICAL AND CHEMICAL PROPERTIES OF PEAT.

The peat formed through the agency of the bog sedges and their attendant plants has a fibrous and matted appearance. The structures of the various dead stems, roots, and leaves have suffered but slight alteration. They were originally strongly cuticularized, and this has aided in their preservation. The color is commonly a pale yellowish-brown. During life these plant materials become strongly matted and interwoven, and this structure frequently persists. It is this structure that gives to the Carex-Eriophorum zone in many lakes its strength to support heavy bodies. A man's weight will carry the substratum a foot beneath the surface of the water, but it seldom breaks under the strain. In the case of lakes where this zone is unusually developed, it may cover a large part of the lake surface and be of great importance in the filling in of peat. In such cases the deposition takes place largely by the gradual falling of material from the under side of the floating substratum. On account of the slight weight of the material, it does not descend and produce a compact deposit on the bottom, but forms a sort of thick liquid peat.

The sphagnum-shrub zone, where well developed, usually shows a brown peat beneath it. It is composed largely of sphagnum and the semi-decayed twigs, rhizomes, and leaves of the other plants. It is distinctly fibrous, but of a type different from that of the sedge zone; the fibers are short, and the material is not nearly so tenacious.

Under the tamaracks a large part of the annual peat increment is made up of the tamarack needles, though mosses (Hypnum, Sphagnum, and Polytrichum) usually are of importance in this connection. The color is reddish-brown and darker than that of the shrubby zone. The fibrous structure is still less apparent, though present.

When these bogs have been burned over and partially drained, there frequently comes in a dense ground covering of moss (Polytrichum). In such cases the peat continues to accumulate, largely through the agency of this plant. In such situations the peat is a reddish-brown, and the plant structures have practically disappeared through decay. Below the upper layer, the peat when moist has the sticky, clayey properties of well-decomposed peat.

One other well-marked stage is shown in the areas of muck land now under cultivation to onions and celery. Under the influence of drainage and tillage, the disintegration is nearly complete. All plant structures have disappeared, the humous acids have been largely neutralized or washed out, and there is left only a fine, powdery, brownish-black "muck."

The following table shows some other physical properties of these several varieties of peat.

	Eriophorum Zone Peat	Fresh Sphagnum	Cassandra-Sphagnum Zone Peat	Tamarack Zone Peat	Chelsea Bog Peat	Onion Marsh Muck
H_2O-capacity % by volume.......	87.0	78.0*	91.0	84.0	82.0	75.0
H_2O-capacity % by weight........	892.0	1550.0	960.0	530.0	477.0	283.0
Air dry H_2O-content %..........	8.5	10.6	10.0	10.0	10.0	10.0

*Low volume percentage due to air present in tissues.

These measurements were made by placing the peat samples in a zinc cylinder of 600 ^{cc} capacity. The bottom of the cylinder was closed with a wire gauze cap. The moist peat was tamped into the cylinders with as nearly uniform a stroke as possible. The cylinders were then set in a dish of water for eighteen hours, after which the cylinder was removed and allowed to drip. When all dripping had ceased, the cylinder was weighed. The peat was then removed and allowed to dry at room temperature, and again weighed. Finally it was dried at 110° C., and the absolute weight determined. As usual in such measurements, considerable irregularity was shown by the different samples, owing to the difficulty of removing the air, and of packing to the same degree. However, the figures bring out clearly the fact that sphagnum more than any other plant influences the water-capacity of a peat containing it. The eriophorum peat has a lower capacity, owing to its coarse fibrous structure. Of the series examined, the highest water-capacity was found in the cassandra zone. The effect of further decay and destruction of the plant tissue is shown by the reduction in water-capacity of the last three members of the series. The percentages are of interest in connection with the utilization of such lands for agricultural purposes, in showing the difficulty of proper drainage. It is the experience of the men who ditch these bogs that until the peat has reached the condition termed "muck" the ditches act only with extreme slowness.

Chemically, peat or humus is made up of varying quantities of several substances of a rather indefinite character, which are commonly classified among the dehydration products of the carbohydrates. These bodies not only occur in nature, but may be artificially produced by the action of strong acids on starch, sugar, and cellulose. The relation of nitrogen to these bodies is still unknown. Principally on the basis of color and solubility in alkalies and acids, there are several substances distinguished. Ulmin and ulmic acid are brown, and are early products of decomposition. Humin and humic acid are black, and occur more abundantly where eremacausis has been active for a long time. Crenic and apocrenic acids appear to be further oxidation products; the former is colorless, and the latter varies from yellow to brown. MAYER believes these bodies to be organic nitrogen compounds (**36**), and on this basis STOCKBRIDGE (**50**, p. 135) explains the insolubility of peat soils and the presence of the unavailable nitrogen in peat. Beside these substances xylic, saccharic, and glucinic acids have been recognized. Although great advances have been made in soil chemics, it seems strange that the only suggestion of formulæ for these substances was made by MULDER in 1861 (**38**).

Humic acid forms water-soluble compounds with the alkalies, and to these are due largely the brown colors of the bog waters. The color may be produced by the presence of free humic acid. With the alkaline earths humic acid forms insoluble or difficultly soluble compounds. Hence there is slight chance of lime and magnesia penetrating from the surrounding soil into the peat deposits.

During the changes which the plant material undergoes in the process of peat-making there are alterations in the relative amounts of volatile hydrocarbons, fixed carbon, and ash—using these terms as in ordinary coal analyses.

	Eriophorum Stems and Leaves	Sphagnum	Eriophorum Zone Peat	Cassandra Zone Peat	Tamarack Zone Peat	Onion Marsh Muck
Volatile combustible	68.2	67.0	62.0	54.0	53.0	45.7
Fixed carbon……	21.0	17.9	21.8	22.9	23.4	21.8
Ash…………	3.8	4.5	7.4	13.8	13.6	22.5
H_2O…………	7.0	10.6	8.8	9.3	10.0	10.0

The proportion of volatile combustible matter decreases regularly as the humification proceeds. The ash regularly increases, while the air-dry water content shows but slight modification.

(*To be continued.*)

BRIEFER ARTICLES.

NOTES ON NORTH AMERICAN WILLOWS. I.

(WITH PLATES XII AND XIII)

Salix Gooddingi, n. sp.—A shrub or small tree 2–3^{m} high: twigs straight, slender, yellowish, only slightly shining, glabrous or finely puberulent just above the axils of the short fertile branches (very young shoots probably pubescent): leaves on fertile twigs lanceolate or narrowly elliptic-lanceolate, sharply acute or sometimes abruptly short-acuminate at the apex, acute at the base, 2.5–4.5^{cm} long, 6–10^{mm} wide (probably considerably larger on sterile shoots), entire or sparsely to closely glandular-serrate, frequently somewhat falcate; usually glabrous, or puberulent to finely silky-pubescent when young, especially near the base, becoming entirely glabrous with age, dull green on both sides, scarcely paler beneath; midrib distinct, yellowish, nerves not prominent; petioles pubescent, 1–3^{mm} long; stipules none: aments appearing with the leaves, solitary, terminating short lateral leafy pubescent branches which are 1–2.5^{cm} long, and bear 3–6 leaves; pistillate abundantly produced, slender, rather lax in fruit, 3–5^{cm} long, the rachis densely gray-pubescent: capsules short ovate-conic, 3–4^{mm} long, densely gray-tomentose, long pedicelled; pedicels densely gray-tomentose, 1.5–3^{mm} long; scales yellow, linear-oblanceolate, obtuse, 0.5^{mm} wide, 2.5–3^{mm} long, white-tomentose on both sides; style none; stigmas divided, short, thick, reddish-brown.—*Plate XII, figs. 1, 2.*

S. Gooddingi belongs to the section LONGIFOLIEAE and is probably most nearly related to *S. Bolanderiana* Rowlee, from the Yosemite Valley, California. It is easily separated from all other species by the long pedicels, nearly equalling the capsule in length. The foliage bears a superficial resemblance to that of *S. nigra* Marsh.

The type was collected by LESLIE N. GOODDING, of the University of Wyoming, no. 689, Flora of Nevada; ditch banks, Muddy Creek, May 2, 1902. Muddy Creek is a tributary of the Virgin River, which flows into the Colorado in Lincoln County, in extreme southeastern Nevada. The specimen consists of pistillate shoots bearing numerous nearly mature aments. No other material has been seen. The species is named in honor of the collector, who has furnished the following notes on the plant and the locality in which it was found:

"Collected along a ditch where it grew quite profusely, 8–10 feet high. It grows in patches or clumps, much the same as *S. exigua* and *S. fluviatilis*, only with a tendency to branch more from central axes. It was quite abundant where collected, appearing along the ditch for some distance, but I believe its distribution quite local, as it was collected at no other place. It doubtless is common along the Muddy. The region of the Muddy is a very barren desert, scarcely anything growing except along the streams or ditches. The water and the soil are quite salty and there are low hills of salt which border along the Muddy and the Virgin. The willow, however, seeks the stream banks and ditches, the little marshy places being too alkaline."

Salix Tweedyi (Bebb) n. comb. *S. Barrattiana Tweedyi* Bebb, Contrib. U. S. Nat. Herb. **3**:572. 1896.—A shrub, with short stout divaricate branches; bark on the older twigs gray, somewhat shining, on younger twigs chestnut to deep reddish-brown, usually quite glabrous except the twigs of the season, which are commonly densely pubescent with spreading gray hairs: buds large, 6–10^{mm} long, chestnut, thinly pubescent with long hairs, at length glabrate: leaves elliptical and acute at both ends, to oval, acute to somewhat obtuse at the apex, acute to rounded at the base, or subcordate in mature foliage, occasionally obovate-oval, rounded at the apex, especially when young, 5–7^{cm} long, 2.5–4^{cm} wide; glabrous on both sides or the young leaves sparsely pubescent above with long gray hairs, green above, paler but not glaucous beneath; margin finely and closely glandular-denticulate or serrate, the yellowish glands projecting at right angles to the apparently entire margins of the young leaves, in mature leaves the glands on the points of irregular, spinulose teeth, perpendicular or sometimes pointing toward the apex of the leaf; petioles 8–15^{mm} long, frequently tomentose; stipules large, broadly reniform, somewhat clasping, 5–14^{mm} long, glandular spinulose-denticulate: pistillate aments precocious, sessile, stout, lateral and terminal, spreading, often curved, 4–6^{cm} long, 1.5–1.8^{cm} wide in fruit: capsules green and glabrous, or sometimes finely pubescent near the apex, ovate-conical, pedicellate, 7–8^{mm} long when mature; pedicel 1^{mm} long, smooth; style 1.5–2.5^{mm} long, green, stigmas divided, about 0.5^{mm} long; scale obovate, acute or obtusish, 2–2.5^{mm} long, black, clothed with long, straight, white hairs; gland about 1^{mm} long.—*Plate XII, figs. 3–7.*

WYOMING: head of Big Goose Creek, Big Horn Mountains, nos. 11 (the type) and 12, *Frank Tweedy*, July 15–24, 1893; "along streams in Teton Basin, July. With ovaries nearly smooth! Professor *Porter*." J. M. Coulter, 1872.

This last specimen is listed by COULTER[1] under the name of *S. Barrattiana*. In the U. S. National Herbarium the Hayden Survey specimen is ticketed "Trail R. Mts., Idaho Terr." Trail Creek, along which the party worked, is, however, in southwestern Montana, not far north of the Yellowstone Park. The sheet carries pistillate aments and both young and mature foliage. Though collected twenty-one years earlier than the type collection, it is not mentioned by BEBB, and was probably unknown to him.

The variety was named and described by BEBB in an article by J. N. ROSE,

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[1] Hayden, Ann. Rept. U. S. Geol. Surv. Terr. **6**:781.

based on a small collection of plants made by FRANK TWEEDY, of the U. S. Geological Survey. His collections were made in the Big Horn Mountains, "between longitude 107° and 107° 30′ and latitude 44° 30′ and 44° 40′, chiefly on the headwaters of the east and west forks of Big Goose Creek and on the high divide between these streams and Shell Creek."

The original description and the accompanying data are as follows:

> "Leaves at first thinly overspread on the upper surface with floccose hairs, soon smooth and green both sides; capsules glabrous. In bogs and along mountain streams, altitude 2,460 to 3,080$^{\mathrm{m}}$ (8,000 to 10,000$^{\mathrm{ft}}$). Head of Big Goose Creek, Big Horn Mountains, July 15 (nos. 11 and 12)."

BEBB, after noting the original and few subsequent collections of the rare *Salix Barrattiana* and remarking on its silky leaves and capsules, continues:

> "That there should be more or less variation in this vesture was to be expected from what is known of the two most nearly allied species. *S. Hookeriana* was first described as having 'very smooth' capsules, but subsequent observations have shown that they are more frequently tomentose, and a like variation, though in less degree, prevails in the case of *S. Richardsoni;* but in neither is this variation so pronounced as to lessen the surprise with which we find the one species of the group heretofore most conspicuous for its silky vesture, appearing, as in Mr. TWEEDY's specimens, so markedly glabrate. The leaves, and in fact the aments as well, bear a very close and deceptive resemblance to some forms of *S. Barclayi;* but the aments are closely sessile, terminal as well as lateral, the styles longer and the stigmas bifid; the leaves alone could scarcely be distinguished one from the other."

A study of the type material and of later collections leaves no doubt that this willow is specifically distinct from *S. Barrattiana*. Not only do the nearly glabrous leaves and the glabrous capsules serve to distinguish it, but the leaf margin thickly set with conspicuous glands is a marked character.

The varietal name proposed by BEBB was "*denudata*," but as this was preoccupied by *S. commutata denudata* Bebb (1888) ROSE substituted the name "*Tweedyi*" and credited it to BEBB, whose name appears in the text as the author. COCKERELL has since contended[2] that ROSE and not BEBB must be considered the author of the variety. This view, however, cannot be accepted.

Salix Wolfii Idahoensis, n. var.—Leaves usually densely silky-villous with shining hairs, giving a decided luster to the surface, scarcely blackening in drying: capsules 3–4$^{\mathrm{mm}}$ long, thinly but permanently silky pubescent; style about 1$^{\mathrm{mm}}$ long.

WYOMING: Mammoth Hot Springs, Yellowstone National Park, no. 5655, *Aven* and *Elias Nelson*, July 3, 1899; Swan Lake Valley, Yellowstone National Park, alt. 7300$^{\mathrm{ft}}$ (2250$^{\mathrm{m}}$), *F. H. Knowlton*, July 9, 1888.

MONTANA: Madison Cañon, *J. M. Coulter*, Hayden Survey, 1872. The specimen so labelled in the U. S. National Herbarium (accession no. 253,723) bears on the label, "Madison Cañon, Idaho Ter.," which must certainly be an error, since the

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[2] BOT. GAZETTE **22**: 268. 1896.

Madison Cañon explored by the Hayden Survey in 1872 is in Montana, not far from the boundary of the Yellowstone Park. This specimen was probably listed under the name of *Salix glauca* L., which is credited by COULTER in his list[3] to the "Upper cañon of the Madison." *S. Wolfii* is, of course, not mentioned, because it was not published until six years later, in 1878.

IDAHO: Forks of Wood River, alt. 6000^{ft} (1800^{m}), no. 3399 (type), *L. F. Henderson*, July 25, 1895.

OREGON: Banks of Wallowa River, mouth of Hurricane Creek, no. 2400, *W. C. Cusick*, June 11, 1900.

The relationships of this little willow are all with *S. Wolfii* Bebb, from the typical form of which it differs mainly in the silky-pubescent capsule and the rather more silky leaves. The different specimens show considerable variation in the amount of pubescence on the capsules. In general, the specimens from the more northwestern localities show the denser pubescence, both on leaves and capsules. In some cases they tend toward a glabrate condition in age. In *S. Wolfii* the capsules are glabrous even when young. This variety is found from the Yellowstone Park northwestward across Montana and Idaho to eastern Oregon. The species is found from central Colorado to Montana and Idaho.

Salix Nelsoni, n. sp.—A shrub, 1.2–3^{m} high, freely branching, very leafy; twigs shining, the older gray with a reddish tinge, the younger bright chestnut or darker, and often drying dark: buds large, smooth, chestnut, 7–9^{mm} long, beaked: leaves petioled, petioles 3–7^{mm} long, smooth; stipules none; blades oblanceolate or rarely narrowly lanceolate, acute at both ends, cuneate at the base, 8–15^{mm} wide, 3–5.5^{cm} long, entire (except as noted below), the margin somewhat involute, especially toward the base; glabrous, or thinly silky villous when young, green and very shining above, pale and somewhat glaucous below; primary veins prominent, usually elevated and rather greenish-yellow on the upper surface, prominently reticulate below by the elevation of both primaries and secondaries;[4] apical and subapical leaves on sterile shoots narrowly elliptical, the margin shallowly glandular crenate-serrate: pistillate aments sessile with sometimes a few small foliaceous bracts at the base, spreading, slender and cylindrical when young, very much thickened in fruit, 1.5–3^{cm} long: capsules silky pubescent, sessile, 5–6^{mm} long; styles entire or rarely bifid, 0.3–0.5^{mm} long; stigmas smooth, 0.7–1.0^{mm} long, dark; scales dark, ovate, acute, clothed on both sides with long white hairs: staminate aments not seen.—*Plate XIII, figs. 8–11.*

COLORADO: Little Fountain Creek (south of Pike's Peak), alt. 9200^{ft}, no. 12, *J. C. Blumer*, September 5, 1903; Mt. Lincoln, Park Co., alt. 12,000^{ft}, *J. M. Coulter*,

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[3] Ann. Rept. U. S. Geol. Surv. Terr. **6**:782. 1873.

[4] In the type the primaries and sometimes also the secondaries on the upper surface are very broad and deep green in color, giving a strikingly beautiful effect, which is not so evident in other specimens.

July 9, 1873; Beaver Creek, Larimer Co., roadsides in pine woods, no. 1440, *L. N. Goodding*, July 4, 1903.

WYOMING: Centennial Valley, no. 1754, *Aven Nelson*, August 18, 1895; Centennial, Albany Co., bogs, no. 8822, *Aven Nelson*, August 7, 1902; Laramie Peak, Albany Co., along the creek, in clumps, 4–10 ft high, no. 7580 (type), *Aven Nelson*, July 13, 1900; head of Big Goose Creek, Big Horn Mountains, no. 47, *Frank Tweedy*, July 15–24, 1893.

ALBERTA: Banff, low ground, side of road to Devil's Head Lake, alt. 4500 ft, no. 2253, *W. C. McCalla*, June 8 and August, 1899.

This beautiful willow is found at high altitudes in the mountains of Colorado and northward. It is most closely related to *S. chlorophylla* Anderss. and the pistillate aments closely resemble those of that species. It is readily distinguished by the oblanceolate leaves which, when mature, are prominently nerved above and reticulated beneath. Authentic staminate material has not been seen.

I take pleasure in dedicating this species to Professor AVEN NELSON, of the Rocky Mountain Herbarium, who has made available so much valuable material in this difficult genus.—CARLETON R. BALL, *U. S. Department of Agriculture, Washington, D. C.*

EXPLANATION OF PLATES XII AND XIII.

PLATE XII.

FIGS. 1 and 2. *S. Gooddingi* Ball; *fig. 1*, fruiting branch, natural size; *fig. 2*, capsule and scale. ×10.

FIGS. 3–7. *S. Tweedyi* (Bebb) Ball. *Fig. 3*, sterile twig; *fig. 4*, pistillate ament; *fig. 5*, mature leaf showing stipule and bud; *fig. 6*, capsule (×10); *fig. 7*, outline of margin of young leaf showing glands. ×10.

PLATE XIII.

FIGS. 8–11. *S. Nelsoni* Ball; *Fig. 8*, Sterile twig, from type; *fig. 9*, fruiting branch; *fig. 10*, elliptical apical leaf; *fig. 11*, capsule, ×10.

BALL on SALIX

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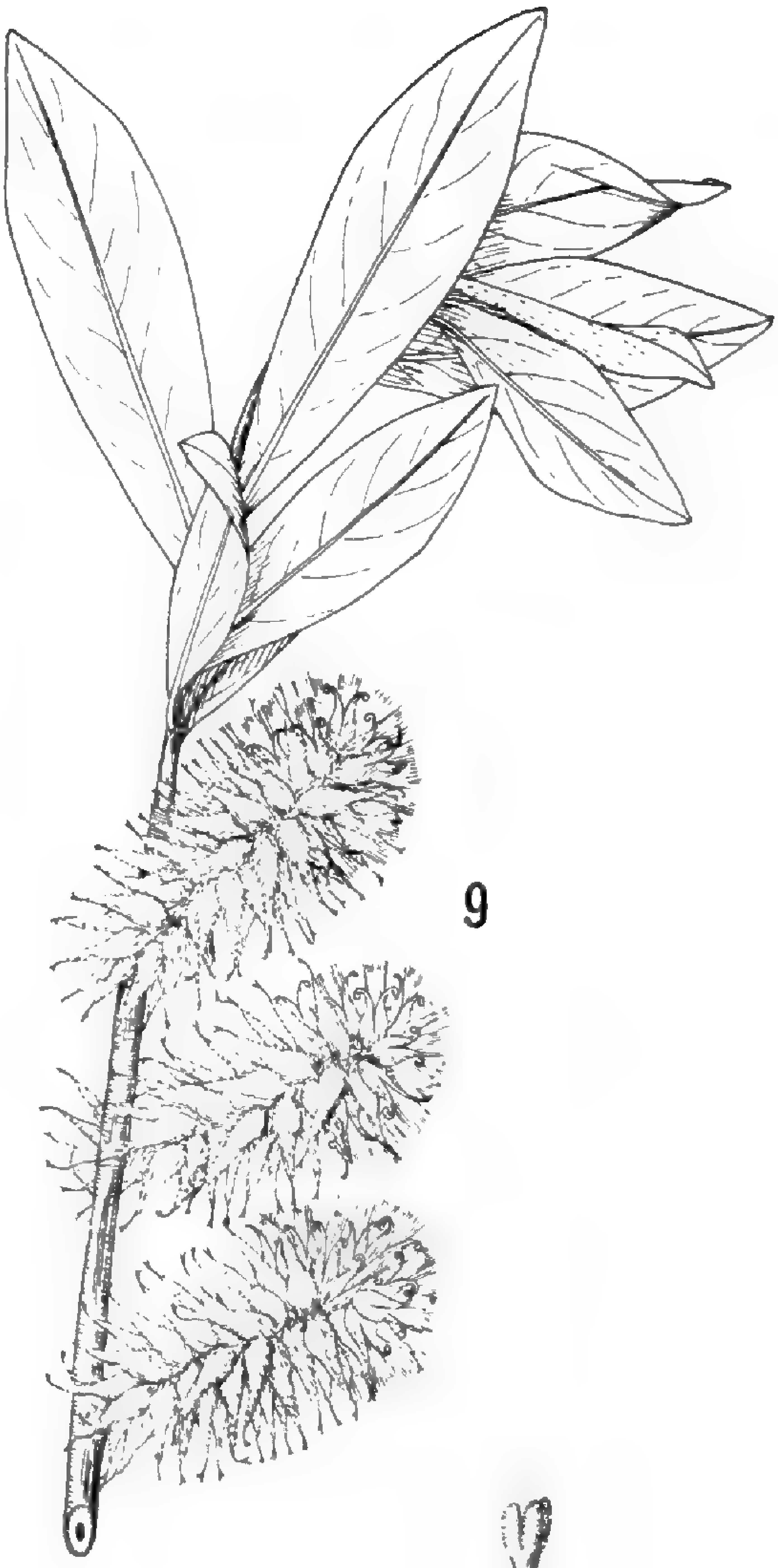

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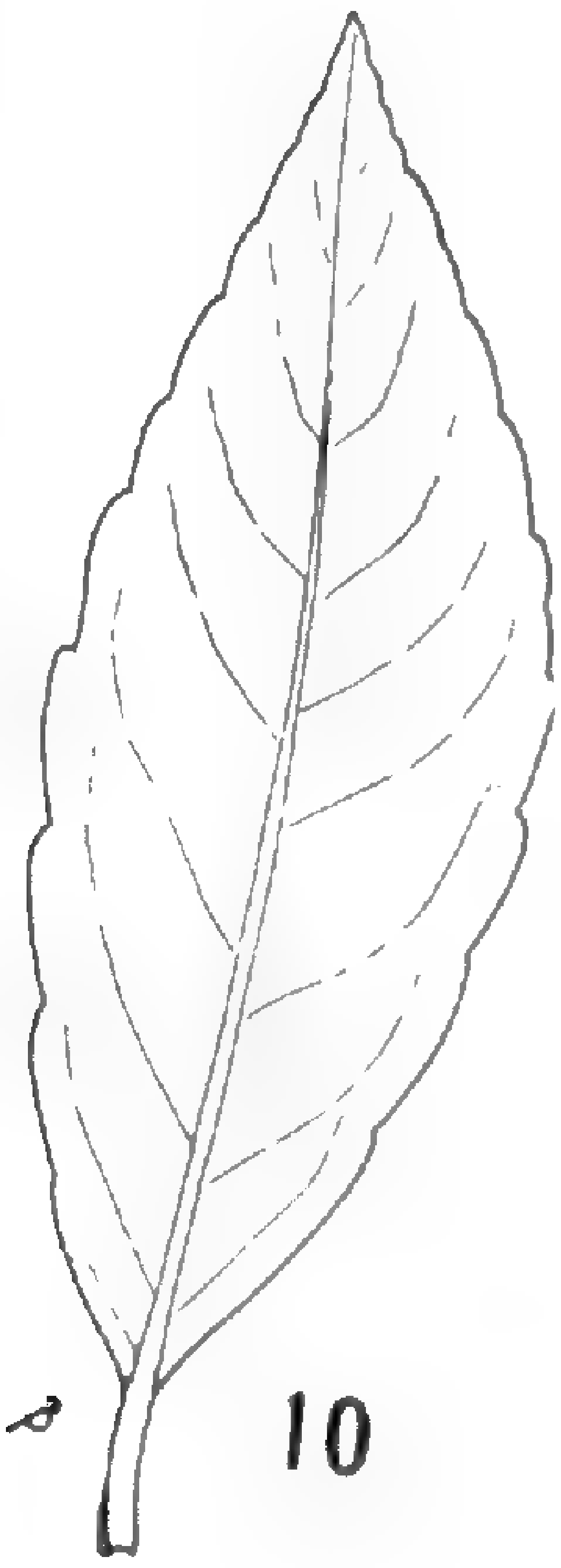

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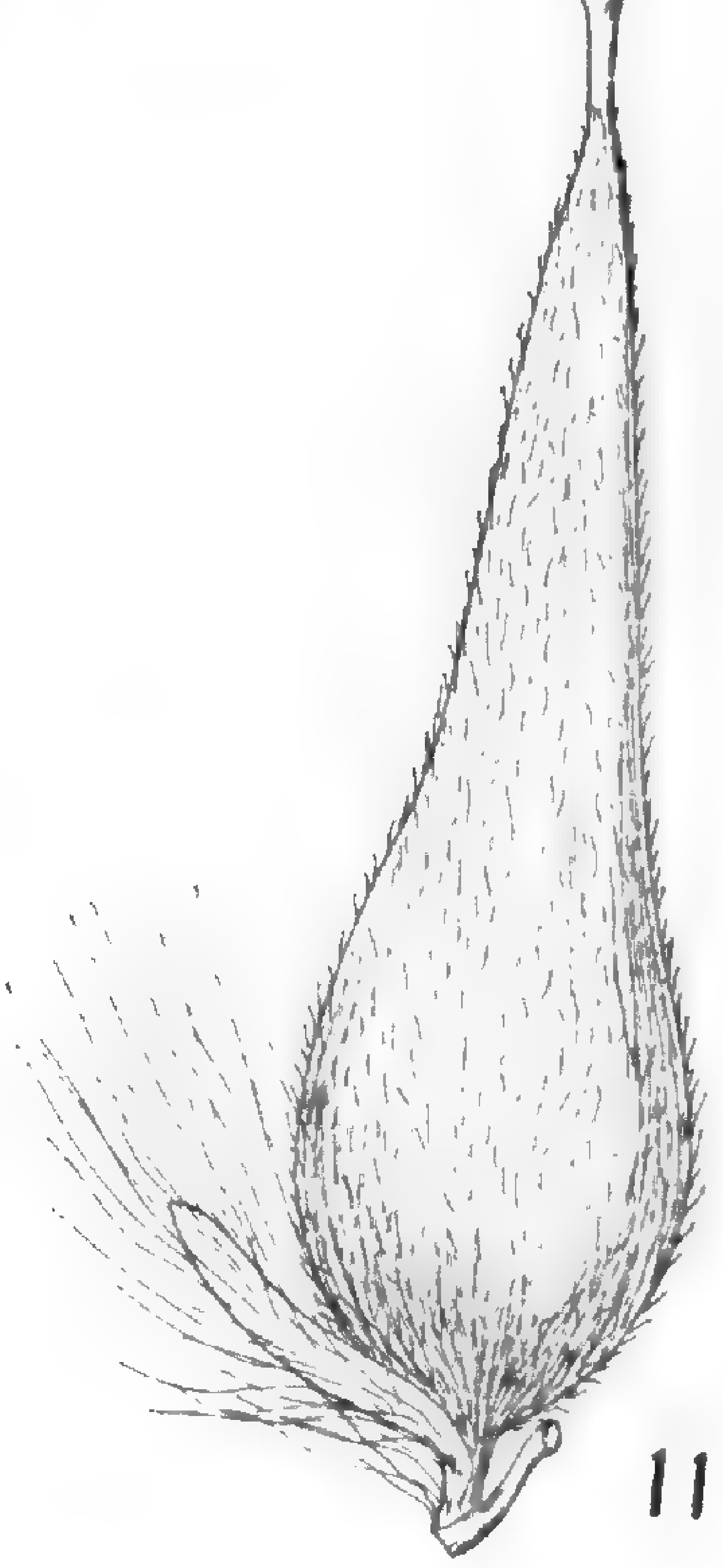

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BALL on SALIX

CURRENT LITERATURE.

BOOK REVIEWS.

Research methods in ecology.

WE seldom receive a work whose central idea is essentially new, but Dr. CLEMENTS's latest volume[1] almost if not quite attains this distinction. The ecology of our day is to be divided into the true and the false, and most of it, unfortunately, is of the latter type. It is a subject which, on the surface, seems to lend itself well to the lovers of fads, and there are many "contributions" to ecology which consist of a hasty gathering together of notes made in leisure moments during summer holidays. The true ecology, the ecology that is to be, is developed only by the most arduous and long-continued work. The dilettante ecology is to pass away, and one of the foremost causes for this change will be this new book of CLEMENTS.

The opening chapter reveals the author's ideals as to the meaning and place of ecology, its historical development, its present status (largely deplorable, because so many tyros are making desperate attempts to enter the new and inviting field), and its relationships with other botanical lines of research. The second chapter, entitled the habitat, considers in detail the various ecological factors, and will be of extraordinary value to ecological research, because it recounts in full the ingenious and multiform methods that have been employed by the author in the study of the Nebraska and Colorado vegetation. Soil, water-content, atmospheric humidity, and light are regarded as direct factors, and hence more attention is paid to them than to indirect factors (such as temperature), or remote factors (such as altitude). The various instruments of precision, such as psychrometers, psychrographs, photometers, thermographs, and many others, are figured and their use explained in full. For the physical and physiological water-content of the soil, the author proposes respectively the terms holard and chresard. The word ecograph is employed as a general term embracing all instruments that are used for the determination of physical habitat factors. Much space is devoted, and properly, to the intelligent expression of results; we greatly regret that the metric system is not exclusively employed in these tables.

"The plant" is the title of the third chapter, and an admirable survey is given of the more important adjustments and adaptations; the former word is used to denote functional response, the latter structural response. These most important distinctions are often disregarded, thus leading to deplorable confusion. Response to water is termed hydroharmose, to light photoharmose. In this, as

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[1] CLEMENTS, F. E., Research methods in ecology. pp. xvii+334. Lincoln, Neb.: The University Publishing Co. 1905.

in the preceding chapter, methods of measurement are described, but of course they are much less satisfactory. This is a difficulty that in part inheres in the more complex phenomena that are to be measured, but also in part in the fact that physiologists have failed to cultivate as they might this fertile and enticing field. One might wish for a softening of the teleological terminology, as in p. 129 and p. 143; whether there is or is not an ultimate teleology, it seems wiser to discard its vocabulary. It seems to the reviewer that expressions implying purpose are in part responsible for the disfavor in which ecology is sometimes held. The close of this chapter is devoted to a consideration of experimental evolution, and a full account is given of natural, habitat, and control cultures.

The final chapter considers plant formations, and their study is based on the quadrat method, much of which the author has previously published. Among the subjects here treated are cartography, photography, and formation herbaria. The discussion of the development and structure of vegetation is much like a separate treatise on the same subject already reviewed in these pages. Methods for the study of succession and competition are given. At the close is a helpful glossary.

One can scarcely praise this work too much; it is what is needed to prevent ecology from falling into a swift and merited disfavor. If read and pondered, it will prevent the thoughtless from entering the ecological field, and it will serve the higher end of directing the thoughtful as to the methods of procedure.—H. C. COWLES.

MINOR NOTICES.

THE ADMIRABLE illustrations of vegetation issued by KARSTEN and SCHENCK have frequently been noted in the GAZETTE. A somewhat similar idea has been pursued by WETTSTEIN,[2] who has issued reproductions of a large number of the Brazilian photographs secured by F. VON KERNER and himself on their recent journey to South America. There are fifty-eight plates in phototype, four colored plates, and six text figures. In nearly every instance the original photographic work and the subsequent reproductions have been admirable, and one who has never visited the Brazilian tropics may yet gain herefrom an accurate idea of their general appearance. Not only are there illustrations from the tropical and subtropical rainy forests, but the savannas and the mountains are figured as well.—H. C. COWLES.

SCOTT[3] has given an exceedingly interesting and comprehensive account of the recent development of knowledge in reference to the seed plants of the Carboniferous. It will prove very useful to those who have neither the time nor

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[2] WETTSTEIN, R. VON, Vegetationsbilder aus Südbrasilien. Leipzig and Vienna. 1904.

[3] SCOTT, D. H., The early history of seed-bearing plants, as recorded in the Carboniferous flora. The Wilde Lecture. Manchester Memoirs **49**: no. 12. pp. 32. *pls. 3.* 1905.

the opportunity to read the more extensive and scattered papers that deal with the subject.—J. M. C.

The second and concluding part of the second supplement (1896–1900) of the *Kew Index* has appeared.[4] A notice of the first part appeared in Bot. Gazette **39**:68. 1905. The second part includes the letters L–Z, and also six pages of corrections and additions.—J. M. C.

NOTES FOR STUDENTS.

The problem of heredity.—This important contribution[5] is similar in plan to the famous *Cytologische Studien aus dem Bonner Institut* which played such an important part during the centrosome controversies. The present work deals with the problem of chromatin reduction and with theoretical considerations connected with this problem. Strasburger[6] writes on typic and allotypic[7] nuclear division, Allen on the behavior of the nuclear substance during synapsis in the pollen mother-cells of *Lilium canadense*, Miyake on the reduction division in the pollen mother-cells of certain monocotyledons, and Overton on the reduction division in the pollen mother-cells of certain dicotyledons.

The four writers agree that the nuclear network consists of both linin and chromatin, and all but Allen describe a reducing or qualitative division of the chromatin during the first mitosis in the pollen mother-cell.

Strasburger studied various pollen mother-cells and also the megaspore mother-cells, all of which are drawn from nuclei of the ovary walls and placenta of *Galtonia candicans* and *Funkia Sieboldiana*. His figures represent close series from the resting stage to telophase. Considerable variation in the number of chromosomes was found in both forms. The bearing of this fact upon the theory of the individuality of the chromosomes is discussed, and the conclusion is reached that the number of chromosomes is fixed by heredity, but not within such rigid limits as to exclude some variation in vegetative cells. The definite

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[4] Index Kewensis plantarum Phanerogamarum: supplementum secundum nomina et synonyma omnium generum et specierum ab initio anni MDCCCXCVI usque ad finem anni MDCCCC complectens. Ductu et consilio W. T. Thiselton-Dyer confecerunt herbarii horti regii botanici Kewensis curatores. Leucocoryne–Zygostates et emendanda addenda. Pp. 105–204. Oxford: Clarendon Press. 1905. *12s.*

[5] Strasburger, E., Allen, C. E., Miyake, K., and Overton, J. B., Histologische Beiträge zur Vererbungsfrage. Jahrb. Wiss. Bot. **42**:1–153. *pls. 1–7.* 1905.

[6] Strasburger, E., Typische und allotypische Kernteilung. Jahrb. Wiss. Bot. **42**:1–70. *pl. 1.* 1905.

[7] By typic divisions are understood the ordinary vegetative or somatic divisions; the allotypic divisions are the two divisions usually called the heterotypic and homotypic divisions. The term allotypic is equivalent to the term maiotic as used by Farmer. Strasburger would restrict the term atypic to pathological mitosis.

number seems essential only in the gonotokonts,[8] when it insures the pairing of paternal and maternal chromosomes. The chromosomes of a nucleus probably differ among themselves, and it is almost certain that the two chromosomes of each pair pass to different nuclei. The heterotypic and homotypic mitoses differ in that the first distributes to the daughter nuclei the paired, univalent, and already longitudinally split paternal or maternal chromosomes, while the second separates the longitudinal halves of chromosomes whose longitudinal splitting was already prepared during the prophase of the first mitoses. The behavior of chromatin in fertilization and in parthenogenesis is discussed in detail. STRASBURGER'S paper closes with a reinvestigation of the peculiar hybrid, *Cystisus Adami*, showing that there is no cytological basis for the assumption that it is a graft hybrid.

ALLEN[9] describes, in greater detail than in his previous papers, the behavior of the nuclear material from the resting reticulum up to the spirem of the heterotypic division. Some of the principal features of this period are: (1) a collecting of the materials belonging to the somatic chromosome, (2) an approximation and pairing of two somatic (presumably paternal and maternal) groups of substances, (3) a stretching of the visible nuclear structures (except the nucleolus) into slender threads which come to lie side by side and finally fuse, (4) the disappearance of anastomoses and the formation of a continuous spirem, and (5) a uniseriate distribution of chromosomes in each thread, the opposition of the chromosomes of parallel threads, followed by the fusion of the threads and union of the chromosomes in pairs.

MIYAKE[10] studied the reduction division in the pollen mother-cells of Galtonia, Iris, Lilium, Allium, Funkia, and Tradescantia. In synapsis there is not a pairing of fully formed chromosomes, but of groups of chromatic substance. These groups are drawn out into a double thread, which may be regarded as approximated chains of chromosome pairs. The chromosomes, paired at this early stage, continue to grow as pairs until mature. In the heterotypic mitosis the two members of each pair are separated and pass to opposite poles. Consequently, this mitosis is a reduction or qualitative division. The second mitosis is a doubling (*Äquationsteilung*) division.

OVERTON[11] studied the reduction division most thoroughly in *Thalictrum purpurascens*, but for comparison used also *Helleborus foetidus*, *Podophyllum*

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[8] The term, *Gonotokonten*, proposed by LOTSY, applies to spore mother-cells of plants and to the primary spermatocytes and primary oocytes of animals.

[9] ALLEN, C. E., Das Verhalten der Kernsubstanzen während der Synapsis in den Pollenmutterzellen von *Lilium canadense*. Jahrb. Wiss. Bot. **42**:71–82. *pl. 2.* 1905.

[10] MIYAKE, K., Ueber Reduktionsteilung in den Pollenmutterzellen einiger Monokotylen. Jahrb. Wiss. Bot. **42**:83–120. *pls. 3–5.* 1905.

[11] OVERTON, J. B., Ueber Reduktionsteilung in den Pollenmutterzellen einiger Dikotylen. Jahrb. Wiss. Bot. **42**:121–153. *pls. 6–7.* 1905.

peltatum, *Calycanthus floridus* and *Campanula grandis*. In very young pollen mother-cells he finds masses of chromatin which he calls prochromosomes. The prochromosomes are in pairs and their number is the same as that found in somatic nuclei. The parental chromosomes maintain their identity during synapsis. The first division is a reduction division in which entire univalent chromosomes, which were united during synapsis, become separated. The second mitosis is a doubling division. It is probable that the two halves of the presynaptic chromosomes are of paternal and maternal origin, and that during synapsis there is a union of paternal and maternal elements.—C. J. CHAMBERLAIN.

THE INHERITANCE of coat characters in guinea-pigs and rabbits has been studied by CASTLE[12] during the last five years, and his first detailed report has appeared in the series of papers of the Station for Experimental Evolution. In breeding about 3,000 guinea-pigs and several hundred rabbits he finds that the following characters obey MENDEL'S laws, the first mentioned member of each pair of characters being dominant: pigmented coat *vs.* albino, rough coat *vs.* smooth, long coat *vs.* short. Albinism and long hair are conceived to be new characters and their recessiveness agrees, therefore, with the view that phylogenetically older characters dominate the newer; but the rough coat, which is dominant over smooth, is nowhere found among guinea-pigs in their native state and is likewise a new character. This shows, as has been done recently by CORRENS[13] also, that ancestral characters do not necessarily dominate the new characters in inheritance. The dominance of the rosetted or rough coat over the smooth may be considered as supporting CORRENS's view that the morphologically higher dominates the lower, but this view is negatived in the dominance of short coat over long. It seems to be impossible at the present time to predict which of an uninvestigated pair of characters will be dominant.

The author draws a sharp distinction between recessive and latent characters, the latter being defined as "characters normally dominant, which have disappeared in recessive gametes beyond hope of recall, except under conditions of cross breeding which are in most cases not entirely clear." He expresses a doubt whether a recessive character may ever be latent, though there appear to be no *a priori* grounds for such a difference of behavior in the two kinds of characters.

In a case between certain white individuals and red, about half the offspring were black pigmented. The assumption that in these individuals two kinds of gametes were produced in nearly equal proportions, the one kind containing latent black, the other being entirely free from black, was proved by breeding tests of the non-black offspring, no black pigmented young resulting from these matings. This difference of behavior between the purebred race and the extracted recessives resembles BATESON'S experiences with sweet peas and stocks.[14]

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[12] CASTLE, W. E., Heredity of coat characters in guinea-pigs and rabbits. pp. 78. Washington: Carnegie Institution of Washington. 1905.

[13] See résumé in BOTANICAL GAZETTE **40**:235. 1905.

[14] See résumé in BOTANICAL GAZETTE **40**:313. 1905.

Several irregularities were noted, such as occasional imperfect dominance in combinations where one of the characters is usually fully dominant, but in these cases the blended condition in the first generation was followed by typical splitting in the second. Length of ears and lop ears of rabbits were found to blend in inheritance, the second and subsequent generations retaining the blended or intermediate condition.

The paper is illustrated with six plates of excellent halftone engravings, representing the various coat characters and their hybrid combinations. Ten of these engravings with a few others are reproduced in another paper[15] by the same author, in which his more important results are used to illustrate the recent advances in our knowledge of the laws of heredity and their practical applications in plant and animal breeding. This paper was read before the American Breeders' Association at its second meeting, at Champaign, Ill., February 1–3, 1905, and is also published without the plates in the Proceedings[16] of that organization.—G. H. SHULL.

THE SYMPOSIUM of six addresses on the mutation theory, delivered before the American Society of Naturalists at Philadelphia, December 28, 1904, has been published in full in *Science*. One of these addresses, which was published elsewhere, has already been noted in these columns.[17] CASTLE[18] discusses the subject from the standpoint of the animal breeding, illustrating with his results in guinea-pigs. He observed extra toes and long hair to arise as mutations and shows that long-haired and normal short-haired animals could coexist and interbreed freely without ever swamping the long-haired condition, as it behaves as a Mendelian recessive. Natural selection could then determine which if either of these forms should be eliminated. If inheritance is not sharply alternative the mutation would simply act to increase the fluctuating variability and could never become a racial character through natural selection.

In considering the relation of cytology to the mutation theory, CONKLIN[19] emphasizes the fact that all evolution must be the evolution of the germ-cells and is founded primarily upon cytological phenomena. The great morphological complexity of the germ-cells which recent studies have demonstrated, and the speaker's observations on the diffusion of chromatin from the nucleus to definite areas of the cytoplasm of the ascidian egg, are cited as favoring the hypothesis

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[15] CASTLE, W. E., Recent discoveries in heredity and their bearing on animal breeding. Pop. Sci. Monthly **66**: 193–208. 1905.

[16] Proc. Amer. Breeders' Assn. **1**: 120–126. 1905.

[17] MACDOUGAL, D. T., Discontinuous variation and the origin of species. Torreya **5**: 1–6. 1905; and Science N. S. **21**: 540–543. 1905.

[18] CASTLE, W. E., The mutation theory of organic evolution from the standpoint of animal breeding. Science N. S. **21**: 521–525. 1905.

[19] CONKLIN, E. G., The mutation theory from the standpoint of cytology. Science N. S. **21**: 525–529. 1905.

of "intracellular pangenesis." Modifications of the germinal organization are probably the immediate causes of evolution. Even a slight alteration in the unsegmented egg may result in a profound change in the adult as illustrated in the production of dextral and sinistral forms of mollusks by maturation taking place, now at the one pole, now at the other.

DWIGHT[20] concludes that evidences from human anatomy offer no support for the theory of evolution by minute changes, and that although they do not give any direct support to the mutation theory they are not in disaccord with it.

BAILEY[21] discusses the relation between taxonomy and evolution, pointing out some of the weak points in the present system of classification, particularly in that taxonomic systems are rigid and arbitrary, whereas the organic world is plastic and changing. He holds that the ideal taxonomy of the future must make no distinction between "natural" and "artificial" forms, and that the type of a species should be the real phylogenetic or biological type instead of the first specimen which chanced to be named. There can never be such a thing as a satisfactory "stable" nomenclature.

WHEELER[22] considers the mutation theory even more important in the explanation of the origin of new instincts, new functions and new habits of life, than for the origin of new morphological characters, especial mention being made of parasitic species and species with profound and sudden metamorphoses.—G. H. SHULL.

THE GERMINATION of *Coleochaete scutata* has been studied by ALLEN[23] who has paid particular attention to cytological features of the first and second divisions of the fertilized egg. Fertilization takes place in the summer. After resting during the winter, the fertilized egg segments into a number of cells, in each of which a zoospore is developed.

In the prophase of the first mitosis a condition is found which the author regards as a genuine synapsis, during which a fusion of somatic chromosomes occurs, as in his account of Lilium. The chromosomes formed from the spirem are bivalent, the line of separation corresponding to the earlier longitudinal splitting of the spirem. Occasionally the arrangement of chromatin granules suggests that the chromosomes may be quadrivalent. The number of chromosomes is probably thirty-two. No centrosomes or centrospheres could be distinguished. At the second division the chromosomes are longer and more slender than those of the first division. A cell plate is formed at each division. The two divisions correspond quite closely with the heterotypic and homotypic divisions

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[20] DWIGHT, THOMAS, Mutations. Science N. S. **21**:529–532. 1905.

[21] BAILEY, L. H., Systematic work and evolution. Science N. S. **21**:532–535. 1905.

[22] WHEELER, W. M., Ethology and the mutation theory. Science N. S. **21**: 535–540. 1905.

[23] ALLEN, C. E., Die Keimung der Zygote bei Coleochaete. Ber. Deutsch. Bot. Gesells. **23**:285–292. *pl. 13*. 1905.

in pollen mother-cells of angiosperms. It seems probable that a reduction of chromosomes is effected during these two divisions. If this is correct, there is in Coleochaete no generation with the double number of chromosomes, except the zygote itself. There is no generation which could be called a sporophyte. Each cell of the spore mass which has usually been regarded as the sporophyte has the reduced number of chromosomes like the vegetative cells of the thallus.

The statement that there is no generation which could be called a sporophyte, seems to the reviewer to be a serious mistake. Riccia has a sporophyte just as truly as has Sequoia, the extent of its development being unessential as far as the logical presence of a sporophyte is concerned. The sporophyte generation in lower plants as well as in higher begins with the fertilized egg. Whether the egg then divides once, twice, or a million times, or not at all, neither strengthens nor weakens its title to the term, sporophyte. It seems to us that there is an important difference between extreme reduction and complete elimination.—C. J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: R. VIGUIER (Bull. Soc. Bot. France IV. **5**:285–314. 1905), in presenting the Polyscias group of Araliaceae, has described two new genera—*Tieghemopanax*, with 26 species; and *Bonnierella* with one species.—J. M. GREENMAN (Proc. Amer. Acad. **41**:235–270. 1905) has published descriptions of new species of angiosperms from the southwestern United States, Mexico, and Central America, the new genera being *Mimophytum* (Boraginaceae) and *Lozanella* (Urticaceae), both from Mexico, and the new species from the southwestern United States belonging to Cassia, Cedronella, Salvia, and Erigeron.—B. L. ROBINSON (*idem* 271–278), among diagnoses and notes relating to American Eupatorieae, has described new species in Ageratella (which here receives its first formal and detailed characterization as a genus), Fleischmannia, Piptothrix, and Eupatorium (5).—W. A. MURRILL (Bull. Torr. Bot. Club **32**:353–371. 1905), in a synopsis of the brown pileate species of North American Polyporaceae, describes the following new genera: *Coriolopsis* (2), *Flaviporus* (2), *Cerrenella* (2), *Nigroporus*, *Fomitella*, *Amauroderma* (3), and *Porodaedalea*.—C. L. GRUBER (*idem* 389–392) has described 3 new species of Crataegus from Berks Co., Pa.—PH. VAN TIEGHEM (Ann. Sci. Nat. Bot. IX. **1**:247–320. 1905) has established a new family *Irvingiaceae* upon the genus Irvingia and three allied genera, which have been associated heretofore with the Simarubaceae.—W. J. TUTCHER (Jour. Linn. Soc. London **37**:58–70. 1905), among other new Chinese plants, has described a new genus (*Dunnia*) of Rubiaceae.—OTTO STAPF (*idem* 79–115), in his "Contributions to the flora of Liberia," has described the following new genera: *Atroxima* (Polygalaceae), *Urobotrya* (Olacaceae), *Androsiphonia* (Passifloraceae), and *Afrodaphna* (Lauraceae).—M. L. FERNALD (Rhodora **7**:146–150. 1905), in presenting the genus Arnica in northeast America, recognizes seven species, describing three as new.—J. M. C.

IN A PAPER read before the Royal Dublin Society, DIXON[24] answers recent

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[24] DIXON, H. H., The cohesion theory of the ascent of sap. Notes Bot. Soc. Trinity Coll. Dublin **1**:203–216. 1905.

criticisms made on the cohesion theory of the ascent of sap by STEINBRINCK and by COPELAND.

STEINBRINCK established the fact that the walls of the conducting tracts are permeable to air and regards this as incompatible with the cohesion theory, since air diffusing through the tracheal walls would tend to break the continuity of the water columns within them, by the formation of free bubbles. In reply to this, DIXON states that the air in solution does not cause the rupture of a water column under tension; that the permeability of the walls does not necessitate the formation of free bubbles in the conducting tracts; and that even if bubbles are formed the current is merely deflected from that portion of the channel.

In regard to the results obtained by COPELAND, that the ascent of water in his "tree" was due not to a pull transmitted downward by the cohesion of water, but to some force which is measured by the difference in pressure as indicated by the manometers at the bottom and 8.4^{m} from the bottom of the "tree," DIXON shows that according to COPELAND a column of water 8.4^{m} high, equivalent to 617^{mm} mercury, is supported by a pressure of 122^{mm} of mercury, which is impossible. DIXON further believes, and brings experimental evidence to support his belief, that the pressure conditions indicated by COPELAND's manometers are local and have nothing to do with the true pressure conditions in the tube as a whole. The arguments on this point are twofold. First, it is shown that plaster of Paris long continues to absorb water and this may cause the rise of mercury in the manometers; second, the rate of transmission of water through tubes of plaster of Paris as used by COPELAND is so slow, that equalization of pressure conditions by the passage of water through a distance of 8.4^{m} is impossible.—H. HASSELBRING.

DIXON[25] describes an interesting transpiration model which will prove useful for illustration. The apparatus consists of a thistle tube closed by two parchment membranes so arranged that a lenticular cell is formed between them. Gelatin tannate is precipitated in the membranes, and the cell is filled with dry sugar. When the tube is filled with water the parchment cell becoming turgid represents the system of turgid cells which in living plants, intervenes between the water-conducting channels and the outer air. This model will act until a leak is formed in the membrane, or until the diffusion of sugar into the tube makes the liquid below isotonic with that of the cell. The actual passage of water can be rendered visible by connecting the lower end of the tube with a capillary tube running across the stage of a microscope and dipping into a beaker of water in which minute solid particles are held in suspension. It is found that the water will rise although under tension, and that even then the cell will remain turgid, owing to the fact that although the water in the cell may be in a state of tension, the dissolved substances exert a pressure. That this condition can exist in the cells of plants is shown by the following interesting experiment. A small strip

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[25] DIXON, H. H., A transpiration model. Notes Bot. Soc. Trinity Coll. Dublin 1:217–224. *fig. 1.* 1905.

of tissue taken from some suitable plant is placed in the long closed arm of a J-tube. The tube is filled with water and the atmospheric pressure is removed from the short arm by means of an air-pump. The strip of tissue, in the upper part of the column of water held in tension by the weight of the lower parts, remains curved showing an osmotic pressure existing in the cells in spite of this tension.—H. HASSELBRING.

CAMPBELL[26] has continued his studies of the Araceae by investigating *Anthurium violaceum leucocarpum* and *Nephthytis liberica.* The account of Anthurium is quite like that of the usual angiosperm. The archesporium in the ovule is a single hypodermal cell, which divides periclinally. The primary sporogenous cell passes directly into the megaspore without division; and in the development of the gametophyte to the fertilization stage there is nothing worthy of remark. In the formation of endosperm there is no free nuclear division, a wall appearing with the first division, which occurs at the antipodal end of the sac, the formation of endosperm thus proceeding from the antipodal toward the micropylar end of the sac. The embryo is at first an almost globular mass of cells, with a "rudimentary" suspensor. Nephthytis proved to be quite variable in the development of the embryo sac. The archesporial cells are variable in number, and generally more than one embryo sac begins to develop. In no case did the mature embryo sac show the usual angiospermous condition, and so great was the variation that no condition could be selected as the prevailing one in the species. Among the most striking forms of mature sacs are the following: two nuclei, one at each end; a complete egg apparatus and a single antipodal nucleus; three antipodal nuclei and a single micropylar nucleus; twelve or thirteen nuclei, the three uppermost fusing; various forms of chambered sacs; fusion of contiguous sacs. The general conclusion is reached that the Araceae are relatively primitive monocotyledons.—J. M. C.

VON SCHRENK[27] has given an account of intumescences formed on leaves of cauliflowers as a result of chemical stimulation. The plants had been sprayed with copper sprays; several days after application the wart-like growths were observed on the leaves. By an experimental analysis of the conditions causing the intumescences the author finds that they are readily produced by sprays of ammonium copper carbonate and other copper salts, and in some cases with ammonia and ammonium carbonate. Soil and atmospheric conditions, including heat and water supply, had nothing to do with their formation.

It is clear that the peculiar outgrowths of leaves known as intumescences are produced by various factors in different plants. Usually they have been attributed to excessive water in the tissues due to moist atmosphere, coupled with reduced photosynthesis. SORAUER, KÜSTER, and HABERLANDT have found them in

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[26] CAMPBELL, D. H., Studies on the Araceae. III. Annals of Botany **19**:329–349. *pls. 14–17.* 1905.

[27] VON SCHRENK, H., Intumescence formed as a result of chemical stimulation. Rept. Mo. Bot. Garden **16**:125–148. *pls. 25–31.* 1905.

certain cases due to the action of different poisons, and VON SCHRENK adds another clearly defined case due to action of specific chemical stimuli. In this connection it is interesting to note that almost simultaneously with VON SCHRENK, STEINER[28] has described intumescences on *Ruellia formosa* and *Aphilandra Porteana* which were produced regularly when the plants were transferred to an atmosphere of relatively greater humidity, while all attempts to produce them on the former plant by means of solutions, including copper sulfate failed. Aphilandra was apparently not subjected to this treatment.—H. HASSELBRING.

THE MICROSPORES of *Araucaria Bidwillii* are described in a preliminary paper by LOPRIORE.[29] The intine and exine are clearly differentiated, the intine being about twice as thick as the exine. The numerous large starch grains make it rather difficult to get a clear view of the internal structures. The spores germinate best in darkness in a 12 per cent. sugar solution. The pollen tubes reach their greatest length—about ten to twenty times the diameter of the pollen grain—in eight to ten days.

At the first division of the pollen mother-cells the number of chromosomes is twelve. As the spore germinates, two lens-shaped cells are cut off from the main body of the spore. These are not evanescent, but divide and give rise to a mass of about fifteen cells. The walls of these cells soon disappear, leaving the nuclei free in the general cytoplasm of the spore. Further nuclear division then takes place until the spore contains 20–44 nuclei, 36 being the most frequent number. There are no divisions after the pollen tube begins to develop. Two nuclei in the end of the tube, somewhat larger than the rest, are regarded as vegetative nuclei, while the others are regarded as equivalent to spermatozoids. Judging from LOPRIORE's figures of the germination of the spore, the reviewer ventures to hazard the guess that the two larger nuclei are the male nuclei, while the rest of the numerous nuclei result from an unusual development of the prothallial region.—C. J. CHAMBERLAIN.

HENRY N. RIDLEY,[30] director of the Botanic Gardens at Singapore, has recorded some of his observations in the tropics on the dispersal of seeds by wind. He uses three categories: (1) winged fruits and seeds; (2) plumed fruits and seeds and (3) "powder-seed," by which he means such fine and dust-like bodies as the seeds of orchids and the spores of ferns. The nature of the observations may be illustrated from the account of *Shorea leprosula* (Dipterocarpaceae). The greatest distance the winged fruit of this species was observed to travel was about "100 yards," which is much more than the usual distance. The estimate is made that under the most favorable circumstances the species can spread only "300

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[28] STEINER, R. S., Ber. Deutsch. Bot. Gesells. **23**:105. 1905.

[29] LOPRIORE, G., Ueber die Vielkörnigkeit der Pollenkörner von *Araucaria Bidwillii* Hook. Vorläufige Mitteilung. Ber. Deutsch. Bot. Gesells. **23**:335–346. *pl. 15.* 1905.

[30] RIDLEY, HENRY N., On the dispersal of seeds by wind. Annals of Botany **19**:351–363. 1905.

yards in 100 years," or it "would take 58,666 years to migrate 100 miles." The estimate is further made that a species of Dipterocarpus which ranges from the Malay Peninsula to the Philippines could not cover that distance, if there was land connection, in less than "one and a half million years." After the citation of numerous cases in each category, the general conclusion is reached that the winged seed or fruit is the slowest method of dispersal and is unable to cross any large stretch of sea; that the plumed seed or fruit, while adapted for quick dispersal over an open country. "is liable to be stopped in its migrations by dense forests;" and that "powder-seed" is adapted to the most rapid and distant dispersal.—J. M. C.

WORSDELL[31] has begun the publication of a series of papers entitled "The principles of morphology." The first one deals with the alternation of generations, and with the origin of the leafy sporophyte under which the theory of antithetic origin is approved and the opposing testimony of apogamy and apospory discredited; the conclusion being reached that "the three morphological categories of organs, viz., the leaf, stem, and root, which have persisted and remained distinct each from the other ever since the antiphytic generation attained any development, find their natural origin, therefore, in the capsule, seta, and foot or sucker respectively of the primitive bryophytic sporogonium."

The second paper[32] discusses the evolution of the sporangium. The conclusions are that the sporogonium of the primitive bryophyte is at once the homologue (1) of every type of foliar organ, (2) of every type of sporangiophore, (3) of every type of sporangium, (4) of the entire sporophyte. This is what he calls the doctrine of "variously graded" homologies. A concluding sentence is as follows: "The deductions from this idea are apparently, but only apparently, absurd; thus the sporogonium of a bryophyte must, for instance, be rigidly homologous both with an oak tree and with every single nucellus contained by every ovule of that oak tree." Appearances are not always so deceptive as the proverb would have us believe.—J. M. C.

HARPER continues to publish interesting ecological and floristic papers dealing chiefly with the flora of Georgia. One paper[33] gives an account of his explorations in 1903 in the coastal plain. A second paper[34] on Taxodium makes it pretty evident that *T. imbricarium* and *T. distichum* are specifically distinct, and that they have well defined and different characters and habitats. In noting the earlier paper, the reviewer was inclined to regard *T. imbricarium* as an ecological variety. *Pinus palustris*[35] was found at several stations at altitudes of

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[31] WORDSELL, W. C., The principles of morphology. I. New Phytol. 4:124-133. 1905.

[32] ———, The principles of morphology. II. *Ibid.* 4:163-170. 1905.

[33] HARPER, R. M., Phytogeographical explorations in the coastal plain of Georgia in 1903. Bull. Torr. Bot. Club 32:141-171. 1905.

[34] ———, Further observations on Taxodium. *Ibid.* 32:105-115. 1905.

[35] ———, Some noteworthy stations for *Pinus palustris*. Torreya 5:55-60. 1905.

1,000 to 1,500 feet in northern Georgia. A fourth paper[36] gives a list of the ferns of Georgia, with full notes, and an introduction describing the geological and other features of the state. A paper[37] on the coastal plain plants of New England gives an annotated list of plants common to Georgia and other southern states and New England. Most of the plants belong to what may be called a sandy swamp flora, and many of them are found in northern Indiana near the shore of Lake Michigan.—H. C. COWLES.

ONE OF THE LATEST PUBLICATIONS of the Royal Botanical Garden at Berlin is a guide to the "biological" collections there installed. The beginnings of this phase of the Garden activities dates back to 1890, when Dr. ENGLER[38] assumed the directorship. In the cramped space of the old garden neither the "biological" nor phytogeographical display was such as to satisfy the ambitious director. In the new garden there is sufficient space to make an adequate display possible. The guidebook is arranged systematically by topics, corresponding to the arrangement of the Garden, and interesting notes are incorporated under nearly all of the headings. Among the topics illustrated are leaf position, leaf and stem adaptations in relation to photosynthesis, adaptations that protect against excessive transpiration, plants that utilize organic substances for food, stem types, pollination adaptations, movement phenomena, adaptation for seed dispersal. Such a plan is most admirable, and should be adopted as far as possible in many places.—H. C. COWLES.

THE BOTANICAL SURVEY of Scotland, so auspiciously begun by ROBERT SMITH, has been taken up by his brother, WILLIAM SMITH.[39] In the two districts here under review, the notes were gathered largely by the deceased senior author, and have been appreciatively brought together by the junior author after recent visits to Scotland. The general plan of the Forfar and Fife maps is that of the Edinburgh and Perthaline maps, as would be expected. The maps are accompanied by a text giving a full account of the various formations, in which the regions of cultivation are included as in the earlier studies. The woods are mainly oak, birch, and coniferous. In addition there are moors, heaths, grasslands, alpine, and maritime districts within the district under survey. At the close is a very interesting summary, embracing within brief compass the chief results of the British vegetation surveys to date, arranged according to GRAEBNER'S scheme of classification.—H. C. COWLES.

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[36] ———, The fern flora of Georgia. Fern Bulletin **13**:1–17. 1905.

[37] ———, Coastal plain plants in New England. Rhodora **7**:69–80. 1905.

[38] ENGLER, A., Führer durch die biologisch-morphologischen Abteilungen des Königl. botanischen Gartens zu Dahlem. Notizblatt Königl. Bot. Gartens, Appendix XVI. pp. 66. 1905.

[39] SMITH, ROBERT and WILLIAM G., Botanical Survey of Scotland. III and IV. Forfar and Fife. Scotland Geog. Mag. **20**:617–628. 1904. *Ibid.* **21**:1–20; 57–83; 117–126. 1905.

CLEMENTS[40] has given a short account of formation and succession herbaria. The idea of herbaria based on habitats in addition to those based on taxonomic characters seems to have been suggested by DRUDE, and has now been followed out in several places. No one has worked out the idea more systematically than has CLEMENTS in the Colorado mountains, and he distributed herbaria from there in 1901. Succession herbaria illustrate the dynamics of plant formations, and are the most desirable of ecological herbaria, but the most difficult to prepare. In his Colorado work the cryptogams, apart from the ferns, have been incorporated into a separate herbarium. The paper closes with an illustrated list of Colorado plants arranged by formations; in each formation there appears first the facies, followed by the principal and secondary species of the spring, summer, and autumn aspects.—H. C. COWLES.

KÜSTER[41] takes issue with SENN, who in a recent preliminary report has concluded that the position of chloroplasts in darkness is to be accounted for by an uneven distribution of the substance chemotactically potent upon them. The author's experiments with Dictyota and Padina especially, show that under the influence of hypertonic solutions the chloroplasts arrange themselves along the side walls (*Profilstellung*), while hypotonic solutions cause them to seek the upper and lower walls (*Flächenstellung*). The change in turgor pressure of the cell is thus the direct cause of orientation movements of the chromatophores and this change may be induced by light, or by hyper- or hypotonic solutions independently of light.—RAYMOND H. POND.

MISS LATHAM,[42] Barnard College, in investigating the response of fungi to the vapor of chloroform, has reached the following conclusions: (1) when present in small quantities chloroform vapor acts as a characteristic stimulant to the growth of *Sterigmatocystis nigra* and *Penicillium glaucum;* (2) larger quantities are inimical or fatal; (3) increased growth is attended by relatively less acid formation and less sugar consumption, indicating greater economy in metabolism; (4) the time of greatest sensitiveness is at the germination of the spores; (5) chloroform acts as a stimulant purely, since it cannot be a source of carbon; (6) the effect of a given amount of the anaesthetic is greater as the temperature rises.—J. M. C.

DARBISHIRE[43] has undertaken a study of Mamillaria, especially with a view to interpreting the significance of the plant form and the spines. Observations

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[40] CLEMENTS, F. E., Formation and succession herbaria. University of Nebraska Studies **4**: no. 4. pp. 27. 1904.

[41] KÜSTER, E., Ueber den Einfluss von Lösungen verschiedener Konzentration auf die Orientierungsbewegungen der Chromatophoren. Ber. Deutsch. Bot. Gesells. **23**:254–256. 1905.

[42] LATHAM, MARION ELIZABETH, Stimulation of Sterigmatocystis by chloroform. Bull. Torr. Bot. Club **32**:337–351. 1905.

[43] DARBISHIRE, O. V., Observations on *Mamillaria elongata.* Annals of Bot. **18**:375–416. 1904.

were made on the morphology, stem anatomy, root, and tubercle. The author holds that plant characters are to be regarded as useful now as formerly, and that, especially in adverse conditions, useless characters are unlikely to occur. Thus the structures of a desert plant like a cactus are presumably responses to desert conditions. DARBISHIRE does not favor the protective theory of spines, but he holds that these spines serve the purpose of light screens, whence he calls them paraheliodes.—H. C. COWLES.

PAMMEL[44] has recently published the results of his study in Iowa of the apple rust and of the fungi causing this well known disease. The account of each of five species of Gymnosporangium includes the important literature, its structure, and its polymorphism. Many original inoculation experiments are reported regarding the connection of the above species with the aecidial stage formerly included in the form genus Roestelia. As treatment the removal of the cedar trees is recommended wherever possible. Less favorable results from spraying apple trees were obtained than were reported by Emerson.[45]—E. MEAD WILCOX.

THERE IS BEGINNING to appear[46] in the *New Phytologist* a series of papers on the vegetation of various countries, the aim of which is less the presentation of the results of research than the awakening of further interest in the study of vegetation by making use of vivid personal sketches. The first papers deal with the shore vegetation of Ceylon, and there is a good account given of the typical tropical sand strand and of the mangrove and nipa formations. There are many cuts illustrating characteristic plant forms, and the description of the plant forms and formations is admirable.—H. C. COWLES.

TSCHERNIAJEW[47] finds that temperature affects the intensity of the aerobic respiration of wounded plants (onion bulbs), but not the anaerobic. This was ascertained by determining the rate of exhalation of carbon dioxid at elevated (30°–45°) and at ordinary temperatures (16°–19°). A higher temperature increases the intensity of aerobic respiration—the maximum, after wounding, appearing sooner than at ordinary temperature. Intramolecular respiration, however, at both ordinary and elevated temperatures, decreases in intensity after wounding.—RAYMOND H. POND.

COLLINS[48] has written a short account of an interesting Rhode Island bog,

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[44] PAMMEL, L. H., The cedar apple fungi and apple rust in Iowa. Bull. Iowa Exp. Stat. 84:1–36. *figs. 1–11.* 1905.

[45] EMERSON, R. A., Apple scab and cedar rust. Bull. Neb. Exp. Stat. 88:1–21. 1905. *figs. 1–9.* BOT. GAZETTE **40**:149. 1905.

[46] TANSLEY, A. G., and FRITSCH, F. E., Sketches of vegetation at home and abroad. I. The flora of the Ceylon littoral. New Phytol. **4**:1–17; 27–55. 1905.

[47] TSCHERNIAJEW, E., Ueber den Einfluss der Temperature auf die normale und die intramoleculare Atmung der verletzten Pflanzen. Ber. Deutsch. Bot. Gesells. **23**:207–211. 1905.

[48] COLLINS, J. F., Some interesting Rhode Island bogs. Rhodora **6**:149–150. 1904.

in which four species hitherto unrecorded for the state were discovered (*Andromeda polifolia, Kalmia glauca, Eriophorum vaginatum, Arceuthobium pusillum*). The black spruce is more abundant than elsewhere in the state. Obviously this is a relict vegetation, and it is interesting to know that ice remains in this bog until late in May. The Andromeda was in full bloom, while the stems were yet imbedded in thick ice, a condition surely reminding one of the far north. —H. C. COWLES.

AN INSTRUCTIVE ECOLOGICAL STUDY of the giant cactus has been made by Mrs. SPALDING.[49] It is found that changes in bulk due to varying amounts of stored water are accompanied by circumferential stem changes accomplished by a bellows-like action of the ribs, which draw closer together as the circumference decreases, and move farther apart as it increases. Variations in circumference are least pronounced at the base and top; and differences are shown between the north and south sides. These changes in no way impair the mechanical system.—H. C. COWLES.

BLANKINSHIP[50] has published an historical account of botanical work in Montana. The frontispiece is an elegant colored plate of *Lewisia rediviva*. The accounts of collecting expeditions are arranged chronologically, and the bibliography of titles dealing with the state flora, arranged alphabetically, will be very helpful to students of the vegetation of that region. BLANKINSHIP[51] has also published a supplement to RYDBERG'S *Montana flora*, and in association with H. F. HENSHALL[52] he has prepared a list of the common names of Montana plants.—H. C. COWLES.

BULLER[53] has obtained some interesting data from the study of a single-gilled fungus whose saprophytism destroys paving blocks. When grown in light or in darkness papillae protrude which in the former case develop pilei but in the latter do not. The papillae remain rectipetal and indifferent to geotropic stimuli until exposed to light, when they become negatively geotropic and positively heliotropic. The latter sensitiveness is lost, however, during the formation of the pileus, which is dependent upon sufficient illumination.—RAYMOND H. POND.

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[49] SPALDING, EFFIE S., Mechanical adjustment of the suaharo (*Cereus giganteus*) to varying quantities of stored water. Bull. Torr. Bot. Club **32**:57–68. 1905.

[50] BLANKINSHIP, J. W., A century of botanical exploration in Montana, 1805–1905; collectors, herbaria, and bibliography. Mont. Agric. Coll. Sci. Studies **1**:3–31. 1905.

[51] ———, Supplement to the flora of Montana: additions and corrections. *Ibid.* **1**:33–109. 1905.

[52] BLANKINSHIP, J. W., and HENSHALL, H. F., Common names of Montana plants. *Ibid.* **1**:113–139. 1905.

[53] BULLER, A. H., R. The reactions of the fruit-bodies of *Lentinus lepideus* Fr. to external stimuli. Annals of Bot. **19**:427–436. *figs. 30.* 1905.

BOLLETER[54] has prepared an extended morphological and physiological monograph on *Fegatella conica* (L.) Corda. The subject is treated under the headings, general considerations, structure of the thallus, structure and development of the sexual shoots (including development of archegonia, antheridia and fertilization), development of the sporogonium and spores, germination of spores, development of the thallus, and asexual reproduction. It is a very complete study of the life-history and will be useful for reference.—C. J. CHAMBERLAIN.

LEAVITT,[55] in an interesting paper dealing with monstrosities in Drosera, Gentiana, and Saxifraga, uses the term "morphic translocation" in speaking of characters of one organ which appear suddenly on another organ, but without atavistic significance. The gentian spoken of had a petaloid fringe on the carpel, and the Drosera had glandular tentacles on perianth and carpels. The possible significance of such translocations, as well as the broader topic of the use of teratological data, is discussed rather fully.—H. C. COWLES.

OLSSON-SEFFER[56] tells of the plans of the Danish ecologist, M. P. PORSILD, for the establishment of a permanent laboratory in Greenland. The realization of these plans, thorough and yet modest from the standpoint of expenditure, would be of untold value to science, and it is to be hoped that the Danish government will grant PORSILD'S request. This seems likely, in view of the liberality of Denmark to previous botanical explorers in Greenland.—H. C. COWLES.

WHILE LIGHT SEEMS to have little or no influence on the germination of most seeds, it favors the germination of some, and in the case of a very few (as Viscum, *Drosera capensis*), light is necessary for germination. Only in the case of *Acanthostachys strobilacea* had light been found to hinder germination. Now REMER[57] adds another plant, *Phacelia tanacetifolia*, to Acanthostachys. The ecological significance of such aberrants is unknown.—H. C. COWLES.

W. H. LAWRENCE[58] has published a short popular account of the Erysiphaceae, together with keys and descriptions of the genera and species found in the state of Washington. Notes are also presented upon six diseases of cultivated plants in Washington due to species of this well-known family. Spraying with Bordeaux mixture, cupram, or flowers of sulfur is recommended as the best means of controlling these mildews.—E. MEAD WILCOX.

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[54] BOLLETER, E., *Fegatella conica* (L.) Corda, Eine morphologisch-physiologisch Monographie. Beih. Bot. Centralbl. **18**:327–408. *pls. 12–13.* 1905.

[55] LEAVITT, R. G., On translocation of characters in plants. Rhodora **7**:1–17. 1905.

[56] OLSSON-SEFFER, P., A biological station in Greenland. Science **21**:189–191. 1905.

[57] REMER, W., Der Einfluss des Lichtes auf die Keimung bei *Phacelia tanacetifolia* Benth. Ber. Deutsch. Bot. Gesells. **22**:328–339. 1904.

[58] LAWRENCE, W. H., The powdery mildews of Washington. Bull. Wash. Exp. Stat. 70:1–16. *figs. 22.* 1905.

COCKAYNE[59] has found that *Discaria Toumatou*, a New Zealand xerophytic shrub that normally has long pungent spines, fails to develop these spines in moist chamber cultures. It is believed that the juvenile leafy shoots instead of spines would continue indefinitely in such conditions. He regards these facts as highly favorable to the xerophytic rather than the protective theory of thorns.—H. C. COWLES.

HARSHBERGER[60] proposes that the term zone in plant geography be restricted to broad belts determined by latitude, conforming to the law of priority as well as dominant usage. Mountain zones he would term belts; concentric pond zones, circumareas; submerged shore zones, shelves; strand, river, or prairie edge, strips; island zones, girdles; and vertical forest zones, layers.—H. C. COWLES.

HARSHBERGER has been making further floristic studies on the North American flora. One paper[61] deals with the comparative age of the various elements in eastern North America, and there is a chart that shows the supposed relative time of appearance of these elements from the Miocene until now. A second paper[62] deals briefly with centers of dispersal.—H. C. COWLES.

SWELLENGREBEL[63] finds something to attract him in the dunes of the Netherlands in spite of H. BLINK'S assertion that they have no true dune plants, and that if present they would be of no interest! The plant societies noted are those of the sea dunes, the gray dunes, and the dune hollows. Detailed notes are given concerning the source of the dune flora.—H. C. COWLES.

IN A LECTURE before a convention of practical farmers at Breslau, January, 1905, TSCHERMAK[64] gave a clear exposition of the recently discovered laws of inheritance and their significance for practical agriculture. He also included a brief discussion of variation and mutation.—G. H. SHULL.

A GOOD ACCOUNT[65] of the Desert Botanical Laboratory and of the more striking vegetation in its vicinity has been published by Professor LLOYD.—H. C. COWLES.

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[59] COCKAYNE, L., On the significance of spines in *Discaria Toumatou* Raoul (Rhamnaceae). New Phytol. **4**:79–85. 1905.

[60] HARSHBERGER, J. W., Suggestions toward a phytogeographic nomenclature. Science N. S. **21**:789–790. 1905.

[61] HARSHBERGER, J. W., The comparative age of the different floristic elements of eastern North America. Proc. Acad. Nat. Sci. Phil. **1904**:601–615.

[62] ———, Original centers concerned in North American plant dispersal. *Ibid.* **1905**:2.

[63] SWELLENGREBEL, N., Ueber niederländische Dünenpflanzen. Beih. Bot. Centralbl. **18**^{2}:181–198. 1905.

[64] TSCHERMAK, E., Die neuentdeckten Vererbungsgesetze und ihre praktische Anwendung für die rationelle Pflanzenzüchtung. Reprint from Wiener Landw. Zeitg. nos. 17, 18, 19. pp. 31. 1905.

[65] LLOYD, F. E., A botanical laboratory in the desert. Pop. Sci. Monthly **66**: 329–342. 1905.

NEWS.

MR. F. J. SEAVER has been appointed professor of botany in Iowa Wesleyan College, at Mt. Pleasant, where he hopes to continue his study of Discomycetes.

DR. R. H. TRUE, in charge of drug-plant investigations for the U. S. Bureau of Plant Industry, is paying special attention to the culture of paprika peppers. The crop of the past season is reported as extremely satisfactory.

PROFESSORS MACBRIDE and SHIMEK, of the University of Iowa, spent part of last summer in the southwestern deserts, especially in the Salton basin. The University herbarium now contains a fairly complete representation of the flora of New Mexico and Arizona.

GEBRÜDER BORNTRAEGER are proposing to reprint certain missing parts of the *Jahrbücher für wissenschaftliche Botanik* so as to offer complete sets of the first forty volumes, provided there are a sufficient number of subscribers at *M* 1250 for the set. We trust they will be encouraged to execute the project.

MR. L. H. DEWEY, in charge of fiber-plant investigations, U. S. Bureau of Plant Industry, has recently distributed to agricultural colleges and other technical schools sets of the principal plant fibers used in the textile industries in this country. Until exhausted, these sets will be forwarded to schools and colleges where they will be of service in teaching economic botany or commercial geography.

THE DEPARTMENT of botany of Purdue University has this year added courses in forestry, administered by Professor STANLEY COULTER, covering two years' work, and including instruction in timber physics under the direction of Professor W. K. HATT, in charge of timber tests for the U. S. Forest Service. With prerequisites covering Freshman and Sophomore work, the initial enrolment is thirteen. The University of Iowa is also extending its courses along forestry lines.

THE SYSTEMATIC botanical work of the U. S. Bureau of Plant Industry has recently been brought together and put in charge of Mr. F. V. COVILLE. Heretofore, considerable work of this character has been carried on in several offices of the Bureau, more especially in that of the Agrostologist, where systematic studies of grasses have been conducted for many years. The grass collections have also been placed under the charge of Mr. COVILLE, and Mr. A. S. HITCHCOCK, in general charge of systematic work on grasses, has been assigned to the office of the Botanist for the continuance of this work.

AT THE University of Nebraska changes have been made which provide better accommodations for the herbarium (now containing about 100,000 specimens) and the botanical library. The plant houses, hitherto shared with the department of horticulture, are to be under the full control of the department of botany. A new botanical laboratory has been fitted up in connection with the School of Agriculture and the Experiment Station, in the recently completed Agricultural Hall on the University Farm. While part of the general department, this laboratory is specifically in the charge of Dr. F. D. HEALD. Dr. F. E. CLEMENTS is to give courses in ecology as part of the larger division of plant physiology of which he was recently appointed associate professor.

FROM THE *Journal* of the New York Botanical Garden we learn that Dr. and Mrs. N. L. BRITTON, accompanied by Mr. STEWARDSON BROWN, curator of botany in the Philadelphia Academy of Natural Sciences, spent three weeks in Bermuda in September, bringing back a large collection of plants, live and dried, in all about 3,000 specimens.

DR. P. A. RYDBERG spent two months last summer in collecting about Salt Lake City, Marysvale, and Nephi, Utah.

MR. GEORGE V. NASH has recently returned from an exploring expedition in the interior of Hayti, reaching some regions hitherto unvisited by any botanist and bringing back large quantities of live plants, seeds, and preserved material.

DR. FORREST SHREVE is spending the winter at the tropical laboratory of the New York Botanical Garden, Cinchona, Jamaica, having been appointed a laboratory assistant of the Garden and Bruce Fellow of Johns Hopkins University.

THE FOLLOWING movements among the staff of the U. S. Bureau of Plant Industry have been reported at our request:

DR. W. O. RICHTMANN has returned from a trip to California, undertaken in the interests of camphor and poppy investigations.

MR. W. F. WIGHT has just returned from Europe, where he spent four months in studying type specimens of plants in various herbaria.

MR. F. H. HILLMAN recently visited the Pacific coast in order to study the species of dodder which are so troublesome in alfalfa and clover fields.

MR. G. FRED KLUGH spent several months in Idaho and Nevada studying the relation of poisonous plants to the sheep trouble known as "bighead."

MR. S. C. HOOD, who has been in charge of the Vermont station for drug-plant investigations, at Burlington, has returned to Washington for the winter.

PROFESSOR H. PITTIER is about to start on an exploring trip of four or five months' duration in western Columbia, with a special view to a study of the cottons of that region.

MR. T. B. YOUNG has returned to Washington after a season's work at Ebenezer, S. C., where he has been in charge of the drug-plant farm, in cooperation with Mr. J. W. KING.

MR. EDGAR BROWN recently returned from an inspection of the more important seed laboratories of England, France, Netherlands, Germany, Austria-Hungary, and Switzerland.

MR. W. W. STOCKBERGER recently made a trip through the hop-producing sections of the Pacific coast and the state of New York, where the conditions of brewing and of curing hops have been studied.

DR. J. W. T. DUVEL is spending some time in Ohio and Illinois investigating the curing of seed corn. It has been found that by proper treatment seed corn of high vitality can be assured at planting time.

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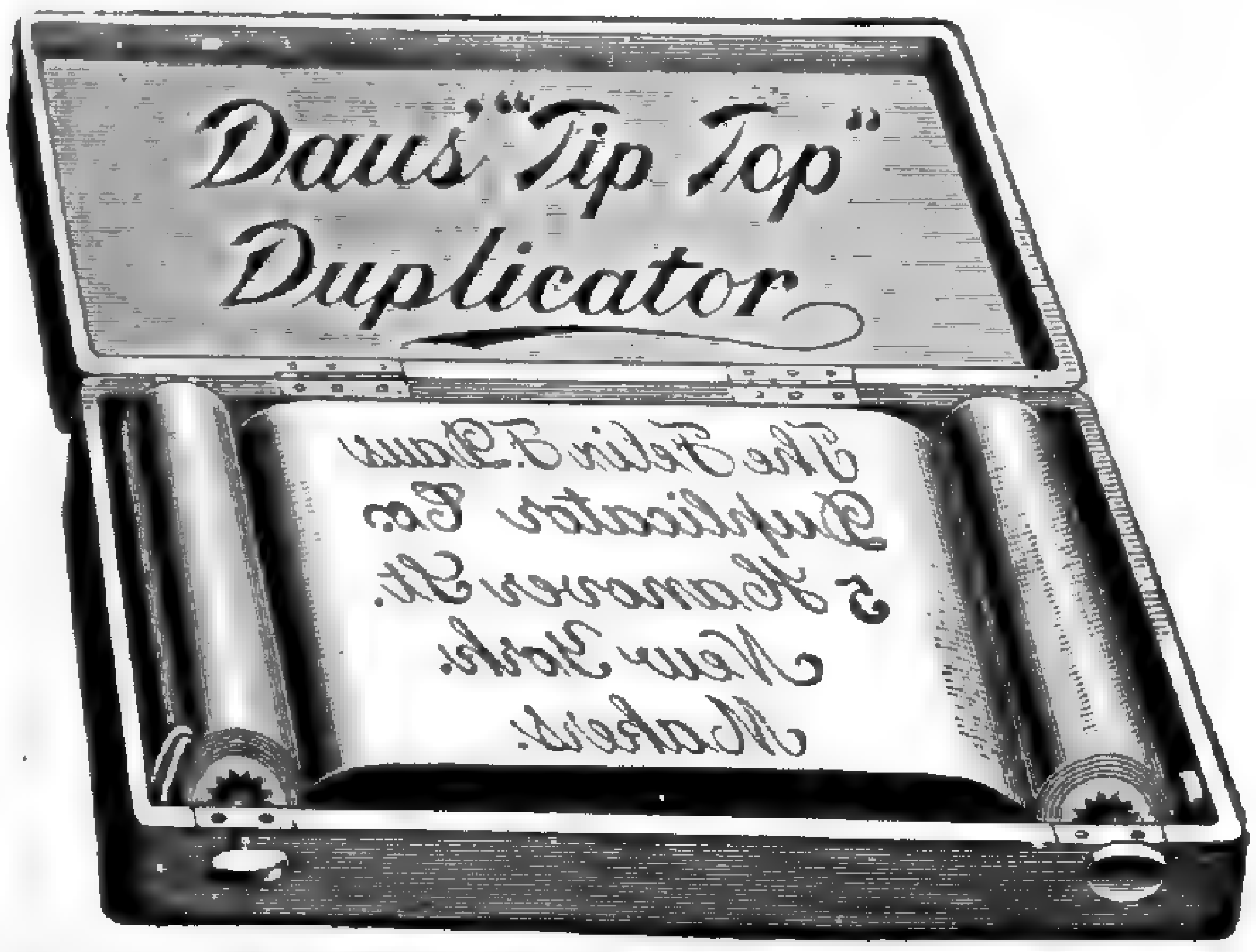

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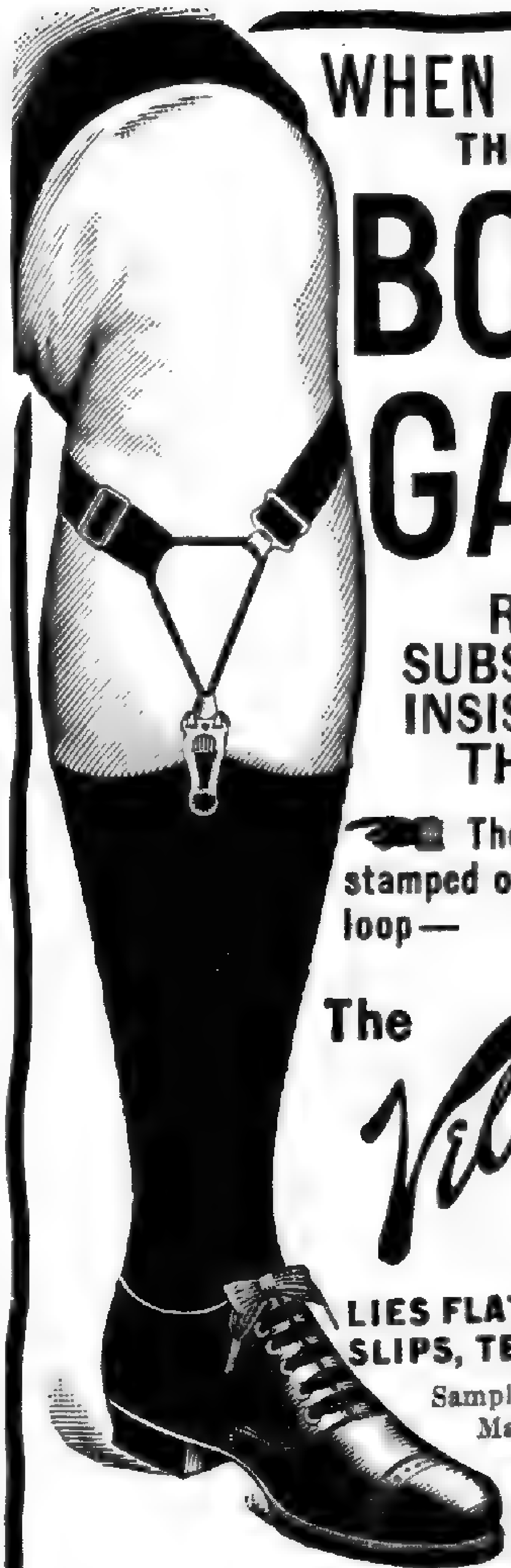


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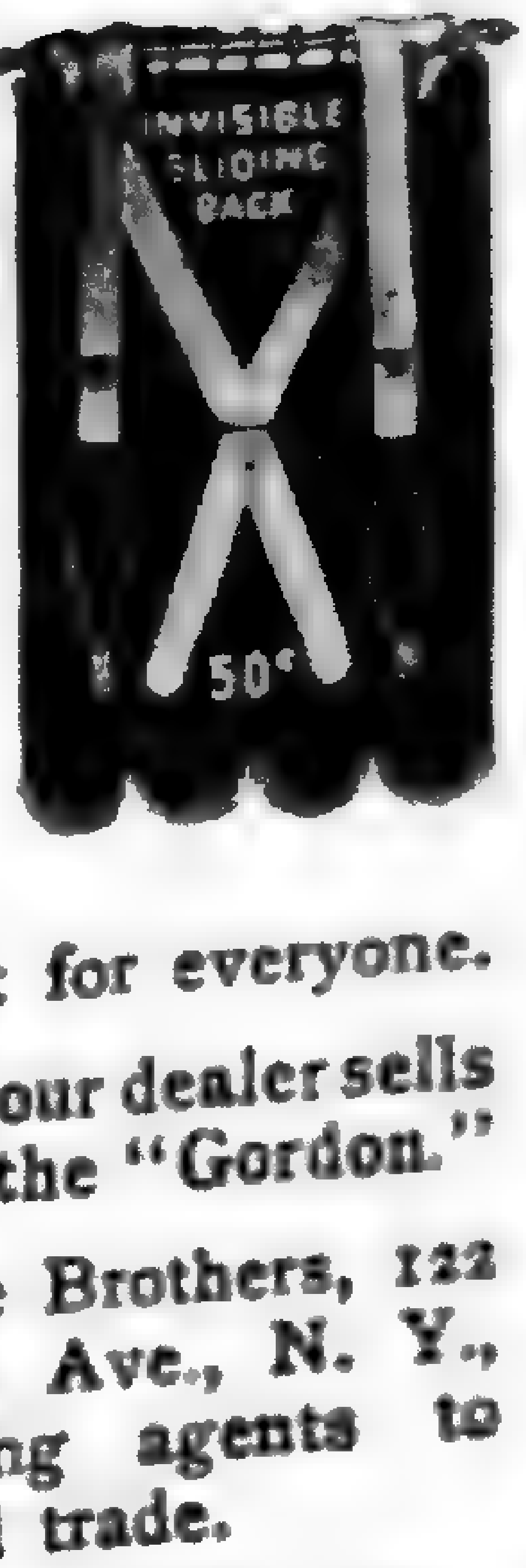
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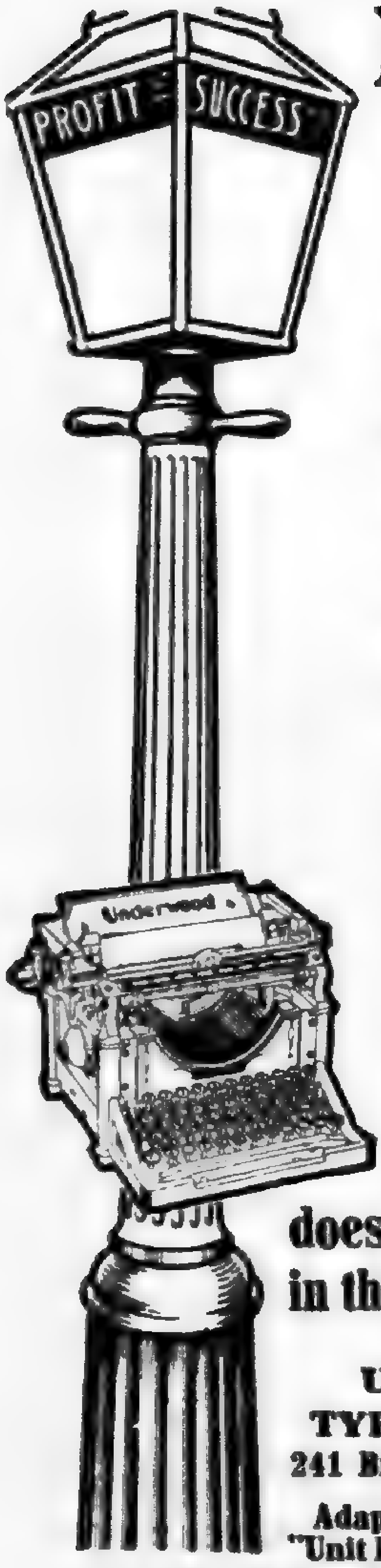
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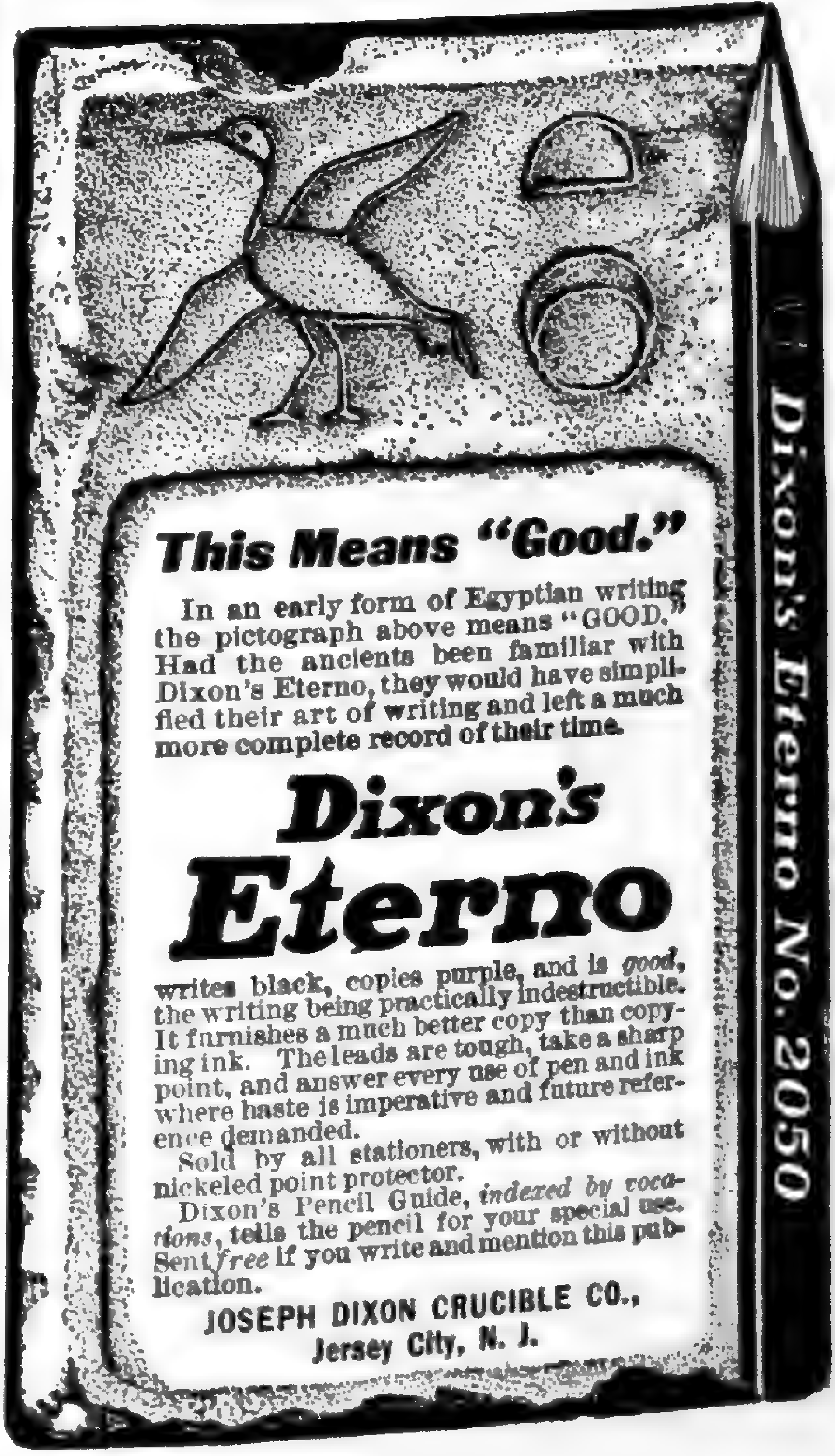

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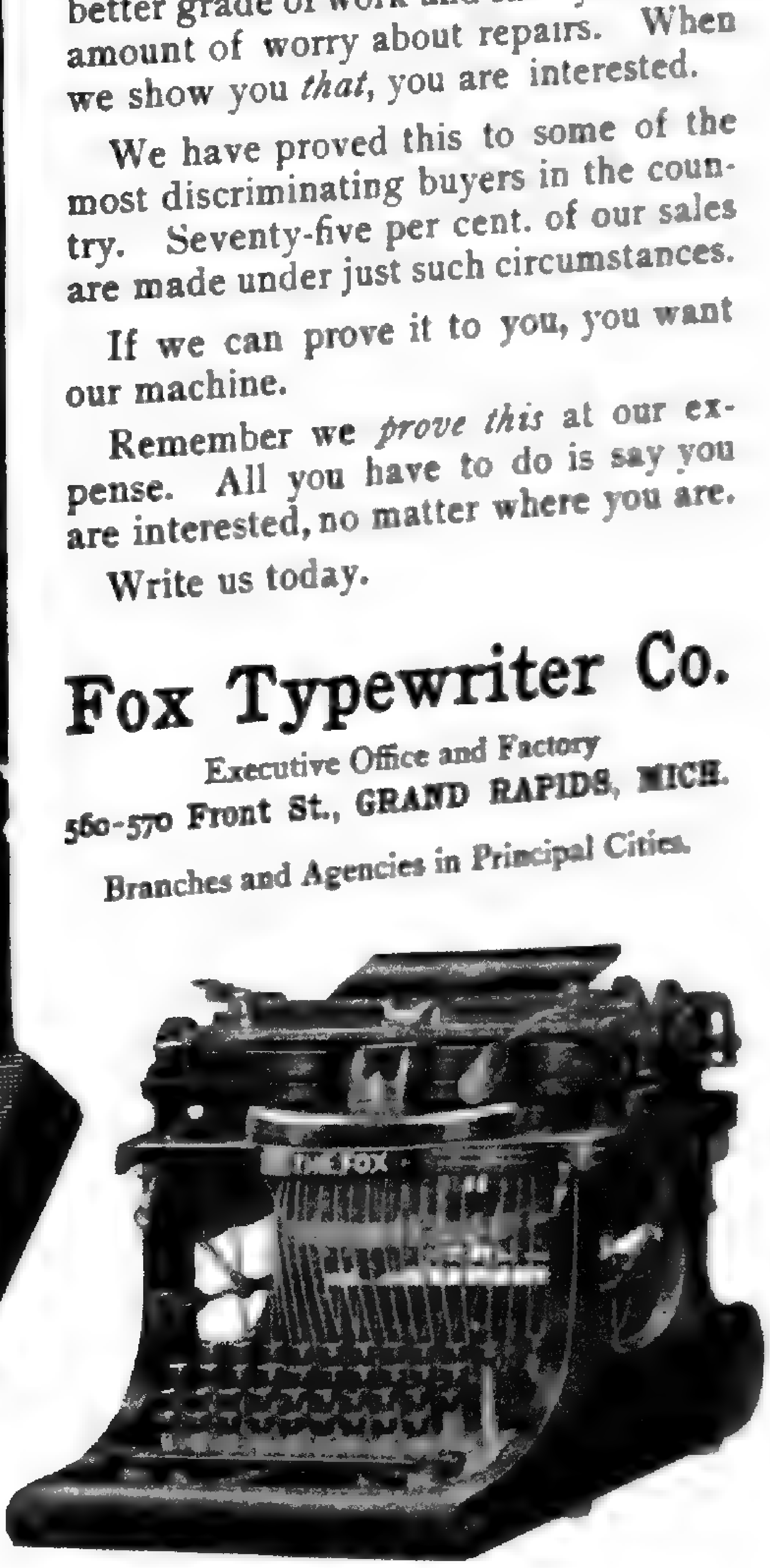

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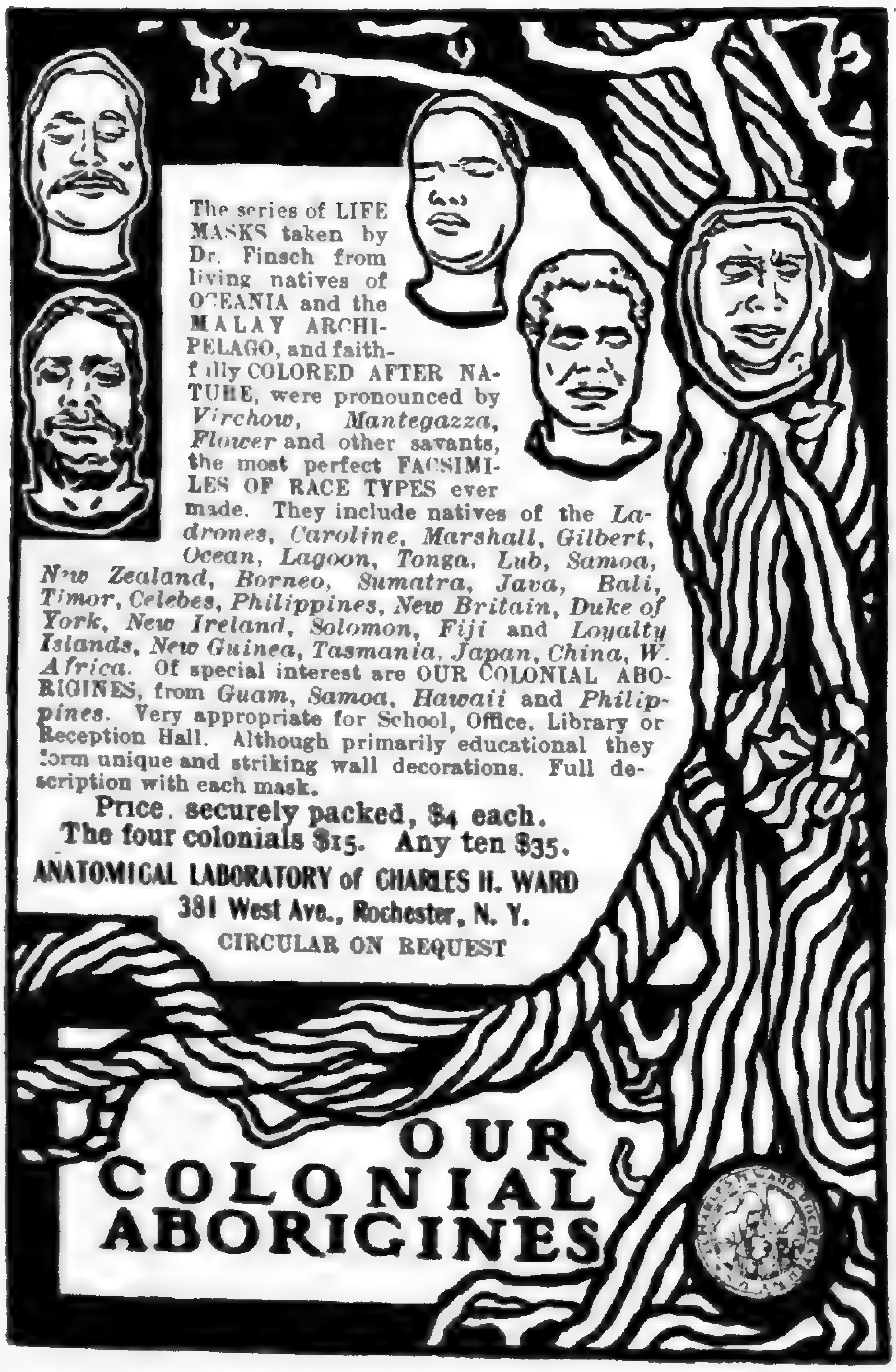
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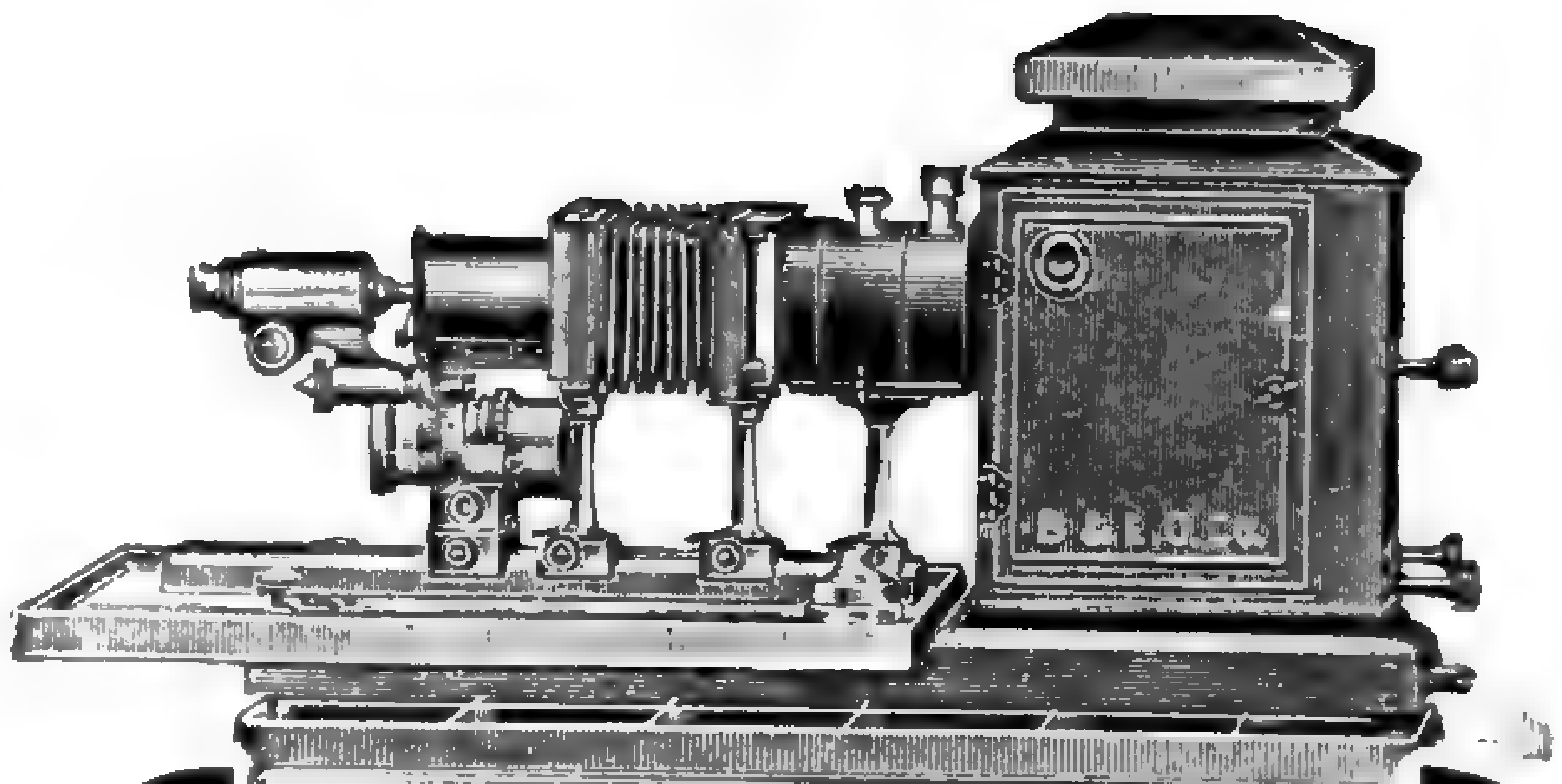

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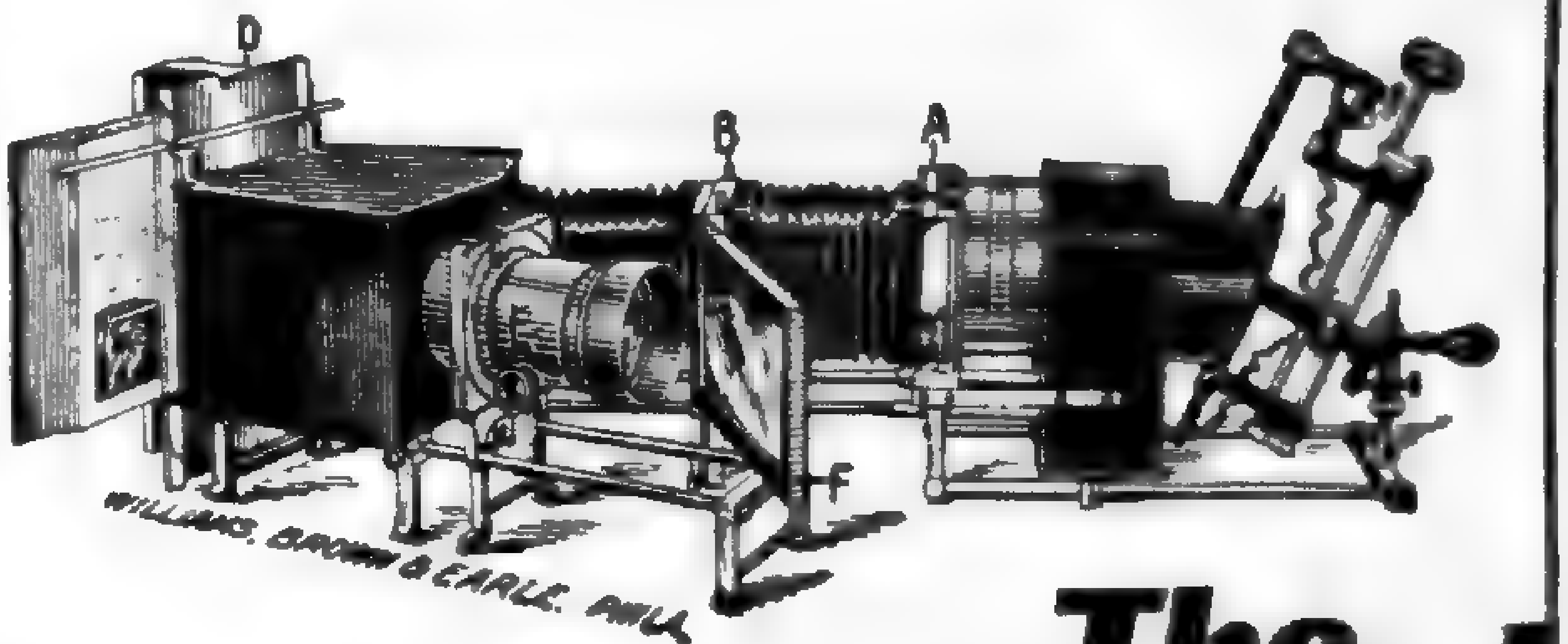
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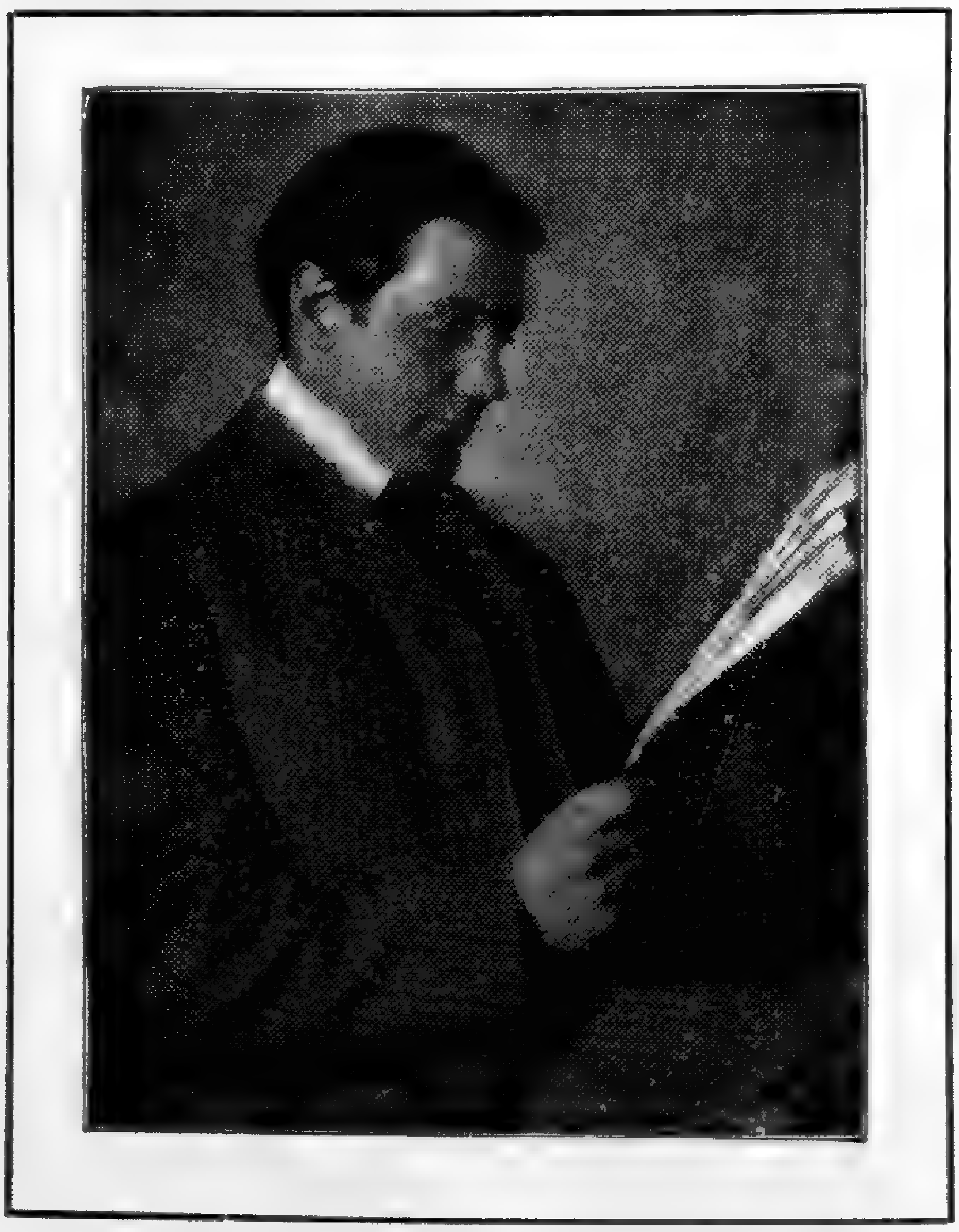

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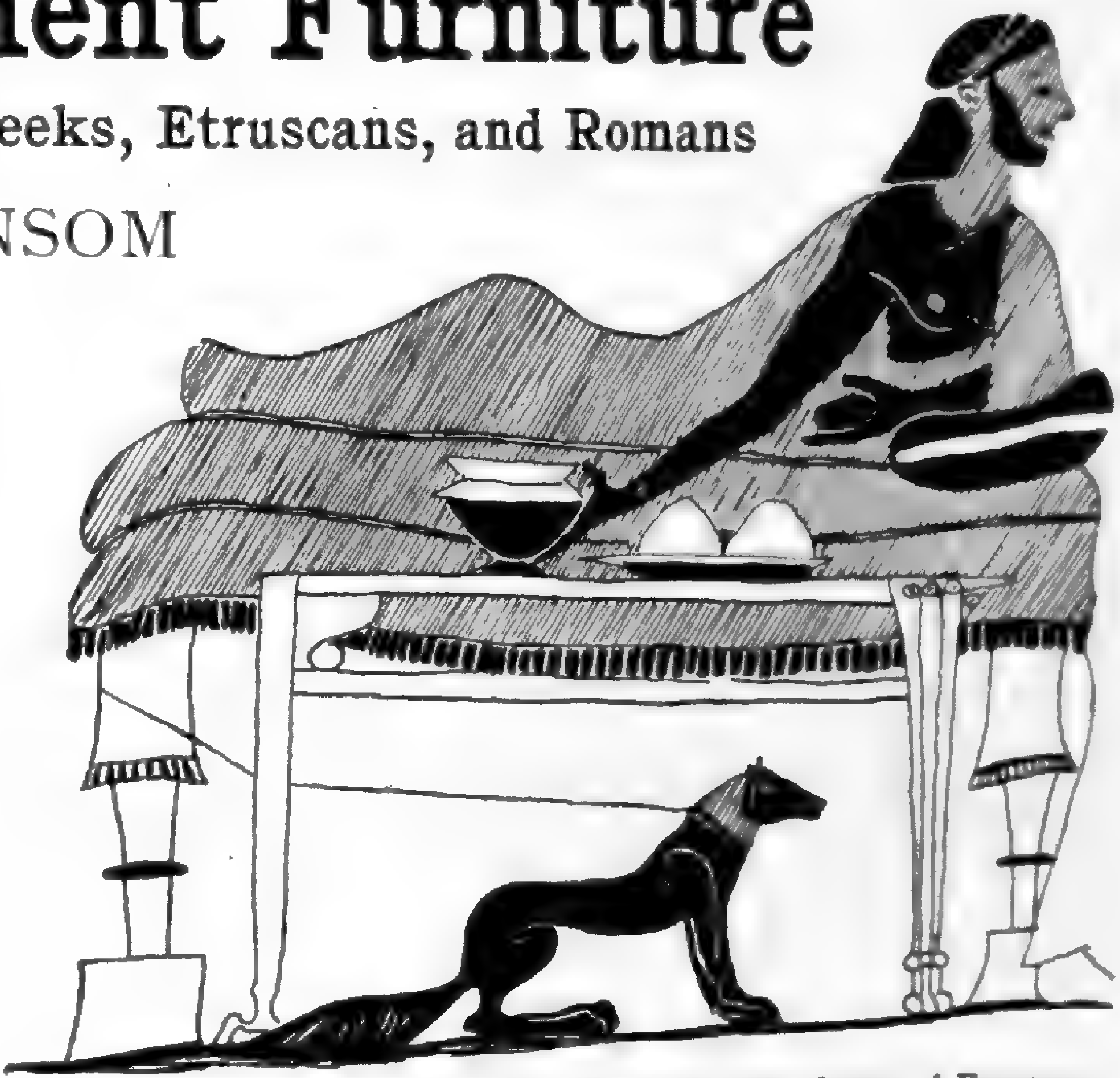

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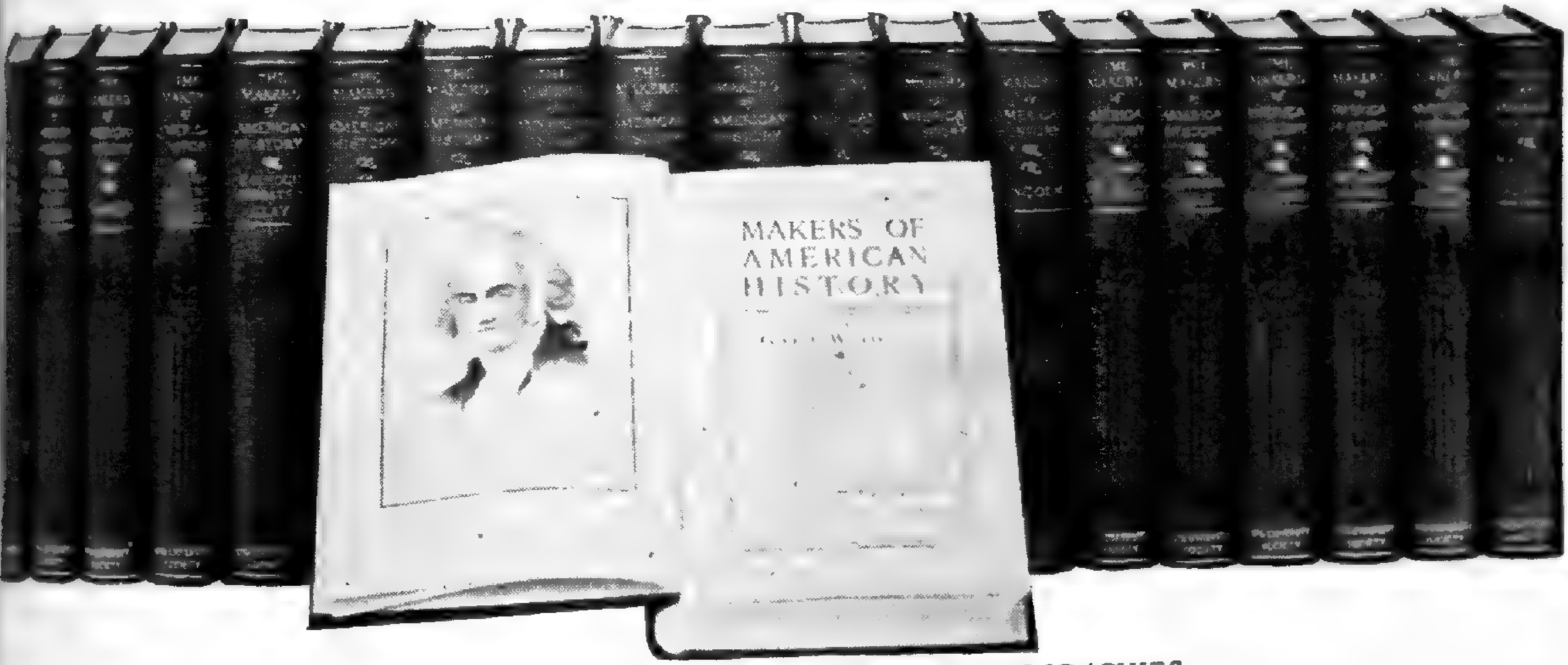
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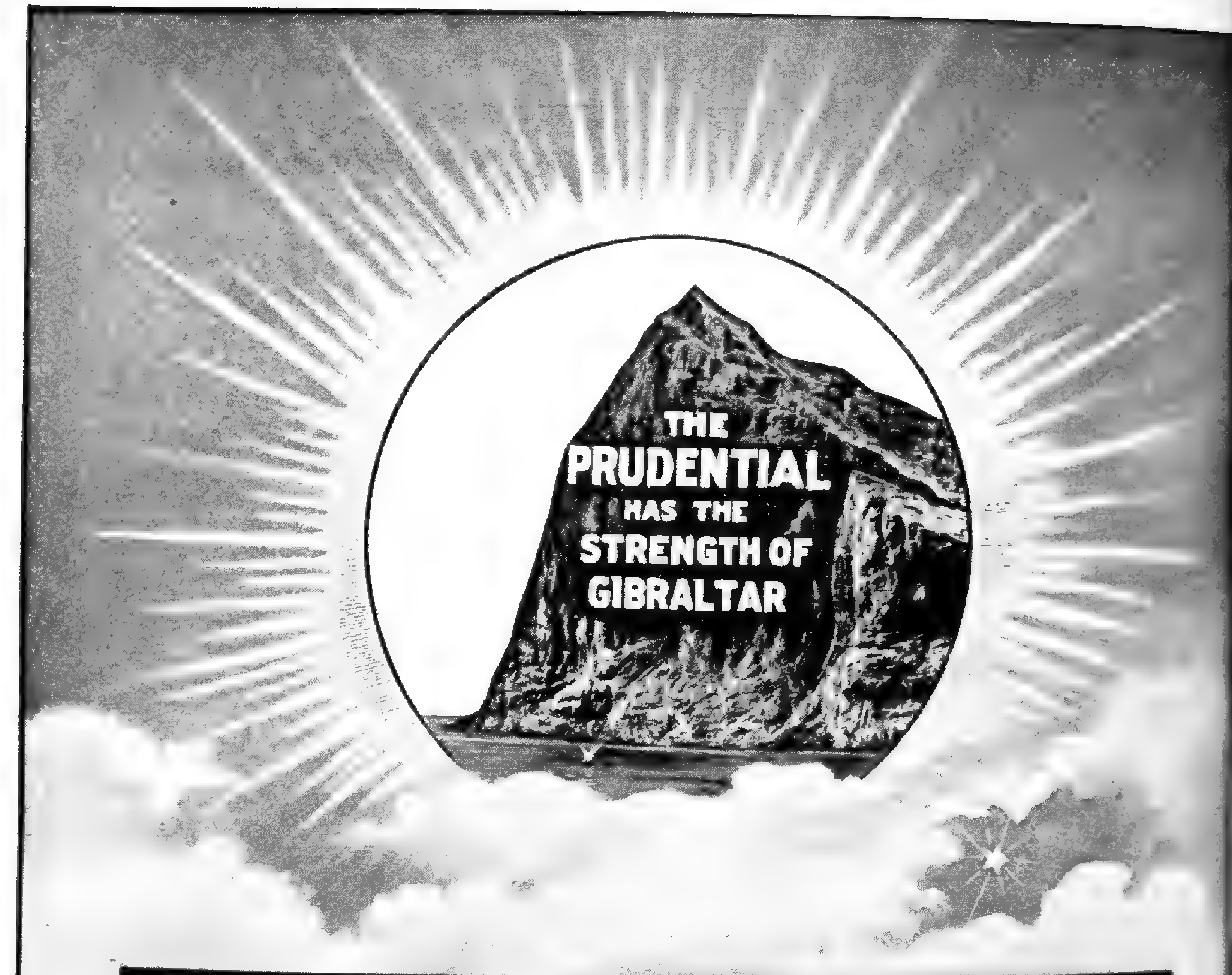
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VOLUME XL NUMBER 6

BOTANICAL GAZETTE

DECEMBER, 1905

LIFE HISTORY OF HYPOCREA ALUTACEA.[1]

GEORGE F. ATKINSON.

(WITH PLATES XIV–XVI)

Hypocrea alutacea (Pers.) Tul. is an interesting plant, not only on account of its history, but because of its peculiar form and color characters, taken in connection with its structure. In shape it is like a club or spatula, one to three inches high, resembling in form other members of the old genus Sphaeria now placed in the genera Xylaria and Cordyceps. It differs from the Xylarias in not being black, as well as in differences of texture and structure. It resembles more nearly a simple Clavaria, in which genus it was first placed as *Clavaria simplex* Schmiedel.[2] It resembles also a Cordyceps, in which genus it has also been placed, and it is even said to grow sometimes on insects. Some forms are also strikingly like species of Spathularia among the Discomycetes. To the collector, therefore, unacquainted with the plant, when he first finds it, it calls forth various emotions, running all the way from admiration of its simple lines of beauty to a possible belief that it is a "brand" new fungus, then to a temporary location in the wrong genus. But an examination of the spores shows at once its relation to the genus Hypocrea. The larger number of species of Hypocrea either form low cushions, or extended incrustations on decaying organic matter, or they are parasitic on the surface of the larger fungi, resembling in this respect some of the species of Hypomyces.

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[1] Contributions from the Botanical Department of Cornell University no. 103.

[2] Icones et Analyt. 18–26. *pl. 4, fig. 2, pl. 5, figs. 1–3.* 1762, according to TULASNE, Selecta Fung. Carp. **3**:35. 1865.

The earlier students looked upon this fungus as an autonomous plant with an erect clavate stroma; among them are the following. PERSOON[3] first described it as *Sphaeria alutacea*. SOWERBY[4] discovered it in 1783, and described it in 1799 as *Sphaeria clavata*. SCHUMACHER[5] followed Persoon. ALBERTINI and SCHWEINITZ[6] in 1805 record it as growing on decaying Alnus. NEES VON ESENBECK[7] in 1816 placed it in his subdivision of clavate Sphaeriae (*Keulensphärien–Sphaeriae Clavaeformes*) which he says are like a simple Clavaria, or Geoglossum in which the ascus layer has changed into perithecia. The first species which he places in this group is the leather-yellow Sphaeria, *S. alutacea* Pers. He states that it grows on the ground in fir woods. FRIES[8] in his treatment of the genus Sphaeria places it in the tribe Cordyceps, series Hypocrea, as *Sphaeria alutacea.*

Those also who have placed it in the genus Cordyceps regarded it as an autonomous plant. LINK[9] first placed it in Cordyceps as *C. alutacea* and was followed by FRIES.[10] It was distributed under two different numbers in *Rab. Fung. Europ. Ex.* 132 (1860) from pine woods, England, as *C. alutacea* (Pers.) collected by C. E. BROOME, and no. 246 (1860) from mossy woods, near Leipzig, as *C. alutacea β albicans* (Pers.), a lighter form, from alutaceus to white, according to the note in connection with the specimen. BERKELEY[11] under *Cordyceps alutacea* Fr. says "clavate, tan colored or nearly white, head confluent with the stem. In fir woods amongst leaves and furze," and his figures show a variation in size between stout and slender forms. QUÉLET[12] in connection with *Cordyceps alutacea* (evidently using the name employed by FRIES in *Summa Veg. etc.*)

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[3] Obs. Mycol. **2**:66. *pl. 1, fig. 2, a, b, c.* 1797. Comm. de fung. clavif. 12. 1797.

[4] English Fungi **2**: *pl. 159.* 1799.

[5] Enum. Pl. Sellandiae **2**:175. no. 1343. 1803.

[6] Consp. Fung. Lusat. Sup. 1. 1805.

[7] System der Pilze 289. *pl. 40, fig. 304.* 1816.

[8] Syst. Myc. **2**:325. 1823.

[9] Handb. z. Erkenn. der Gewächse 3:347, no. 5. 1833.

[10] Summa Veg. Scand. 381. 1849.

[11] Outlines Brit. Fungol. 382. *pl. 26, fig. 6.* 1860.

[12] Champignon du Jura et des Vosges 487. 1869.

says that the spores are cylindrical and two-celled, the upper globose, the lower oblong, and in a footnote says that from the texture and fructification the species would belong rather to Hypocrea. It grew among needles of *Pinus sylvestris.* WINTER[13] records *C. alutacea* QUÉLET from the Jura mountains and says the spores are needle-like, with many segments, and 40–50 μ long! Evidently this is not QUÉLET'S species. CURREY[14] says it is a Cordyceps with the fructification of Hypocrea.

The TULASNES[15] in their classical studies forty years ago pointed out the resemblance in the habit of this plant to that of certain species of Hypomyces, as *H. lateritius* Fr., and *H. lactifluorum* Schw., which are parasitic on species of Lactarius, the *H. lactifluorum* deforming white species of Lactarius and giving them a bright red color. With this interpretation of the dual nature of the fungus they were led to believe that *Hypocrea alutacea* was in a similar way parasitic on a certain species of the simple clavarias, viz., *Clavaria ligula* Schaeff. Their interpretation of the dual nature of the fungus has since been generally conceded to be correct. SACCARDO,[16] WINTER,[17] and other systematists have followed them in considering it as parasitic on either *Clavaria ligula* or Spathularia, on which latter host BROOME reported it according to SACCARDO.[18] It has been reported by DAY[19] in North America also on an undetermined species of Spathularia, where he says, "Apparently parasitic on Spathularia" and reference is made to PECK, Rept. N. Y. State Mus. **26**:84. 1874, where the plant is merely listed as growing on fallen leaves. WINTER (*l. c.*)

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[13] Rabenhorst's Krypt. Fl. etc. Pilze **1**^{2}:149. 1885.

[14] Synopsis of the fructification of the compound Sphaeriae in the Hookerian Herbarium. Trans. Linn. Soc. London **22**:264. 1858.

[15] Selecta Fung. Carp. **3**:35. 1865.

[16] Sylloge Fungorum **2**:530. 1883.

[17] Rabenhorst's Krypt. Flora, etc., Pilze, **1**^{2}:142. 1887.

[18] According to SACCARDO *l. c.* See also ELLIS, N. A. P. 89. 1892, where its occurrence on *Spathularia flavida* is ascribed to BROOME.

[19] DAY, DAVID F., A catalogue of the native and naturalized plants of the city of Buffalo and its vicinity. Bull. Buff. Soc. Nat. Sci. **4**:161. 1882. The reference in FARLOW'S Host Index (see FARLOW & SEYMOUR, A provisional host index of the fungi of the United States 175. 1891) to *H. alutacea* as parasitic on Spathularia, Dr. FARLOW writes me, was made from DAY'S catalogue, and he adds that he has never found it on Spathularia.

points out that the stroma of the parasite is completely merged with that of the host, and that only the upper clavate part of the host bears perithecia, while the stem is free or bears the conidial form.

Some very discriminating observers, however, have dissented from TULASNE'S interpretation of the dual nature of the fungus, though no proof has been brought forward to demonstrate either its parasitic nature or its autonomy. CORNU[20] as early as 1878 collected several specimens on decaying leaves of *Abies picea* in a forest in the environs de Pontarlier. He searched diligently for specimens of *Clavaria pistillaris* of which he says *Clavaria ligula* is like a reduced form. He found none in the neighborhood of the *Hypocrea alutacea*, nor could he find any evidence that it grew either as a parasite or saprophyte on insects or on any subterranean fungus. Although he cannot say with certainty, he does not think the plant can be regarded as a parasite or that it develops at the expense of *Clavaria ligula*. He regards it rather as analogous in habit and nutrition to species of Xylaria which grow, some on wood, others on leaves and humus, and he cites an exotic species *X. compuncta* Jungh., as resembling in some respects the *Hypocrea alutacea*, the plant being alutaceous to pallid, but dark punctate from the perithecia.

In 1894 SCHROETER,[21] a keen and discriminating student of the fungi, also took issue with the prevalent theory that *Hypocrea alutacea* was a parasite on *Clavaria ligula*. He says that this is not the case with the forms which grow in Schlesien. He says the fungus grows on wood as ALBERTINI and SCHWEINITZ have pointed out, and as he himself has observed at Breslau, while *Clavaria ligula* grows on needles of conifers. LINDAU[22] also in his treatment of the Hypocreales follows SCHROETER'S judgment rather than that of TULASNE and WINTER. FARLOW[23] records collecting *Hypocrea alutacea* at Shelburne, N. H., under *Pinus strobus* where was also growing *Clavaria ligula*, but he was unable to trace any direct connection between the two.

There is thus a reasonable doubt probably as to which horn of

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[20] Note sur l'*Hypocrea alutacea* Pers. Bull. Soc. Bot. de France **26**:33–35. 1879.

[21] Krypt. Fl. Schles., Pilze, Zweite Hälfte **3**:272. 1894.

[22] Engler und Prantl Pfl. Fam. **1**^{1}:365. 1897.

[23] Lloyd's Myc. Notes 9 (195):110. 1902.

this dilemma we shall choose. At least none of these students has left us any evidence which can be considered proof of one or the other of the theories as to the nature of *Hypocrea alutacea.*

My first acquaintance with the plant was in August 1901, when Mr. A. M. FERGUSON, one of the students in my laboratory, collected several specimens growing on very rotten wood in one of the forested gorges at Ithaca, N. Y. In looking up the literature at the time I was impressed with the diversity of opinion on the subject, as well as the lack of any attempt at experimental proof one way or the other in support of the theories advanced. It occurred to me that perhaps here was an opportunity to settle by simple experiment this dispute of a century. At least the trial could be made. Accordingly the plants were placed over night in a new and clean pasteboard box, covered. On the following day I found that the bottom of the box was nearly covered with numerous ascospores which had been shot out of the perithecia during the night. There was also a thick and loose covering of the spores over the fruiting portion of the fungus as the plants lay in the box.

For culture media I employed sterilized slices of a species of Lactarius which had been prepared a few days before for culturing *Nyctalis asterophora.* These slices were in test tubes and about half covered with water. With a sterilized platinum needle, transfers of ascospores were made from the fresh pile on the plants to the agaric substratum in the tubes. Twelve tube cultures were started. With this number it was quite probable that from the fresh pile of spores several plantings could be made which would be pure. If the spores should grow, and the mycelium mature perithecia, there would likely be some indication as to whether *Hypocrea alutacea* is single or dual in its nature. If single, then we would expect the development of a clavate stroma in the pure culture. If dual, the stroma would be spread over the surface of the dead slice of the agaric. At the same time dilution cultures were made in agaric agar-agar in Petri dishes. None of the spores germinated in them, however.

In a week's time I left Ithaca for the mountains of western North Carolina. At the time of leaving there was very little evidence of any growth in the tube cultures, although *Nyctalis asterophora* spores, sowed at the same time, produced a mature crop of plants in a week.

It is interesting now to note the form of the individual plants from which cultures were attempted. One of them resembled in shape *Spathularia flavida*, as if it might have been somewhat arrested in development (*pl. XIV, fig. 1, b*), while others resembled *Clavaria ligula*, and one was more or less deformed, curved strongly, and with a broad groove on the concave side. These forms would seem to satisfy the wish of the most ardent advocate of the parasite theory who does not attempt to put the theory to the crucial test. In structure, however, there was no indication of a difference of the structural elements such as one might expect to find were the plant parasitic on *Clavaria ligula* or Spathularia, and an advocate of this theory would be compelled to join WINTER in saying that the parasite and host were completely merged. It should also be said that no normal specimens of *Clavaria ligula* or of Spathularia were at the time growing in the immediate vicinity of the Hypocrea.

Of course, during the next five weeks, while collecting fungi in the mountains of North Carolina, I was on the lookout for *Hypocrea alutacea* and its relation to either of these supposed hosts. I found one day a large colony of *Spathularia clavata* growing under a white pine tree. The Spathularia extended over an area of 75 to 100 square feet. Among the Spathularia plants I found four or five specimens of *Hypocrea alutacea.* These were growing not on wood, but apparently from decaying organic matter among the pine needles, and, as far as one could judge, their habitat was the same as that of the Spathularia. Singularly, the form of these specimens was quite regular. The form was not, however, similar to that of the Spathularia, but more like that of *Clavaria ligula.* But no specimens of the latter plant were found growing in the immediate vicinity. No other specimens were found during that season.

On returning to Ithaca in the latter part of September, I hastened to examine my tube cultures of the Hypocrea. There were two perfect specimens, one in each of two tubes. Both of them possessed the Clavaria-like form and stood up clearly from the substratum. Here, then, were two specimens of *Hypocrea alutacea* in pure culture from the ascospores, and the form in general like that of the plants found in their natural environment. Moreover, they were certainly growing as saprophytes and not as parasites. This, I believe, demonstrates that *Hypocrea alutacea* is an autonomous plant,[24] and it is the first proof we have that it is not of a dual nature, parasitic on *Clavaria ligula* or Spathularia.

It might still be contended that the plants which I found growing among the pine needles along with the Spathularia in North Carolina, were of a different species from those growing on rotting wood at Ithaca, N. Y. Especially might this view be taken since FRIES[25] describes *Hypocrea alutacea* as growing among needles of the fir, and describes a form *turgida*, growing on rotting wood. SCHROETER (*l. c.*) when he states that according to his observations *Hypocrea alutacea* grows only on wood, cites FRIES's disposition of the two forms and says that possibly the form on wood is a different species which should be called *Hypocrea turgida*. It seems to me, however, more rational to attribute the slight variation in form to a recognizable range of variation in the species, either inherent in the species, or attributable to the change of substratum. According to FRIES the more robust form grows on wood. The form on wood at Ithaca was more robust than the form among the pine needles in North Carolina. But I have collected a form on wood in North Carolina of the same size as, or even smaller than, those among the pine needles. However, the forms which I grew in pure culture on sterilized Lactarius were more slender and were more like those found among the pine needles, although their direct parentage was from the robust form from wood.

The wood forms are found on half-decayed wood, and also on very rotten wood. From this condition of the substratum it is an easy transition to wood mold or leaf mold, in the adaptation of the plant to a limited range in the variation of the condition of the same general substratum. Since the plant can grow as a saprophyte on dead mushrooms, as shown by the pure cultures, it might be possible that sometimes in the forest it grows as a saprophyte on decaying Spathularia or *Clavaria ligula* buried among the leaves. It is very probable, however, that there is a range in the habitat of the species from wood

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[24] These facts, as well as photographs of *Hypocrea alutacea* from the wood substratum and in pure cultures were presented before the Botanical Society of America at the Washington meeting, December 30, 1902 to January 1, 1903.

[25] Syst. Myc. **2**:325. 1823.

or leaf mold to very rotten wood and to wood in a one-fourth to a one-half decayed condition. This range would be represented by a habitat life curve, which rises from the leaf or wood mold in the ground to the upper limit on the decaying wood, influenced, to some extent at least, by other conditions of environment. Or if the wood habitat is the normal one, then the curve would descend according to conditions to the wood mold and leaf mold in the ground. This range in habitat is manifested by a large number of the higher fungi. The curve rises or descends from the normal habitat according to the peculiarities of each species and according to the modifying influences of other environmental conditions.

The history of *Hypocrea alutacea* has become more interesting by the publication of *Hypocrea Lloydii* Bresadola in 1902, which was collected by C. G. LLOYD in West Virginia, in the summer of 1901. Following the brief description, BRESADOLA notes[26] that the species is very interesting, with the aspect of Cordyceps but fructification of Hypocrea. The photograph published at the time, with the description, suggested to me that the plant might be identical with *Hypocrea alutacea*, and I inquired of Mr. LLOYD if he did not think this to be the case. My letter was communicated to Dr. BRESADOLA, and his reply was published in a note by Mr. LLOYD[27] in September 1902. These notes from BRESADOLA are very interesting. In the first place he was not familiar with *Hypocrea alutacea*, since he had never seen the plant; but accepting, as was natural under the circumstances, TULASNE'S interpretation of its parasitic nature, the plant communicated to him by Mr. LLOYD was believed to be a new species in the section Podocrea of SACCARDO,[28] a section formed to include species of Hypocrea with a vertical stroma. BRESADOLA also compared the structure of the stroma of *H. Lloydii* with the structure of both *Clavaria ligula* and *Spathularia flavida*, and finds it very different from either. He concludes by saying that if *Hypocrea Lloydii* is really identical with *Hypocrea alutacea*, a species unknown to him, then he does not believe in the parasitic nature of the latter. At this time LLOYD (*l. c.*) accepted BRESADOLA'S note as

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[26] BRESADOLA, G., *Hypocrea* (Podocrea) *Lloydii* n. sp., Lloyd's Myc. Notes 9 (176):87. 1902.

[27] *Idem* 10 (183):99. 1902.

[28] Syll. Fung. 2:530. 1883.

indicating that *H. Lloydii* and *H. alutacea* were identical. Later, however, he states[29] that PATOUILLARD believes *H. Lloydii* "is a good species and very different from *H. alutacea.*" LLOYD saw specimens of *H. alutacea* at the Herbarium of the Museum of Paris and said that he does not think it possible the two plants are the same.

Through the courtesy of Dr. BRESADOLA I have had the opportunity of seeing the type specimen of *Hypocrea Lloydii*, and I consider it identical with *Hypocrea alutacea*. In *plate XVI* are photomicrographs of a section from the dried specimen through a portion of the clavula showing the perithecia, and in *plate XV* are similar photomicrographs of the plant collected at Ithaca, the material having been fixed while it was fresh. The only differences which can be observed are those which are due to the difference in the age of the plants at the time they were collected. The specimen of *H. Lloydii* was quite mature, as shown by the more advanced stage of disappearance of asci or freedom of spores from the asci. The perithecia are therefore somewhat older and larger, and are thus crowded against each other, and flattened on the sides where they are closely packed.

The form of the plants themselves at first sight appears different, *H. Lloydii*, *plate XIV, fig. 3*, being long and slender, while those of *H. alutacea*, *plate XIV, fig. 1*, are stouter. But the individuals of *H. alutacea* which were all growing close together differ more among themselves than the *H. Lloydii* does from the individual of *H. alutacea* at the left. It is unfortunate that this specimen is curved, and therefore that not all of the stem is shown in the photograph. However, the long stem of the single individual of *H. Lloydii* (the species is based on the single specimen collected), as one can see from an examination of the photograph, is due to the fact that the lower half of it was in the leaf mold, the stroma having its origin about 4^{cm} below the surface of the leaf mold. It is a matter of common observation in the case of many stipitate fungi to find the stem considerably elongated under such conditions. I have seen notable examples in the case of *Collybia radicata*, *Clavaria ardenia*, and others, the length of the stem depending on the depth of the substratum below the surface. The plant is quite variable also in regard to its stoutness. This is perhaps also due to some extent to con-

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[29] Mycological Notes 15 (264): 156. 1903.

ditions of environment, though at present it is difficult to say just what conditions produce a robust form and what ones produce a more slender form. SCHROETER (*l. c.*) found the robust form on decaying wood, and suggested that perhaps it might be a different species which should bear the name given by FRIES (*l. c.*) to the robust form, *β turgida*. Along with this variation in the robustness of the plant, there is a variation in the direction of a deformity where the clavula may be flattened, triangular, curved, etc., which has led some observers to question the identity of some of the forms described and figured by different writers. That the form on wood is not always robust is well shown in a small and slender specimen which I collected several years ago on a log in the mountains of North Carolina. The log was not much decayed, and possibly the conditions of nutrition were not so favorable as in the case of much decayed wood, which was the condition of the substratum on which the robust Ithaca specimens grew (*plate XIV, fig. 1*). The variation in these individuals growing close together is sufficient to show what the range in form may be in specimens from different localities.

There is also a variation in color. The plant is usually said to be "tan" color, or "leather" color (to which the specific name *alutacea*, refers), or "pallid," and sometimes "white." White forms gave rise to the variety *β Sphaeria albicans* Pers.[30] BERKELEY[31] describes the plants as tan-colored or nearly white. The color very likely depends very largely on the age of the plants when collected. The Ithaca plants here described were entirely white when collected. But the fact that the asci are so well preserved and most of the spores are still in the asci shows that the plants were just ripening. The plants in pure culture which had their parentage directly from the white ones, had white stems, but the clavulae were tan-colored at the time they were photographed, probably because they were quite well ripened. From the general character of the plant we should expect that the young clavula would be white in all cases, and that the color is an attribute of ripening or age, and it is then reasonable to expect, even in specimens with well-formed spores, that as the plants are collected there would be a sufficient variation in age to account for the color variation observed.

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[30] Syn. Method. Fung. 2. 1801.

[31] Outlines British Fungology 382. 1860.

That the American plants are identical with European ones is evident from an examination of the specimens in Raben. Fung. Europ. Ex. nos. 132 and 246 mentioned above, and I had the opportunity also, while in Paris in October 1903, of personally examining, through the courtesy of M. HARIOT, the specimens of *Hypocrea alutacea* in the herbarium of the Museum of Paris, among which were some specimens from TULASNE'S herbarium.

The spores in this species, while presenting slight variations, are quite peculiar. As is well known, the spores in the genus Hypocrea are eight in an ascus uniseriate, and each one is two-celled, but at maturity the constriction at the septum is very strong, and the segments of the spore are separated so that the ascus appears to have sixteen nearly globose or oval spores in a single row. The separation of the two segments of the spore is one of the characters distinguishing Hypocrea from Hypomyces, while short, two-celled spores distinguish *Hypocrea alutacea* from species of Cordyceps, which have long filiform spores separating at maturity into numerous segments. CORNU (*l. c.*) also points out that species of Cordyceps grow on living or recently dead insects or plants, while *Hypocrea alutacea* grows on decaying wood and leaves, though this distinction may not hold good, since as a saprophyte *Hypocrea alutacea* might grow on dead insects under certain conditions, and it has even been reported on insects. The two segments of the spores of *Hypocrea alutacea* are somewhat different in form. They are usually described as 'superior cell globose, inferior cell oval, or suboval, or oblong.' BRESADOLA[32] does not call attention to the difference in shape of the two segments in *Hypocrea Lloydii*, but says "articuli subcuboideis subglobosi." But the two segments are different in form, as I have found by examination, and the spores in the photomicrograph, *plate XVI, fig. 9*, from *H. Lloydii* show very clearly this difference in form, a globose and oblong segment alternating throughout the chain formed by the juxtaposition of the spores in the length of the ascus. The upper segment (the one nearest the free end of the ascus) is globose or subglobose or subcuboid, while the lower segment is elongated slightly in the direction of the axis of the spore and is usually not quite so broad as the upper segment. The lower segment is very

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[32] Lloyd's Myc. Notes 9 (176):87. 1902.

short oblong, or suboval. The shape of the segments is exactly the same in the Ithaca specimens of *Hypocrea alutacea* as can be seen in *plate XV, fig. 6,* a photomicrograph. The spores measure from 4.5–5.5 μ long × 2.5–3 μ wide. The upper segment is 2.5–3 μ in diameter, and the lower one is 2.5–3.5 μ long × 2–2.5 μ in diameter. After fixing and imbedding in balsam the measurements are somewhat smaller than here given.

The spores lie very close together, end to end in the ascus, so that the sixteen segments often appear connected into a necklace-like string. They appear sometimes to adhere to some extent even after escaping from the ascus, but the individual spores can be determined usually by the difference in shape of the two segments.

There is one other question in connection with this plant which it is now necessary to consider. In what genus shall the species be placed? Typical species of Hypocrea have a crustaceous, or cushion-shaped or hemispherical stroma, while the stroma of *Hypocrea alutacea* is vertical and elongated. Such a marked difference in the form of the plant is usually regarded as representing a different generic type, just as the erect stromata of the species of Xylaria represent a different generic type from the crustaceous, cushion-like or hemispherical stromata of Hypoxylon. SACCARDO[33] used the name Podocrea as a subgenus for the species of Hypocrea with a vertical stroma, and included three species: *Cordyceps larvata* Mont.,[34] *C. brevipes* Mont.,[35] and *Hypocrea Petersii* B. & C.[36] *Hypocrea alutacea* he did not place in this section, since he followed the TULASNES in believing it parasitic on *Clavaria ligula.* LINDAU[37] in 1897 raises Podocrea to generic rank, and places *Hypocrea alutacea* as the first species, although KARSTEN[38] had founded the genus Podostroma five years earlier, for a species which he found on a larva of a decaying insect among mosses in Finland. *Podostroma* Karsten, therefore, should have precedence over *Podocrea* (Sacc.) Lindau, and it is unfortunate that LINDAU did not use the name *Podostroma alutacea.*

KARSTEN (*l. c.*) described one species, *P. leucopus.* The char-

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[33] Syll. Fung. **2**:530. 1883.

[34] Syll. Crypt. no. 674, p. 200. 1856.

[35] *Idem* 676, p. 201. 1856.

[36] Grev. **4**:13. 1875.

[37] Engler und Prantl Pflanzenf. **1**^{1}:364. 1897.

[38] Hedwigia **31**:294. 1892.

acters of this genus and species are so remarkably like those of *Hypocrea alutacea* that it may be well here to give a translation both of the generic and specific diagnosis.

PODOSTROMA n. gen.—Character of the Hypocreaceae. Stroma stipitate, clavate, erect, entomogenous, fleshy, bright colored. Perithecia immersed in the stroma. Asci cylindrical, 16-spored. Spores sphaeroidal, hyaline. Paraphyses none.

Pod. leucopus n. sp.—Stromata solitary. Clavula bearing the perithecia obovoid to oblong, alutaceous-pallid, about 6^{mm} long and 4^{mm} stout. Stipe equal, terete, flexuous, about 5^{cm} long and 2^{mm} stout, white. Perithecia in the periphery, spheroidal, immersed, opening by a pore. Asci cylindrical, subsessile, about $75 \times 4\,\mu$. Spores 16, monostichous, spheroidal, hyaline, 2–$3\,\mu$ in diameter. On larva of certain putrid insects among mosses in coniferous woods, Syrjãås, October.

The specimens of no. 246 Rabenh. Fungi Europ. Ex. in the herbarium of the Botanical Department here represent very well in form and size the *Podostroma leucopus* described by KARSTEN. The plants are slender when dry, 3^{cm} high, the stem less than 1^{mm} in diameter and was likely not more than 2^{mm} when fresh. The clavula is obovoid, about 3.5^{mm} long a trifle over 2^{mm} in diameter, and was very likely stouter when fresh. The plants of no. 132 Rabenh. Fungi Europ. are much stouter, the stem more than 2^{mm} in diameter when dry, short, and the clavula elongate and tapering gradually into the stem. The spores in no. 246 are mostly cuboidal in the specimen examined, and the asci show that they are young. Many of the asci give the appearance of having sixteen equal subcuboidal spores. But occasionally, where they are a little older, every alternate one is slightly elongated and narrowed, so that it is suboval or short suboblong. Still younger asci show the plasma content divided into eight parts, and then occasionally one of these young spores is divided into two cells. This indicates clearly that here are eight spores. The second division is so prominent and the constriction so deep it gives soon the appearance of sixteen spores. It would appear that in the later growth of the spores the inferior segment elongates slightly at the expense of its diameter. The specimens collected at Ithaca show the same character from the individuals when asci are just maturing the spores. The plasma is first divided into eight portions, showing that there are eight spores.

In older ones each of these is divided into two equal parts, and the inferior one is usually elongated slightly. But many asci which were dried at this stage show sixteen segments in a crowded chain, all of about the same form, and subglobose to subcuboidal. In a very few cases the spore is pyriform, divided into two cells by a cross wall cutting off the lower smaller cell without any perceptible constriction at the septum. It will be seen that the age of the asci and spores at the time of collection of the plant will vary, and consequently there will be a variation in the form of the spore segments. All may be subcuboidal and of the same size and form, or when older the inferior segment may be slightly elongated and narrowed, and the superior one will be globose to subcuboidal. They are so crowded also in the ascus that there is a tendency for them to cling into a chain or necklace, and this may be aided not only by a small amount of periplasm, but also by remains of the disintegrating ascus which are difficult to perceive.

If KARSTEN'S plant had not been reported as growing on an insect, one would have no hesitancy in placing it in *Hypocrea alutacea*, for all the characters of form, color, and structure agree. The only difference is that of the substratum. The fact that it is reported as growing on a decaying insect, taken in connection with its agreement in form, structure, and color with *Hypocrea alutacea*, is rather strong evidence that this is only a further extension of the range of decaying organic matter on which the fungus grows. It should also be noted that *Podostroma leucopus* was found in coniferous woods, and *Hypocrea alutacea* is usually found under pines or spruces, though it occurs on decaying wood of the broad-leaved trees, as is seen from its occurrence on Alnus cited above, and ELLIS[39] reports it at Newfield, N. J., on "bark of a decaying (maple?) limb, lying on the ground."[40]

There remains to be considered the standing of the subgenus *Fracidia* proposed by FRIES[41] in 1849 for certain exotic species of

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[39] Jour. Myc. **2**:50. 1886.

[40] The Tulasnes find a conidial form (Select. Fung. Carp. **3**:38. *pl. 4, fig. 4.* 1865) *Verticillium globuligerum* Sacc. (see Syll. Fung. **2**:530. 1888) growing on the lower part of the stem, which they regard as the conidial stage of *Hypocrea alutacea*. I have not seen it.

[41] Summa Veg. Scand. 381, 382. 1849.

Xylaria. In a footnote on page 381 of his *Summa Veg. Scand.* he definitely cites *Xylaria flabelliformis* (Schw.) B., *X. pumila* Linn., *X. comosa* and *X. collabens* Mont., as pertaining to the subgenus Fracidia. In 1864 he transfers *Sphaeria alutacea* Pers., which he had formerly placed in Cordyceps (*l. c.*), to the subgenus Fracidia, where he writes it as follows: "*Sphaeria s. Fracidia alutacea*,[42] but differing in color from the species of Xylaria first placed in this subgenus, as *Cordyceps militaris* differs from *C. ophioglossoides*." This short paper by Fries is a critical review of Currey's *Synopsis of the fructification of the compound Sphaeriae of the Hookerian Herbarium.*[43] Currey (*l. c.*, 260) employs the genus Sphaeria, which is divided into sections and divisions. Fries in his annotations on certain species (*l. c.*) merely follows Currey in writing Sphaeria as the genus, the *s.* probably standing for subgenus. It is therefore difficult to see how "*Sph. s. Fracidia alutacea*" can be taken as raising Fracidia from subgeneric to generic rank, and if the name is to be employed for a genus it should be used for those species of Xylaria first ascribed to it by Fries and cited above. The Tulasnes[44] list *Fracidia alutacea* in their synonymy of *Hypocrea alutacea*, but this could not be taken as raising Fracidia to generic rank. *Podostroma* Karsten[45] (1892) is therefore the generic name to be employed for our plant, instead of *Podocrea* Lindau[46] (1897), although it was employed as a subgenus by Saccardo (*l. c.*) in 1883; but Saccardo did not include the *Hypocrea alutacea* in his subgenus. The International Botanical Congress at Vienna, June 1905, recommends that when the species of a subgenus are raised to generic rank, the name of the subgenus in which they were placed be employed, but this is a recommendation

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[42] Adnotata ad Cel. Fr. Currey dissertationem; Synopsis of the fructification of the Sphaeriae of the Hookerian Herbarium in Act. Soc. Linn. Lond., Vol. XXII, pp. 257–86 et 313–35. Bot. Zeit. **22**: 189, 190. 1864.

[43] Trans. Linn. Soc. London **22**: 257–286. *pls. 45–49.* 1859; and "Synopsis of the fructification of the simple Sphaeriae," etc. *Idem* 313–335. *pls. 57–59.*

[44] Selecta Carp. Fung. 35. 1865. The reference is "in Schlechtendalii Ephem. Bot. Berol., t. XXII (1864), p. 189, n. 22," which is Tulasne's way of referring to Bot. Zeit. of which Schlechtendal was an editor. I wish to acknowledge here the aid of Dr. Farlow of Harvard University and Dr. Britton of the New York Botanical Garden in straightening out this reference.

[45] Hedwigia **31**: 294. 1892.

[46] Engler und Prantl Pflanzenf. **1**^{1}: 364. 1897.

and therefore not mandatory. Fracidia, as shown above, was never raised to generic rank, and if it were to be it should be used for the species of Xylaria which FRIES first referred to it. KARSTEN might have used SACCARDO'S subgenus Podocrea in 1892, but since he founded the new genus Podostroma five years before LINDAU raised Podocrea to generic rank, Podostroma should stand. Furthermore it is very doubtful if any of the three species first placed by SACCARDO in his subgenus Podocrea are generically the same as *Hypocrea alutacea*, although SACCARDO[47] suggests that *Podostroma* Karsten appears to be very like his section Podocrea.

In the light of this study, then, the name to be applied to *Hypocrea alutacea* (Pers.) Tul. with its principal synonymy would be as follows:

Podostroma alutaceum (Pers.) Atkinson.

Clavaria simplex p. p. Schmiedel. Icon. et Analyt. 18–26. *pl. 4, fig. 2, pl. 5, figs. 1–3.* 1762, according to Tulasne.

Sphaeria alutacea Pers. Observ. Myc. **2**:66. no. 99. *pl. 1, fig. 2, a, b, c* 1797. Comm. de fung. Clavif. 12. 1797.

Sphaeria clavata Sowerby. Eng. Fung. **2**: *pl. 159.* 1799.

Sphaeria alutacea Alb. & Schw. Consp. Fung. Lusat. Sup. 1. 1805.

Sphaeria alutacea β Sphaeria albicans Pers. Syn. Method. Fung. 2. 1801.

Sphaeria alutacea Fr. and *β turgida* Fr. Syst. Myc. **2**:325. 1823.

Cordyceps alutacea Link. Handb. z. Erkenn. der Gewächse 3:347. no. 5. 1833.

Cordyceps alutacea Fr. Summa Veg. Scand. 381. 1849.

Cordyceps alutacea Berk. Outlines Brit. Fung. 382. *pl. 23, fig.* 6. 1860.

Cordyceps alutacea Quélet. Champ. Jura et d. Vosges 487. 1869.

Hypocrea alutacea Tul. Selecta Fung. Carp. **1**:62. 1861, and **3**:35. *pl. 4, figs. 1–6.* 1865.

Hypocrea alutacea Peck. Rept. N. Y. State Mus. **26**:84. 1894.

Hypocrea alutacea Cornu. Bull. Soc. Bot. de France **26**:33–35. 1879.

Hypocrea alutacea Sacc. Syll. Fung. **2**:530. 1883.

Hypocrea alutacea Winter, Rabenhorst's Krypt. Flora Deutschland, etc., Pilze **1**^{2}:142. 1887.

? *Podostroma leucopus* Karsten. Hedwigia **31**:294. 1892.

Hypocrea alutacea Schroeter. Krypt. Flora Schles., Pilze, Zweite Hälfte **3**:272. 1894.

Podocrea alutacea Lindau. Engler und Prantl's Pflanzenf. **1**^{1}:364. 1897.

Hypocrea Lloydii Bresadola. Lloyd's Mycolog. Notes 9 (176):87. *fig. 55.* 1902.

CORNELL UNIVERSITY, ITHACA, N. Y.

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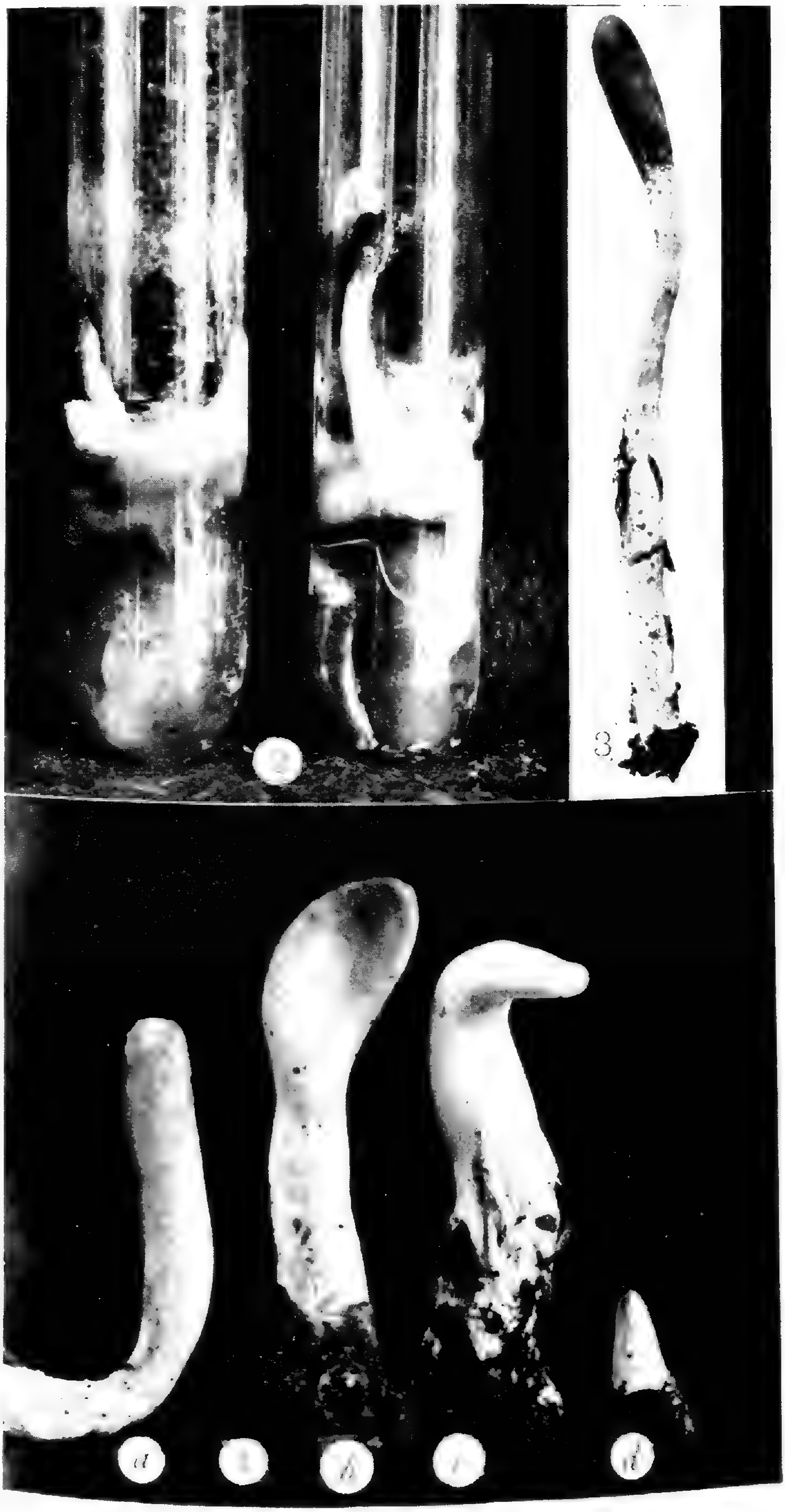
[47] Syll. Fung. **11**:355. 1895.



ATKINSON on HYPOCREA

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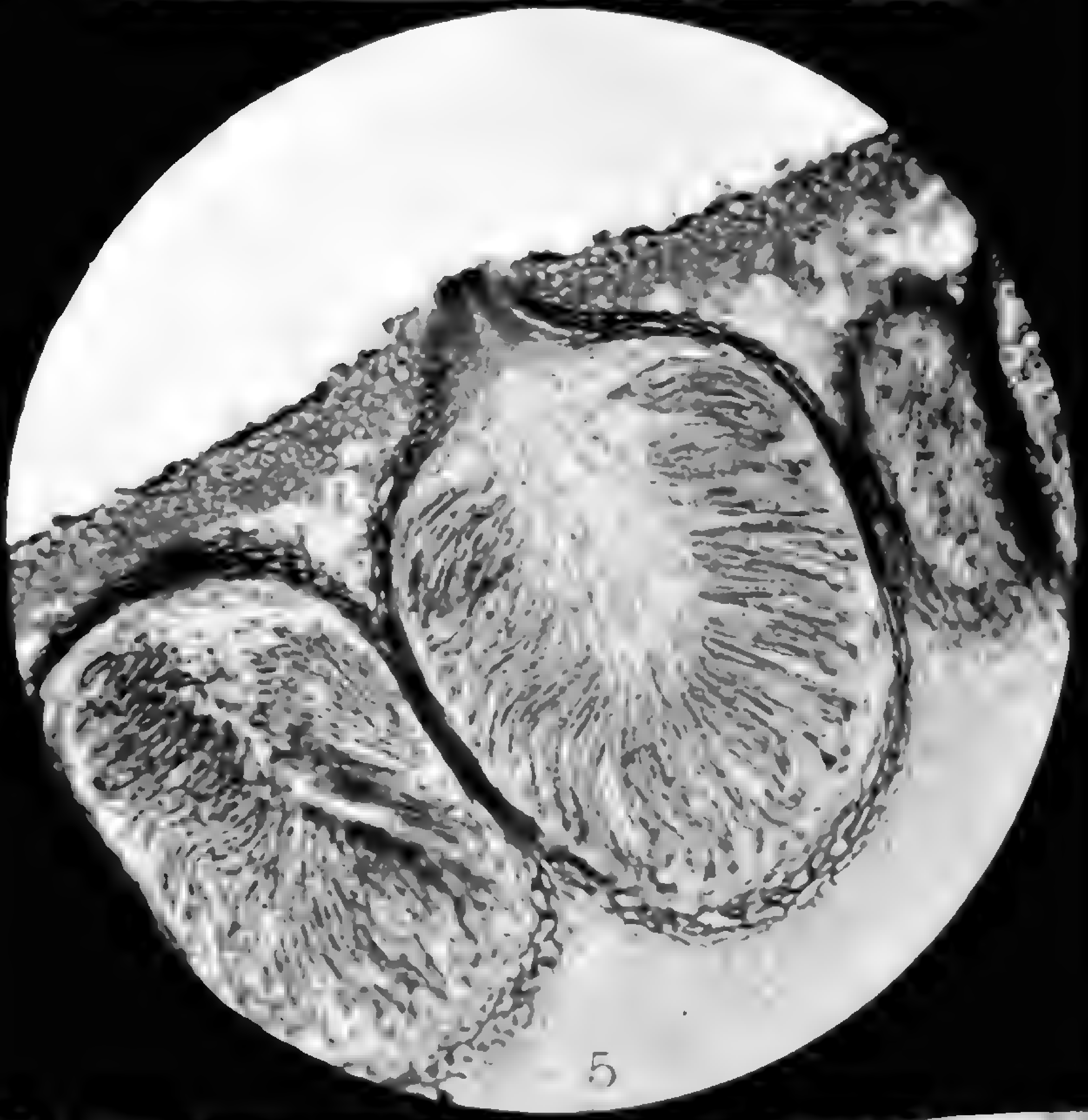

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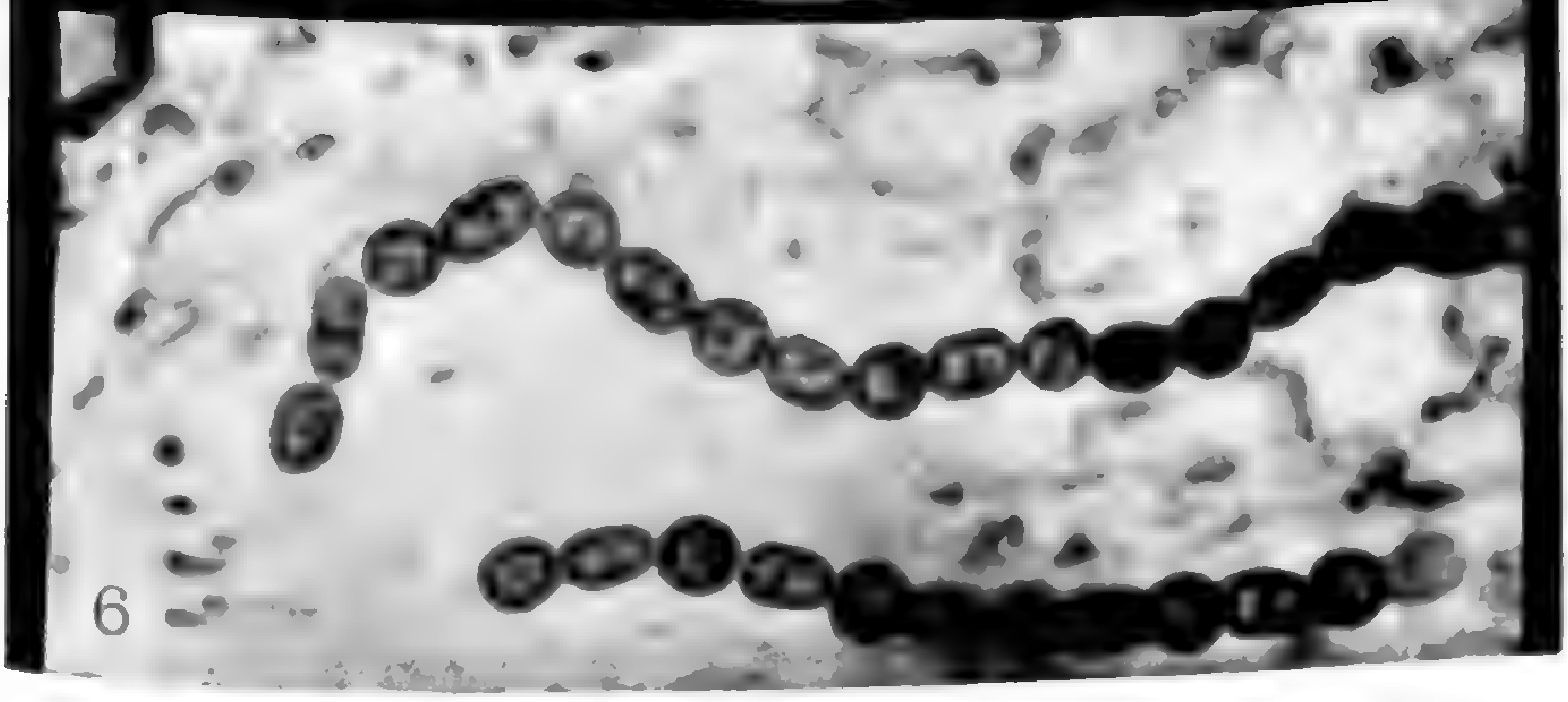

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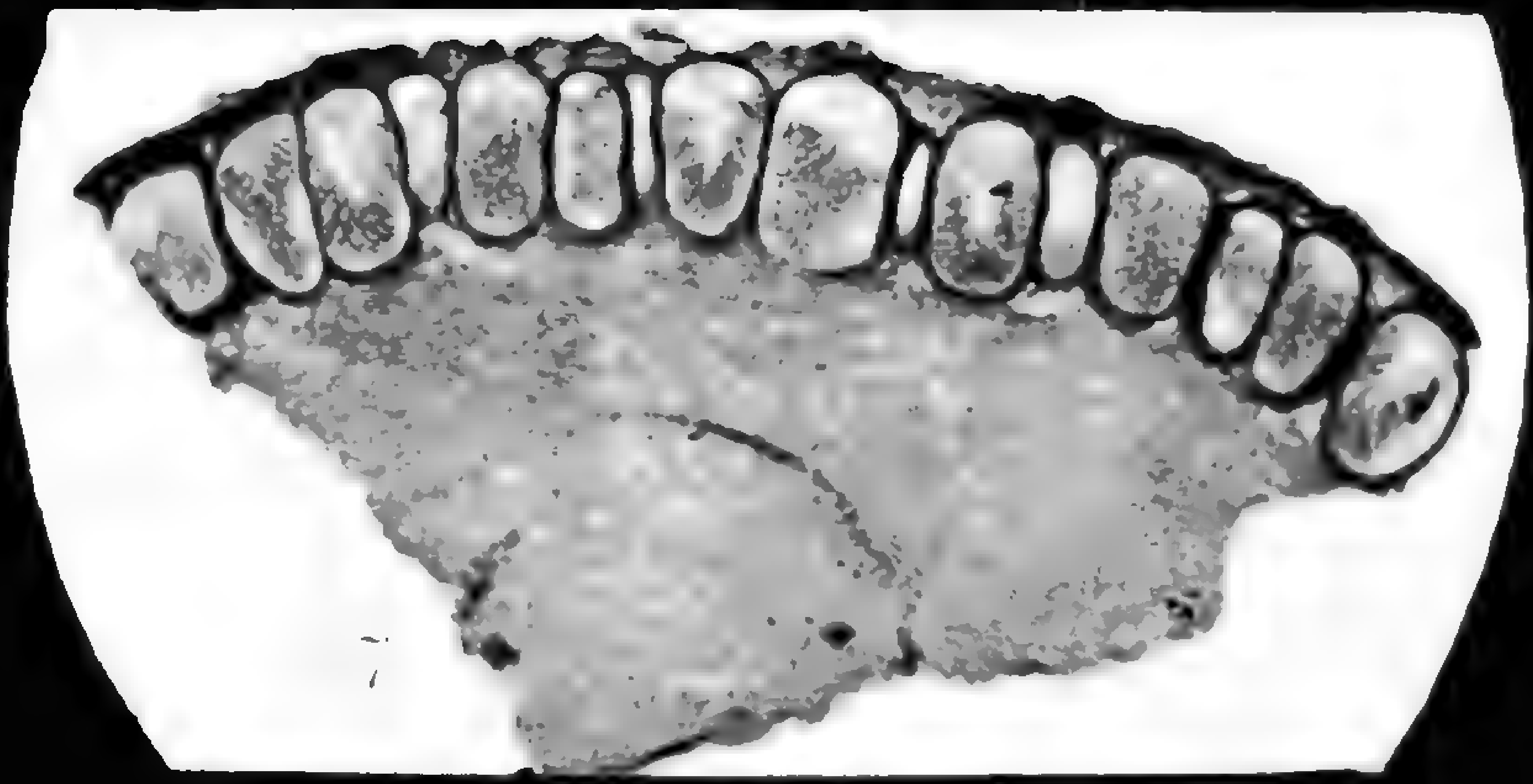
ATKINSON on HYPOCREA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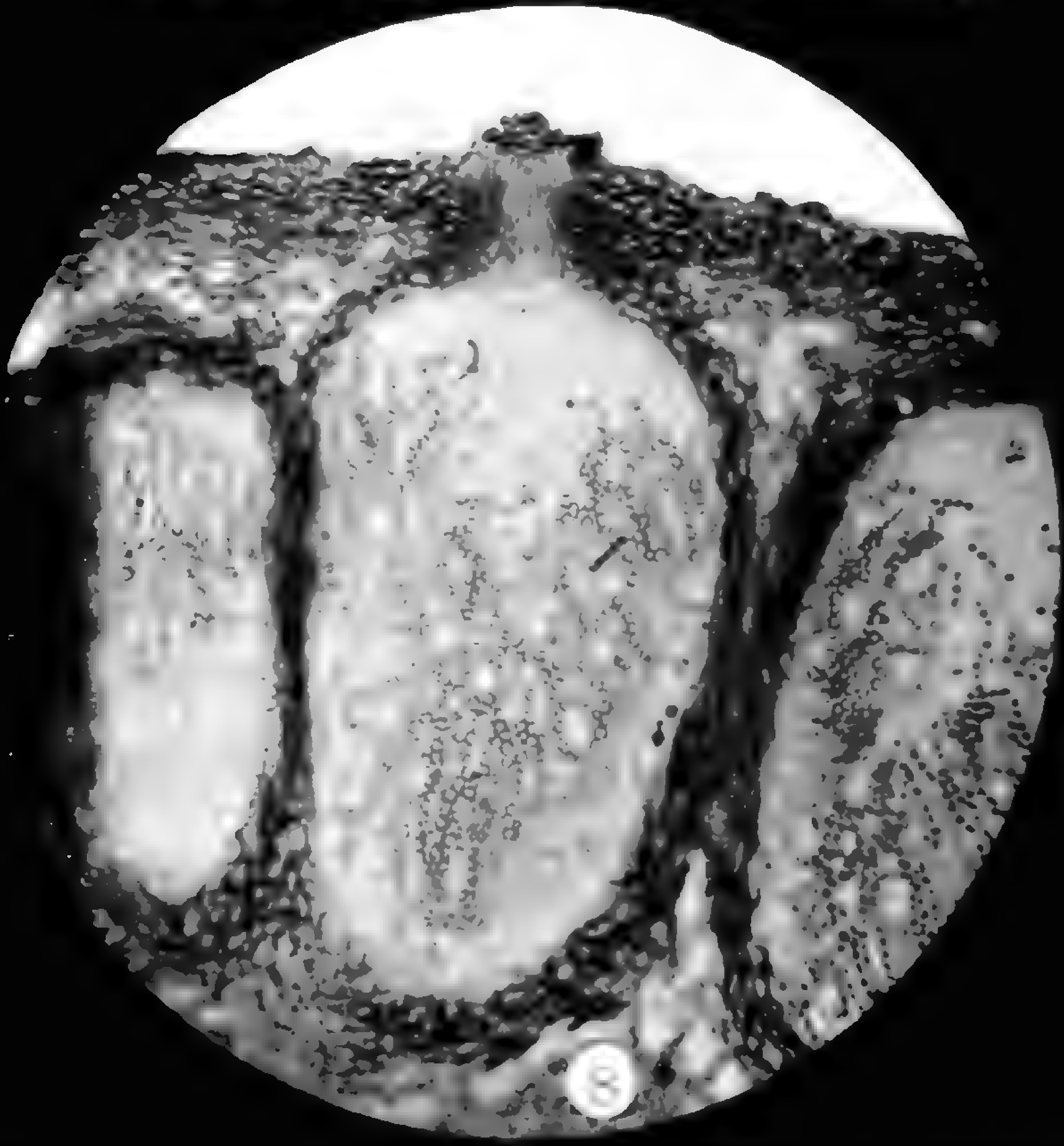
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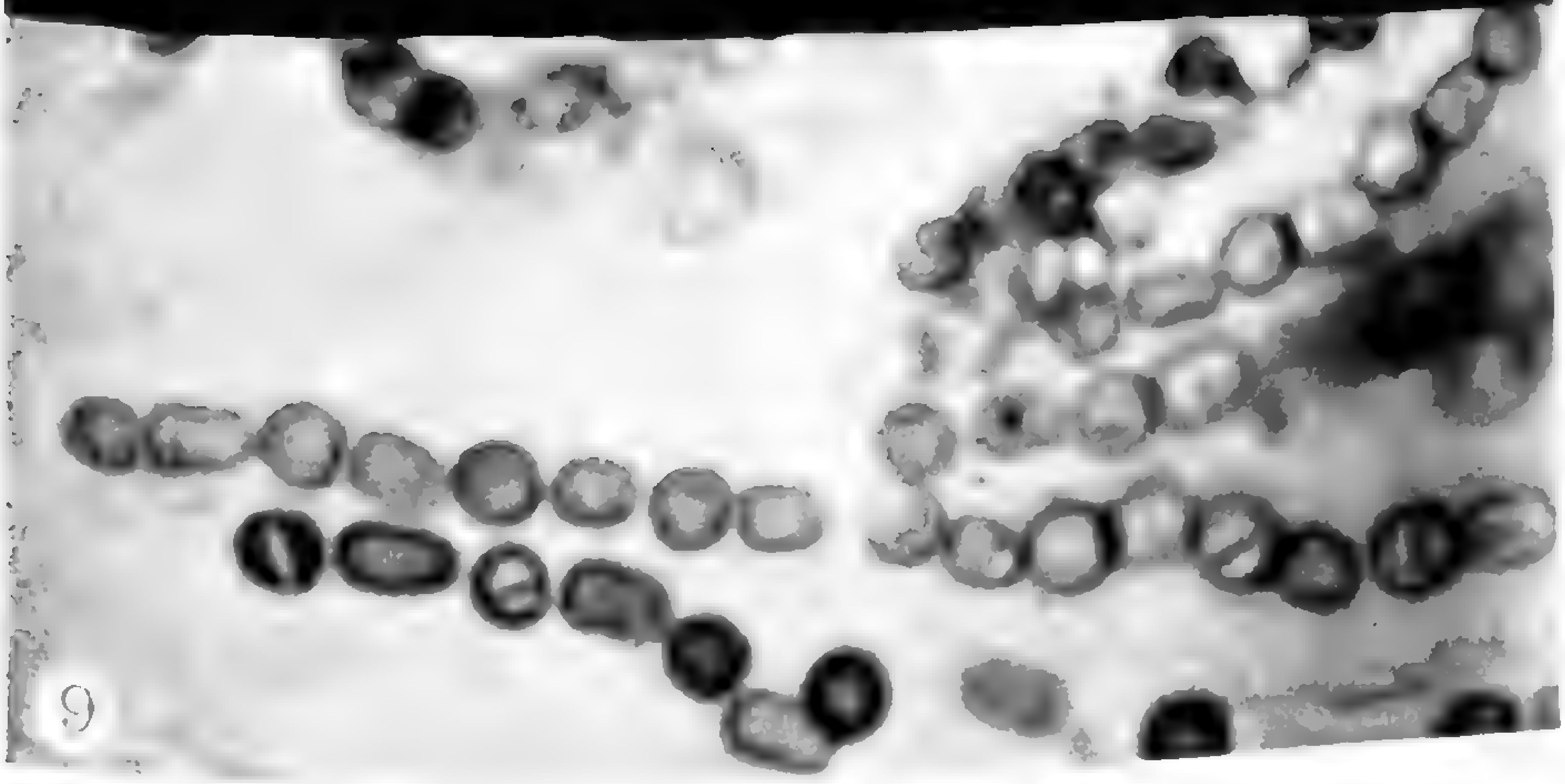
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ATKINSON on HYPOCREA

EXPLANATION OF PLATES XIV–XVI.

The photographs and photomicrographs were made by the author, except *fig. 3* of *plate XIV* which was made from a print kindly loaned by Mr. C. G. LLOYD.

PLATE XIV.

FIG. 1. Plants collected at Ithaca on very rotten wood. *a*, Clavaria form; *b*, Spathularia form; *c*, abnormal form; *d*, young individual; real size.

FIG. 2. Pure culture in test tubes, parentage from *a* and *b* of *fig. 1;* real size.

FIG. 3. *Hypocrea Lloydii* Bresadola, from leaf mold; note that one-half of the stem was developed underneath the leaves and leaf mold, which makes the stem long; real size.

PLATE XV.

Photomicrographs from plants collected at Ithaca. In *figs. 4, 5* the plate-holder was 36^{cm} from the object, and in *fig. 6*, the plate-holder was 48^{cm} from the object.

FIG. 4 with Zeiss ocular 4, obj. 16^{mm}.

FIG. 5 with ocular 4, obj. 3^{mm}.

FIG. 6 with ocular 18, obj. 3^{mm}. Note the chain of 16 segments of the eight spores from a single ascus, beginning at apex of series at left, the segments alternate, globose or cuboidal, and oblong.

PLATE XVI.

Photomicrographs from type specimen of *Hypocrea Lloydii* Bresadola. In *figs. 7, 8* the plate-holder was 36^{cm} from the object, and in *fig. 9* the plate-holder was 48^{cm} from the object.

FIG. 7 with ocular 4, obj. 16^{mm}.

FIG. 8 with ocular 4, obj. 3^{mm}.

FIG. 9 with ocular 18, obj. 3^{mm}. Note form of the sixteen segments in the chain of 8 spores from one ascus, apex of series at left.

THE BOGS AND BOG FLORA OF THE HURON RIVER VALLEY.

EDGAR NELSON TRANSEAU.

(WITH SIXTEEN FIGURES)

[*Continued from p. 375.*]

THE BOG AS A HABITAT FOR PLANTS.

WHEN we consider the bog as a habitat for plants, there is at once brought to mind the marked contrast between its characteristics and those of the other plant habitats of its vicinity. In both its atmospheric and edaphic conditions it is unique. The various factors entering into the plant environment will be discussed as physical, chemical, and biotic agents.

A. PHYSICAL FACTORS.—1. *Wind.*—Because of the fact that so large a number of our bogs lie in depressions surrounded by hills, the influence of the wind is somewhat lessened. It is only in the case of the larger basins that its effects become marked. It has been noted by several students of bogs (**41, 5,** p. 37; **59, 47**) that in the region of prevailing westerly winds the greatest development of bog areas and peat deposits occurs on the western sides of lake basins. Where the deposition has taken place in a large lake basin, which is now only partially filled, we commonly find open water occurring toward the eastern side. The peat deposits at Portage, Parks, and West Lakes in the vicinity of Ann Arbor are massed on the western shores, while the eastern margins exhibit an ordinary lake beach. At the bogs north of Delhi, although nine-tenths of the original basin has been filled, the two small lakes are near the eastern margin. The facts noted in this region all favor the idea of the bog plants being unable to gain a foothold on the eastern side in the presence of wave action. The shoreward thrust of the ice is of importance at times in this connection.

Farther north in Michigan the wind frequently shows its extreme effect in these bog areas in the presence of "windfalls." Owing to the character of the substratum, such areas are more readily affected than the forests of mineral soils. These phenomena have not been observed in any of the bogs in this vicinity.

The same statement holds for the presence of loose floating bogs which are driven about on lakes by winds (**35**).

2. *Temperature.*—In its temperature relations both the topography and the character of the substratum combine to influence the bog habitat. It has long been noted by agricultural writers that reclaimed bog areas are particularly subject to late frosts in the spring. One of the causes of this peculiarity lies in the fact that on clear and quiet nights the cooled air overlying elevations drains into the depressions (**11**). Some recent observations made by SEELEY (**45**) near Chicago show how effective such atmospheric drainage may be even in districts whose range of elevations amounts to but 15 feet (4.5^m). He found that the hilltop averaged, on the night of the observations, 2.5° F. (1.4° C.) higher than that of the depression while a thermometer placed 30 feet (9^m) above the hilltop averaged 8.8° F. (5° C.) above that of the "swale." On comparing the temperatures of atmospherically undrained and drained depressions with that of the hilltop, he found that the hilltop temperature was 36.3° F. when that of the drained depression was 36° F. and that of undrained 31.8° F. Here is a particular instance in which frost occurred in the undrained depression, but not in the other situations. On quiet nights low grounds in general are subject to lower temperatures than the adjoining highlands, and it is probable that these effects are more pronounced in the case of undrained depressions.

A second factor in the production of low temperatures in bogs is found in the nature of the substratum. In the spring the ice which has formed beneath the cassandra and tamarack areas melts with extreme slowness, when once the surface of the soil has been reached. This is explained by the low conductivity of the loose, partially decayed, vegetable covering, and by the shading of the plants above. For example, at First Sister Lake, in 1904, the ice had disappeared from the water surface on April 10. On April 17, with an air temperature of 10° C., the temperature of the substratum in the bog sedge zone averaged 10° C., in the Cassandra zone 6° C., in the tamarack zone 3° C., and the area of willows and sedges 8° C. Ice was found at several points among the tamaracks, an inch below the surface. The sedge zone was covered with 1 to 3 inches (25–75^{mm}) of dark colored water. The other soils were wet, but their loose texture was effective in preventing a rise of temperature.

It follows that of the various situations in bog areas those most liable to extreme low temperatures in the spring are in the cassandra and tamarack zone. Since their maximum temperatures are considerably below those of neighboring areas, on quiet nights the plants there are but little protected by radiation from the soil as compared with plants of other situations.

In the following table it is shown that the soil temperatures of the several plant societies formed about a bog are different, and that each society has a characteristic temperature range. The records were made at First Sister Lake. The temperatures, given in °C, are averages of readings made in the second inch (25^{mm}) below the surface. The "willow-sedge" conditions correspond to those of the ordinary swamp. The "maple-poplar" is an area of these trees on the peat substratum. The "upland" is a sandy, sod-covered area 3 feet (0.9^{m}) above the surface of the bog. The temperatures for the most part were taken on clear afternoons about 3 P. M. when the differences are at their maxima.

Date →	April 4	April 12	April 17	April 25	April 29	May 3	May 6	May 16	May 21	May 27	June 6	June 15
Air temperature	10.5	2.0	10.0	8.5	18.0	24.0	27.0	15.0	26.0	21.0	26.0	26.0
Upland	11.0	7.0	10.0	10.0	17.0	20.0	23.0	16.0	20.5	21.5	25.5	26.0
Willow-sedge	7.0	8.0	8.0	9.0	14.5	17.7	19.5	15.0	20.0	22.0	22.0	20.5
Cassandra	1.5	2.0	6.0	7.5	11.0	14.7	15.5	13.0	16.5	19.0	20.0	19.5
Tamarack	0.0	0.0	3.0	4.5	9.9	11.7	15.0	10.6	15.0	17.0	18.0	18.0
Bog-sedge	9.0	8.0	10.0	9.0	18.0	19.0	22.0	16.0	20.0	23.0	24.0	23.0
Maple-poplar	7.0	8.0	8.0	8.0	15.0	18.0	19.0	15.0	16.0	15.0	17.0	16.5

In the accompanying diagram (*fig. 5*) it will be seen that the upland, bog-sedge, and willow-sedge soil temperatures do not deviate widely from those of the air, while the temperatures of the cassandra and tamarack areas range considerably lower. The high temperature of the bog-sedge zone finds its explanation in that the brown bog water overlying its surface absorbs heat. I have tested this point many times in various bogs and have always found such bog water to have a higher temperature than that of the saturated substratum adjoining it. In its ability to absorb heat rays it approaches that of drained sand. Its range, however, is much less and it retains its heat for a longer time. Consequently on cloudy days and following a sudden lowering of the air temperature, the surface bog-water temperature stands above that of the drained and undrained soil.

When we compare the effects of loss of heat from a free water surface and a saturated humus soil surface due to evaporation, there is a marked difference due to their specific heat. The humus will be cooled more rapidly by the evaporation of a given amount of water. Where so large an evaporating surface is exposed to the air as in the case of a sphagnum-covered area the loss of heat by this process is most effective in preventing the penetration of heat below the surface.

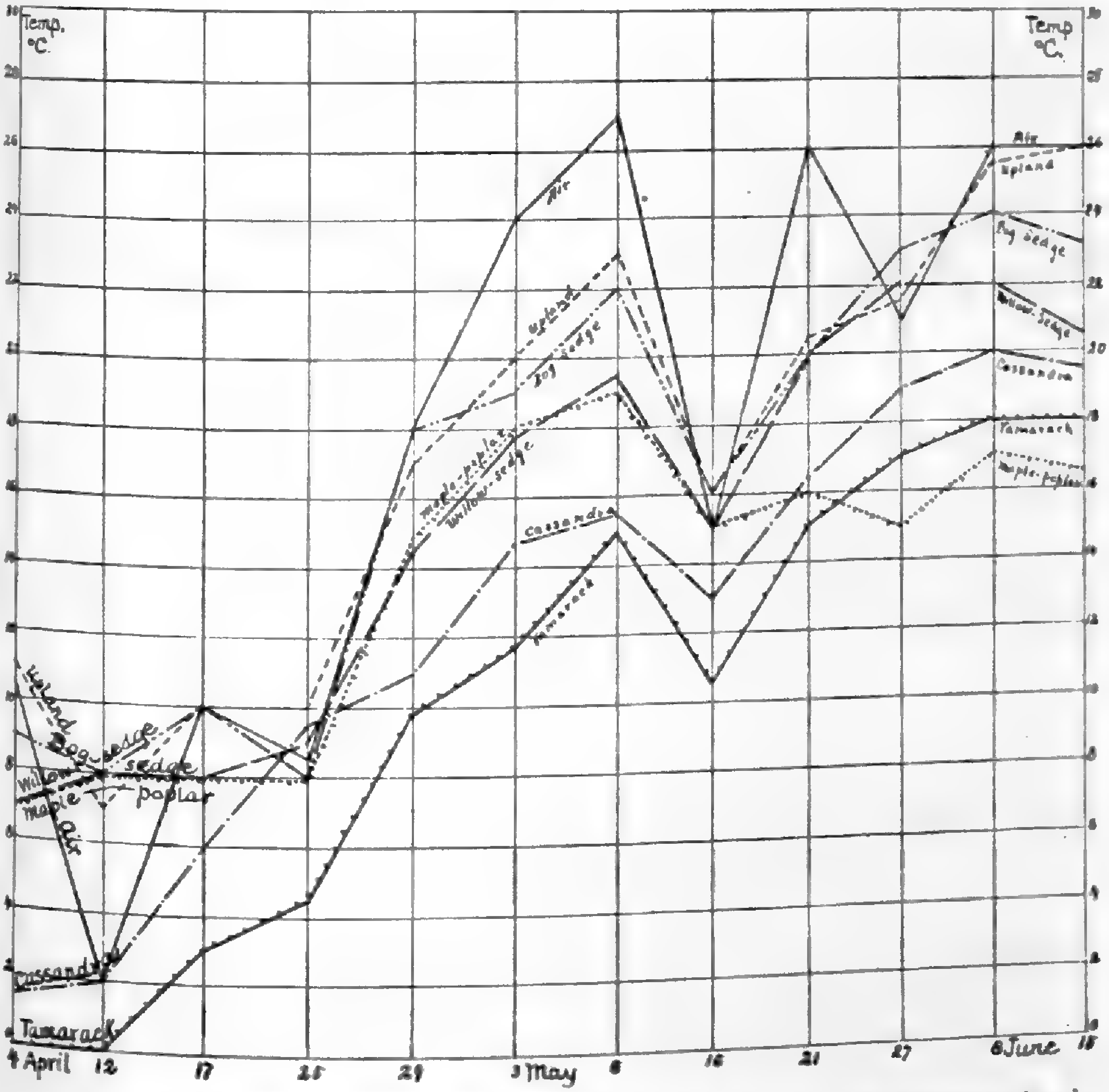

FIG. 5.—Diagram showing temperatures of the air and the substrata in the several plant societies.

In the case of drained soils, the most effective agent in raising the temperature of the subsoil is that of percolating water which has been warmed at the surface of the soil. Because of the high water-table and the stagnant condition of the underground water in bog areas, this source of heat is relatively unimportant.

The effects of these factors, resulting in low soil temperatures, are far-reaching. As compared with well-drained soils, chemical action is retarded, the rate of diffusion, solution, and osmosis is greatly reduced, and the conditions for the existence of soil bacteria made unfavorable. Plants which can successfully compete for the occupancy of such areas must be able to withstand low temperatures and late frosts. The difference between the temperature of the air and that of the substratum favors plants having a low transpiration ratio.

However, in so far as the region of southern Michigan is concerned, the temperatures prevailing in bog areas do not seem to be adequate to account for the presence of the bog plants or their xerophilous structures. It is to be noted that with the leafing-out of the trees, about May 27, the temperature of the maple-poplar substratum falls below that of the tamarack. But that the soil temperature is one of the factors entering into the problem of competition between species there can be little doubt. It is probable also that in the region of optimum conditions for bog plants the conditions which occur here only in the spring are prolonged through the summer. That is, the difference between air and substratum temperatures is more marked, and is a powerful factor in the selection of plants for bog areas and in the production of xerophilous structures.

3. *Texture.*—This property of the substratum has already been referred to in connection with the genetic changes in peat. The sedge zone is developed upon a raft of interwoven rhizomes and roots. It is a coarse meshwork; but since it lies at or below the surface of the water, its texture is of slight importance except as a means of mechanical support. As the bog develops, the admixture of moss and shrub débris brings about the formation of a rather compact peat, overlaid by a stratum of loose material. In some cases, as at Delhi and Oxford, 45 miles (72^{km}) northeast of Ann Arbor, the living sphagnum makes up the bulk of this loose covering. Usually the water level lies just beneath it. As a consequence, this covering becomes the

principal seat of root activity. The small, fibrous roots of cassandra, andromeda, and the cranberry penetrate it in all directions, and it is from the water which is held among this moss and débris that they derive their water and mineral salts.

The substratum beneath the tamaracks is also covered by a loose litter of leaves and twigs, with more or less moss. Depending upon the height above the ground water level, this surface layer is of greater or less thickness. In it occur the wide-spreading roots of the tamarack. During summer and autumn it furnishes admirable conditions for the growth of fungi, and it is penetrated everywhere by their mycelia.

When bog land is cleared, the decomposition of the surface layers is very rapid, owing to exposure to sunlight and higher temperatures. If the water-table is maintained near the surface, sedges and willows develop as the covering. The annual increment of plant material is often decreased, and in place of the fibrous and porous substratum there is produced a black, close-textured, and plastic muck.

If ditching and draining are added to clearing, the summer drought dries the surface layer so thoroughly that it often becomes the habitat for many dry-ground weeds. Decay progresses in moist weather under the influences of the higher temperatures resulting from increased absorption of the sun's energy by the dark colored soil.

4. *Mechanical properties.*—Bog soils in general do not afford as good a foothold for the development of tree species as do the mineral soils. On account of the high water-table, the roots of the plants are not able to penetrate to a depth of more than a few inches. The roots of the tamaracks spread out in all directions from a flat trunk base, and upon the size and strength of these horizontal roots depends the tree's ability to withstand mechanical strains tending to displace it. There can be no doubt but that, in the thick groves in which the tamarack occurs, the interweaving of the roots from adjacent trees becomes of mutual advantage, in so far as the roots function as holdfast organs.

5. *Diffusion properties.*—A most important soil property relates to the diffusion of mineral salts. This becomes of especial significance in saturated stagnant substrata. The mineral salts must be distributed to the roots mainly by diffusion, for lateral drainage

and percolation are at a minimum. It is well known that when salt solutions are passed through soil, much of the salt is retained by absorption. The relative amount is greatly increased in the case of humous bodies. BLANCK (**4**) has further found that the diffusion of water in humus soils is decreased by the presence of acid humus compounds, and that this may be corrected by the addition of a neutralizing agent, such as lime. All analyses of peat show how little of this mineral matter has been derived from the adjacent soils. It is only in the case of samples taken from the bottom or edge of a bog that the mineral salts cannot be accounted for by the amount derived from the decay of the plant material, and that obtained from the atmosphere.

6. *Water-capacity.*—The high water-capacity of peat has already been noted. In relation to plant growth, it is detrimental in that it prevents proper aeration of the substratum (**39**, p. 346). So far as the diffusion of gases is concerned, such substrata are less favorable than a free water surface. King (**29**, p. 161), in speaking of sand and clay soils whose water-capacity is only 17.5 to 32.2 per cent. by weight, says that 30 to 40 per cent. of their saturation amounts must drain away before the soil can contain air enough to maintain the respiration of roots and germinating seeds. As compared with a free water surface, saturated humus cannot admit oxygen as freely, owing to the large part of the surface actually occupied by the humus (**29**, p. 239). In a chemical way it is still more effective, as will be noted later.

7. *Osmotic pressure.*—The osmotic pressure of bog waters has been found to be about the same as that of ordinary lakes and rivers.[3] They are approximately equivalent to a 0.1 to 0.5 per cent. normal Knop's solution. They indicate quite certainly that bog plants do not owe their distribution and their peculiar structures to a high osmotic pressure of the bog water.

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[3] Four samples of bog water from this vicinity were tested by Dr. B. E. LIVINGSTON, of the University of Chicago, and found to have the following pressures in millimeters of mercury at 25° C.:

First Sister Lake, Sample A	50.0742
First Sister Lake, Sample B	40.0593
West Lake, Sample A	100.1484
West Lake, Sample B	150.2226
Lake Michigan water	100.1484

See **33**.

B. CHEMICAL FACTORS.—1. *Ground water*.—The ground water of the Huron basin derives its mineral constituents from the glacial drift. The following analyses show the character of the solution. Quantities are expressed in parts per million (**31**).

	$CaCO_3$	$CaSO_4$	Fe_2O_3	$MgCO_3$	K_2SO_4	SiO_2	NaCl	Na_2CO_3	Na_2SO_4	Organic and volatile	Total mineral matter
Ann Arbor, University well.	178.00	....	3.99	60.58	6.78	7.30	4.48	1.52	5.07	3.85	267.72
Ann Arbor, spring.........	228.00	....	6.43	89.36	5.31	9.20	4.88	0.42	9.71	25.00	353.31
Ypsilanti, water works....	289.00	39.00	21.00	100.00	......	14.00	35.00	....	....	71.00	498.00
Ypsilanti, well..........	156.00	223.00	Tr.	109.00	......	18.00	62.00	17.00	....	14.00	585.00
Ann Arbor, creek.........	128.00	99.00	Tr.	83.00	......	25.00	15.00 (NaK)	25.00 (NaK)	....	14.00	375.00

It is to be noted that they are all high in calcium and magnesium content, and under favorable drainage conditions contain sufficient minerals for plant growth. The ground water is of especial importance in the early stages of bog development, when the sedge and aquatic vegetation is dominant. With the further development of the sedge zone and the formation of a thick peat deposit, its relation to the vegetation becomes of less moment. There is a notable difference between the total mineral content of bog water and that of the soil waters adjoining. In the above table the total mineral content of the ground water varies from 267·7 to 585 parts per million. In three analyses of the bog water at the First Sister Lake I found the total mineral content to vary from 89·9 to 219 parts per million, the highest figure being that for the sample obtained near the margin of the tamaracks, *i. e.*, nearest the mineral soil.

The absence of sphagnum from certain bogs has been explained by the presence of calcium salts (**15**, p. 23, **16**). In order to test this point, I have cultivated the species found in this vicinity in tap water and in a saturated solution of $CaCO_3$, and have found no detrimental effects due to calcium. The experiments will be discussed later. I further found that the ash of sphagnum growing at First Sister Lake contained 18 per cent. of CaO. It would seem, therefore, that, in so far as this vicinity is concerned, the presence of calcareous waters will not explain the absence of species of sphagnum.

2. *Acidity.*—Much stress has been laid by various authors, following SCHIMPER (**44**, pp. 6, 18, 124), upon the acidity of the bog water as a factor in the bog habitat. In order to get a quantitative statement of the acidity for the bogs of this vicinity, a number of 50^{cc} samples have been titrated with an $n/100$ solution of potassium hydrate Phenolphthalein was used as an indicator. The results show an acidity varying from .00015 to .00258 normal acid.[4] The lowest values are found in the areas occupied by bog sedges and by swamp plants, and they are practically the same. The areas occupied by cassandra and sphagnum have a somewhat greater acidity. The highest percentages are found beneath the tamaracks. The explanation of these variations in acidity is suggested by the tests, made from time to time, of the water in my experimental cultures. I found that the acidity of the water increased slowly in the undrained peat substratum cultures (see experiments). The increase was small in the case of the warm cultures, but quite notable in the case of the cold undrained substratum. On exposure to air in the water cultures, and in bottles, the acidity very slowly decreased, the decrease being greatest in the case of the water which was kept warm. This is probably due to increased oxidation. These relative amounts of acid, it will be seen, may be correlated with the temperatures in the several plant societies of the bog, the lowest temperatures corresponding to the highest percentages of acid. This suggests the probability that the acidity of the bog substratum increases farther north.

On allowing open dishes of bog water to stand for some time, I found that the evaporation was not sufficient to raise the acidity of the water, oxidation apparently being more rapid than concentration of the solution.

There is no apparent relation between color and acidity, although the lightest colored solutions usually show but slight acidity. This seems to indicate that only a part of the color is produced by free humus acids, the remainder by humates of the alkalies.

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[4] Following are the determinations expressed in fractions of a normal acid solution:

First Sister Lake: sedge zone, .00066, .00094; cassandra zone, .00152, .00119; tamarack area, .00165, .00179, .00227, .00258; willow-sedge area, .00089, .00072.

Chelsea: ditches, .00086, .00015, .00043, .00019, and .00029.

Delhi: tamarack area, .00146, cassandra zone, .00117.

Oxford: cassandra zone, .00094.

The effect of acidity upon cultivated plants has been investigated in this country especially at the Rhode Island Agricultural Experiment Station, under the direction of Professor H. J. WHEELER. The experiments have been conducted upon "acid upland soils" (**60**), and numerous reports have been published. These experiments involved a great variety of plants and were carried on under natural field conditions. The areas planted for comparison had their acidity neutralized by the addition of $CaCO_3$. The plants which were favored by the liming include the orange quince, black Tartarian cherry, Japan plum, *Tilia americana*, *Ulmus americana*, rhubarb, Australian salt-bush, hemp, barley, oats, onions, *Anthoxanthum odoratum*, *Poa pratensis*, *Festuca ovina*, *Holcus lanatus*, *Festuca elatior*, *Alopecurus pratensis*, etc. Plants which appear to be adapted to the acid soil conditions include cranberry, blackberry, raspberry, sheep sorrel, cow-pea, flax, corn, lupine, and soja bean. It would appear, then, that the acidity of the soil solution is unfavorable for the growth of some plants, and that it is a factor in the selection of species for acid soil conditions.

3. *Food material.*—As to the presence of plant food materials in the bog soil there is an agreement among all the analyses that have been made.[5] The soils are unusually rich in nitrogenous materials, some analyses showing three times as much as good upland soils. But in the slow decay of the vegetable matter the nitrogen remains bound up in organic compounds and is unavailable for the growing plants. This is confirmed by experimental tests in which nitrogen was directly applied, and by tests in which the conditions were modified so as to permit the action of nitrifying bacteria. In such cases crops were produced when the untreated humus produced none.

Under natural conditions the growth of the nitrifying bacteria in bog soils is almost impossible. Three factors work against their activity: (1) the acidity of the soil solution; (2) the lack of oxygen due to high water content; (3) the lower temperature. It has been found that the optimum temperature for these bacteria is 98° F. (36.6° C.), and that their activity is very slight at 50° F. (10° C.)

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[5] Analyses of Wisconsin soils. Ann. Rept. Wis. Agric. Exper. Sta. **13**: 304. 1896. See also **27**, p. 12; **23**; **22**, p. 276; **30**; **48**, p. 234; **12**, p. 39; **14**.

(**3**). Furthermore, it has been shown that when soil rich in nitrogen is saturated with water so as to exclude free oxygen, denitrification takes place and nitrogen gas is set free (**29**, p. 115).

The phosphoric acid content is comparable with that of the best soils, and it is at least partially in a condition for plant use.

The potassium content is very low. Analyses and the results of agricultural experiments show that in order to produce crops this substance must be added, and preferably in an alkaline form. Inquiry among the owners of onion marshes in this vicinity confirms the need for potassium in local bog soils.

The amount of calcium present is reported as equal to that of the best upland soils. But it is probable that as it exists under natural conditions in bogs it is bound up largely in insoluble humates. Under the influence of oxidizing processes it would become available to the plants at the surface.

When we consider the conditions under which the various plant societies in our bogs exist and their competition with one another, there can be little doubt but that the substratum varies in each case as to its chemical composition. That the societies may be classified on a physiographic basis is certain, but how to determine the chemical factors accompanying each physiographic change is an unsolved problem. The ordinary methods of analysis give us the minerals present, but tell us little about their form and availability for plant assimilation. The colorimetric methods for determining the quantity of mineral salts present in bog water are mostly open to objection. The ease with which the humous bodies of the bog water are decomposed render their quantitative estimation by present methods of little value. Yet it seems probable that work upon the chemistry of humus and humous compounds must result in data valuable alike to the ecologist, the forester, and the agriculturist.

C. Biotic factors.—The interrelations of the bog species will be discussed in connection with their other ecological characters. It will be sufficient to mention here that they are with a few exceptions light-demanding forms. Consequently, size and ability to produce shade are the important factors in their competition with one another.

A second element enters into this problem of the struggle between species near the borders of the area of geographic distribution of the bog plants, viz., climate. The bog plants of this vicinity come into conflict with species whose range is either more nearly continental or more southern. That the climatic and edaphic conditions of this region are at present unfavorable to the successful competition of the bog species with swamp species is evidenced wherever the bog conditions have been disturbed. That the reverse is the rule in eastern Canada has been shown by GANONG (**18**, p. 178). The tenacity with which species, whose multiplication is principally accomplished by vegetative means, hold an area under complete control is apparent to any who have studied the vegetation of lake shores. It is just as strongly marked in the case of the herbaceous and shrubby bog vegetation. When we examine the chemical and physical data, now at hand, concerning the soils occupied by bog and swamp plants respectively, the conclusion must be that they are wholly inadequate to account for the difference in vegetation. The forester lays stress upon the fact that trees cannot gain a foothold on areas now covered with a grass turf because of the difficulty of the seedlings getting started. The bog societies form an equally compact plant growth, and their preservation in this region would seem to be dependent upon analogous factors.

III. The bog-plant societies.

The following descriptions of local bog areas occurring in the Huron valley aim not only to present lists of plants found in this vicinity, but to show their natural associations. The order in which the areas are described corresponds to the relative amount of filling which has occurred in the several basins. To a certain extent this order is genetic, yet there can be little doubt but that many arctic plants which were concerned in the pioneer stages of our mature bogs are now extinct. If we accept the areas at West and First Sister Lakes as representing bogs in youth, maturity may be illustrated by the original vegetation of the bog on Carpenter's road. The Chelsea area defines that stage beyond the climax, when the conditions inaugurated by cutting, firing, and ditching have destroyed the original tamarack forest, and in its place has come a rude mixture of bog relicts and arborescent weeds.

WEST LAKE.

This lake, situated three miles north of Chelsea (Sec. 30, Dexter Tp.), is also known locally as Johnson's Lake. In area it is slightly more than a fourth of a square mile (65 hectares). The margin of the lake originally extended a half mile (0.8^{km}) farther west and southwest. This part is now occupied by a partially floating bog. The north, south, and east shores are sandy and low. Patches of bulrushes and water-lilies occur here and there over the lake and show its generally shallow character. Toward the east there is a narrow swampy outlet by which its water after a long and circuitous route reaches the Huron River. There are no streams tributary to the lake. The basin lies near the southeastern margin of the interlobate moraine, and is bounded on the north and south by hills 60 to 80 feet ($18–24^{m}$) in height. Not all of the original extension to the southwest has been filled by peat; two small areas of open water still remain.

The shores, with the exception of the western side, support a vegetation similar to that of many lakes in this region. Three societies of plants may be distinguished.

Aquatics.—The most abundant plants are Scirpus lacustris, Castalia tuberosa, and Sagittaria rigida. These occur not only along shore, but in shallow water throughout the lake. Associated with these are Naias flexilis, Brasenia purpurea, Potamogeton heterophyllus, Chara (sp.), Spirodela polyrhiza, Vallisneria spiralis, Scirpus americanus, and Decodon verticillatus.

Sedge-grass society.—Very near the north, south, and east shores occur a great number of species of grass-like plants. Their associations vary greatly at different parts of the shore line. The dominant forms are Carex filiformis, Panicularia nervata, Eleocharis palustris, Carex teretiuscula, C. Muskingumensis, Dulichium arundinaceum, Panicularia Canadensis, Dryopteris Thelypteris, and Scutellaria galericulata. Among the species of secondary importance are Onoclea sensibilis, Carex riparia, C. stipata, C. hystricina, C. interior, Spartina cynosuroides, Typha latifolia, Iris versicolor, Lobelia Kalmii, Comarum palustre, Lycopus americanus, and Eupatorium maculatum. Closely associated with these plants are the seedlings of the shrubs and trees which make up the next society.

Willow-maple society.—The shrub and tree border is composed, for the most part, of Salix Bebbiana, S. discolor, S. sericea, Cornus candidissima, Acer rubrum, and Ulmus americana. Beside the many plants of the sedge-grass society which remain as relicts, the accessory species include Rosa Carolina, Impatiens biflora, Sambucus pubens, Spiraea salicifolia, Prunus serotina, Quercus alba, Q. velutina, and Opulaster opulifolius. These trees grade into the forests of the upland and establish a natural order of succession.

An interesting comparison is afforded when we note the species dominant along the western or bog margin. Here the outer zone of aquatics is made up of the same species, but this substratum is a floating raft constructed by the plants themselves. Without again enumerating the species, we pass to the society which closely follows their development.

Bog-sedge and shrub society.—This society forms a very complex growth, averaging 50 feet (15^{m}) in width. On the lakeward side are the aquatics; on the other, the growth of tamaracks. The sedges and shrubs are not separable, as in many other localities. Carex filiformis is by far the most important plant in the society. Its vigorous production of rhizomes and roots especially fit it for the position which it occupies. Certain other plants are locally abundant and of great consequence. These include Dryopteris thelypteris, Menyanthes trifoliata, Eleocharis palustris, Comarum palustre, Sagittaria latifolia, Eriophorum polystachyon, Carex teretiuscula, Typha latifolia, Salix myrtilloides, S. candida, Betula glandulosa,[6] Oxycoccus macrocarpus, and Andromeda polifolia. As accessory species may be mentioned Salix discolor, S. Bebbiana, Cicuta bulbifera, Cardamine pratensis, Chamaedaphne calyculata, Campanula aparinoides, Rumex Britannica, Epilobium adenocaulon, Asclepias incarnata, Pogonia ophioglossoides, Blephariglottis blephariglottis, Limodorum tuberosum, Marchantia polymorpha, Aulacomnium palustre, Sarracenia purpurea, Drosera rotundifolia, Boehmeria cylindrica, Carex comosa, C. hystricina, Cornus stolonifera, Parnassia caroliniana, Viola blanda, and Penthorum sedoides. Here and there occur young tamaracks which by their growth inaugurate the next society.

Tamarack society.—As development proceeds, the shrubs and

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[6] The form found here and at Delhi corresponds more closely to this species than to *B. pumila*, but its characters are intermediate.

herbs gradually are superseded by a growth of Larix. This society has been much disturbed by lumbering, and a large part of the original area has been cleared. But there is good evidence to show that the part of the basin filled with peat formerly supported a dense covering of tamaracks. Where best developed and least disturbed, it shows an undergrowth of Vaccinium corymbosum, Aronia nigra, etc. As the other species are practically the same as at the lake to be described next, they need not be enumerated here. In contrast with most of the areas studied, the almost complete absence of sphagnum is worthy of note. It is also important that the absence of any gradation between the forest societies of the upland and of the bog be kept in mind.

On this lake, then, there are two divergent series of plant societies. Starting with practically the same species, the one series leads us on mineral soil through willows, maples, and elms to the oaks of the surrounding forests; the other, owing to the development of a floating substratum, involves a very different set of shrubs and ends with the tamarack. The former series therefore more closely approximates the climatic type, while the latter is dependent upon edaphic factors.

FIRST SISTER LAKE.

This lake and its accompanying bog are located three miles west of Ann Arbor in a glacial drainage valley. Its origin is probably connected with the melting of a mass of stagnant ice after the abandonment of the valley by glacial drainage. The surrounding and underlying soil is a sandy gravel. At least a part of the western side presents an original tamarack bog vegetation, and it is particularly interesting in showing the results of competition between bog plants and those of other habitats (*fig. 6*). The vegetation in general presents a different phase of the bog societies, as compared with West Lake. Especially to be noted are the dominance of cassandra and sphagnum in the shrub zone, the absence of cattails and swamp loosestrife as important members of the outer margin. The tamarack zone is also raised somewhat more above the water level.

Aquatics.—With the exception of the shallow-water forms, the lake is almost free of higher vegetation. Potamogeton lucens and P. zosteraefolius occur sparingly. About the margin, however, Nymphaea advena is of great importance. It forms an almost continuous zone 10 to 25 feet (3–7.5 ^{m}) in width. Patches of Castalia tuberosa and Brasenia purpurea occur. This arrangement in groups seems to be connected with their rapid multiplication by rhizomes. Typha latifolia occurs in a small area at the north end of the lake. Ceratophyllum demersum and Naias flexilis occur as secondary species.

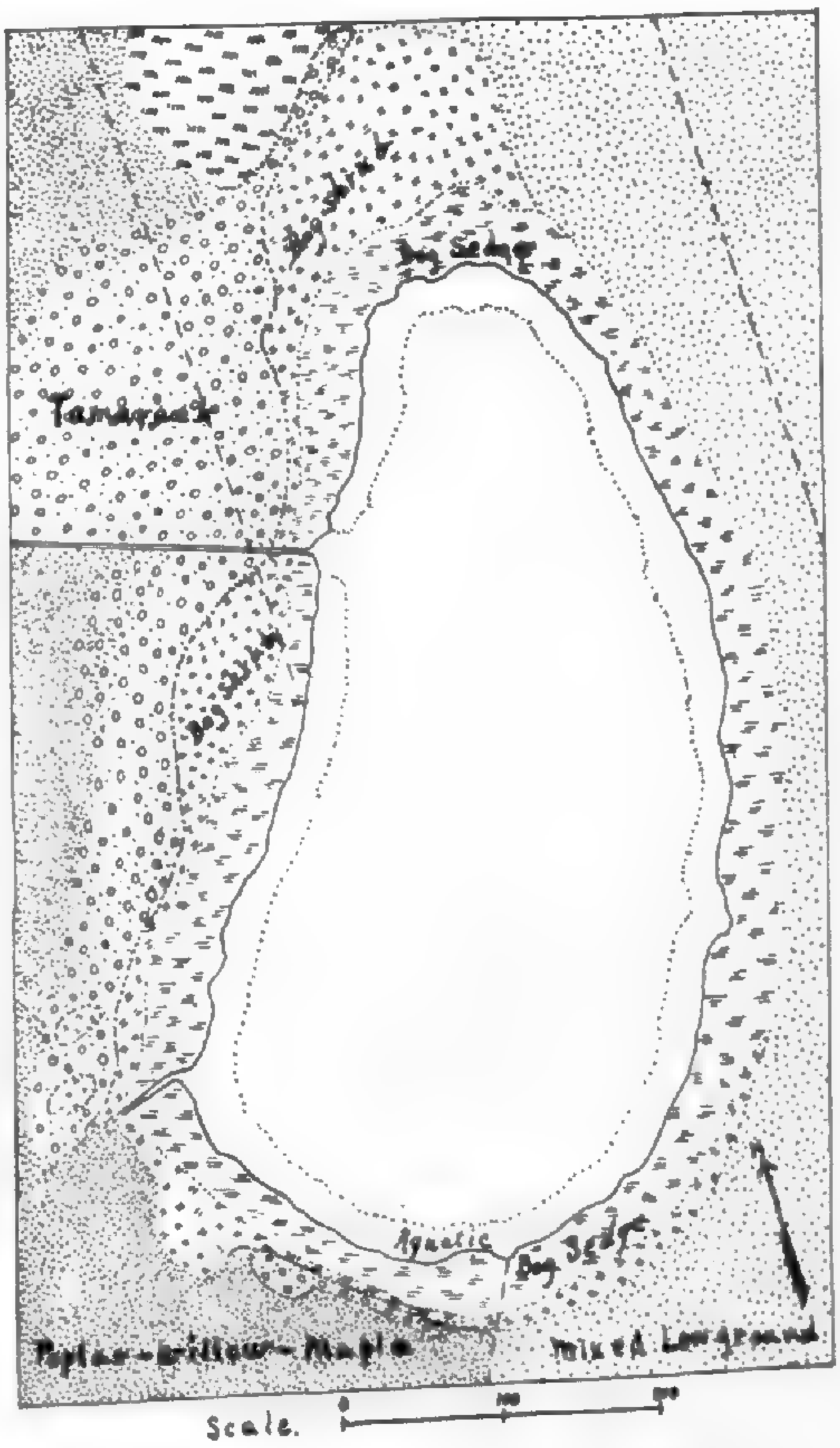

FIG. 6.—First Sister Lake.

Bog-sedge society.—Carex filiformis, C. oligosperma, Eleocharis palustris glaucescens, and Eriophorum polystachyon are the primary factors in the formation of this zone. Carex riparia has gained a foothold at the north end of the lake, where muskrats have been active in destroying the original sedge zone. Dryopteris thelypteris, Onoclea sensibilis, Juncus effusus, J. canadensis, Comarum palustre, Salix myrtilloides, Dulichium arundinaceum, Equisetum fluviatile, Bidens trichosperma tenuiloba, Menyanthes trifoliata, Viola blanda, and Eriophorum virginicum occur as accessory plants. The great majority of these plants aid in the construction of the substratum by their roots and rootstocks.

Here and there among the sedges occur the forerunners of the shrub society. Among the very first to gain a foothold are the sphagnums. These build small tufts of great compactness, and gradually overcome the sedges. The rootstocks of the cassandra also send up shoots and prepare the way for another vegetation form. Oxycoccus macrocarpus and O. Oxycoccus both occur at intervals in this zone.

Cassandra-sphagnum society.—Beyond the sedge zone the vegetation is no longer arranged zonally. Conditions have been so much disturbed that on the western side the area of cassandra-sphagnum dominance is very irregular. On the eastern side this plant society is in the last stage of its existence. The intimate association of Chamaedaphne calyculata, Sphagnum cymbifolium, S. subsecundum, and S. recurvum is well illustrated here. The plants occupy the whole of the territory where they flourish. The other species are decidedly secondary. It is to be further noted that in the competition with the sedge species these plants actually override them, and only an occasional Eriophorum virginicum survives. The water-conserving properties of the sphagnum are too well known to need description here. But the mutual advantage of the cassandra-sphagnum combination is worthy especial note. The former by its numerous branches furnishes a framework which aids in the upbuilding of the moss and in shading. The sphagnum, on the other hand, furnishes a moist cover in which the conditions for the shrub are most favorable.

The accessory species include the moss, Aulacomnium palustre; the herbs, Drosera rotundifolia, Arethusa bulbosa, Habenaria lacera, Sarracenia purpurea, Pogonia ophioglossoides, Limodorum tuberosum, Viola blanda, Osmunda regalis, Campanula aparinoides, Scutellaria galericulata; and the shrubs, Andromeda polifolia, Betula pumila, Oxycoccus macrocarpus, O. Oxycoccus, Aronia nigra, and Ilicioides mucronata.

Tamarack society.—Among the cassandra occur many young tamaracks, and these by their development come to overshade the shrubs and form the tree society of the bog. The dead remnants of the cassandra mounds make up a large part of the floor beneath them. The species of secondary importance are Ilicioides mucronata, Aronia nigra, Chamaedaphne calyculata, Osmunda cinnamomea, O. regalis, Dryopteris spinulosa intermedia, D. cristata, Polytrichum juniperinum, Plagiothecium denticulatum, Thuidium recognitum, Aulacomnium palustre, Marchantia polymorpha, Sphagnum cymbifolium, Boletinus porosus, and Thelephora intybacea.

The tamarack zone has been much disturbed by clearing and burning. At the present time a large part of the area on the southwest side is dominated by other tree species. Some of the plants of the clearing have spread into the pure tamarack growth.

Poplar-willow-maple society.—Where the original conditions have been disturbed and a second growth allowed to come in, Populus tremuloides, Salix sericea, Salix discolor, and Acer rubrum have obtained dominance. Where groups of the more mature poplars occur there is scarcely any undergrowth. Elsewhere the following plants occur: Ilicioides mucronata, Salix Bebbiana, Sambucus pubens, Amelanchier oligocarpa, Aronia nigra, Rubus nigrobaccus, Cornus stolonifera, and Rubus strigosus. These form a dense mixed association, with but slight reference to substratum conditions. The smaller species present are Adicea pumila, Osmunda cinnamomea, Rosa Carolina, Onoclea sensibilis, Epilobium adenocaulon, Spiraea salicifolia, Dryopteris thelypteris, Verbena hastata, Solanum dulcamara, Polygonum sagittatum, Spiraea tomentosa, Geum rivale, Polygonum hydropiperoides, Ribes floridum, Ribes oxyacanthoides, Rumex Britannica, Impatiens biflora, Viola blanda, Osmunda regalis.

On the southeast side of the lake and on the north, conditions have been still more interfered with, and there is now a mixed growth of bog and low-ground plants, which represent stages in the decline of the bog flora and the advent of swamp plants. The tallest forms are willows and clumps of mountain holly. For convenience only, the plants may be enumerated together under the following title:

Mixed low-ground society.—The dominant plants are Salix sericea, S. discolor, Spiraea salicifolia, Poa flava, Solidago serotina, Chamaedaphne calyculata, Oxycoccus macrocarpus, Aster Novae-Angliae, and Rosa Carolina, Epilobium adenocaulon, Aronia nigra, Andromeda polifolia, Rubus strigosus, Dryopteris thelypteris, Scutellaria galericulata, Juncus effusus, Koellia virginiana, Sambucus canadensis, Geum rivale, Osmunda regalis, Scirpus cyperinus, Galium aparine, Homalocenchrus oryzoides, Juncus tenuis, Asclepias incarnata, Salix Bebbiana, Eupatorium perfoliatum, Gentiana Andrewsii, Lycopus virginicus, Osmunda cinnamomea, Cornus stolonifera, Carex riparia, Viola blanda, Sarracenia purpurea, Dryopteris cristata, D. spinulosa intermedia, and Triadenum virginicum also occur.

The last two societies are found upon a black peat substratum which is more thoroughly decayed than in other parts of the bog.

Acidity tests show that the relative acidity is less than in the case of the cassandra-sphagnum and tamarack societies. The soil temperature also runs somewhat higher as noted elsewhere.

The First Sister Lake may be said to be dominated by three well-marked bog and two mixed societies in which bog and swamp species are brought into competition. The result can be foretold with considerable certainty. The bog vegetation will sooner or later be replaced by the swamp species.

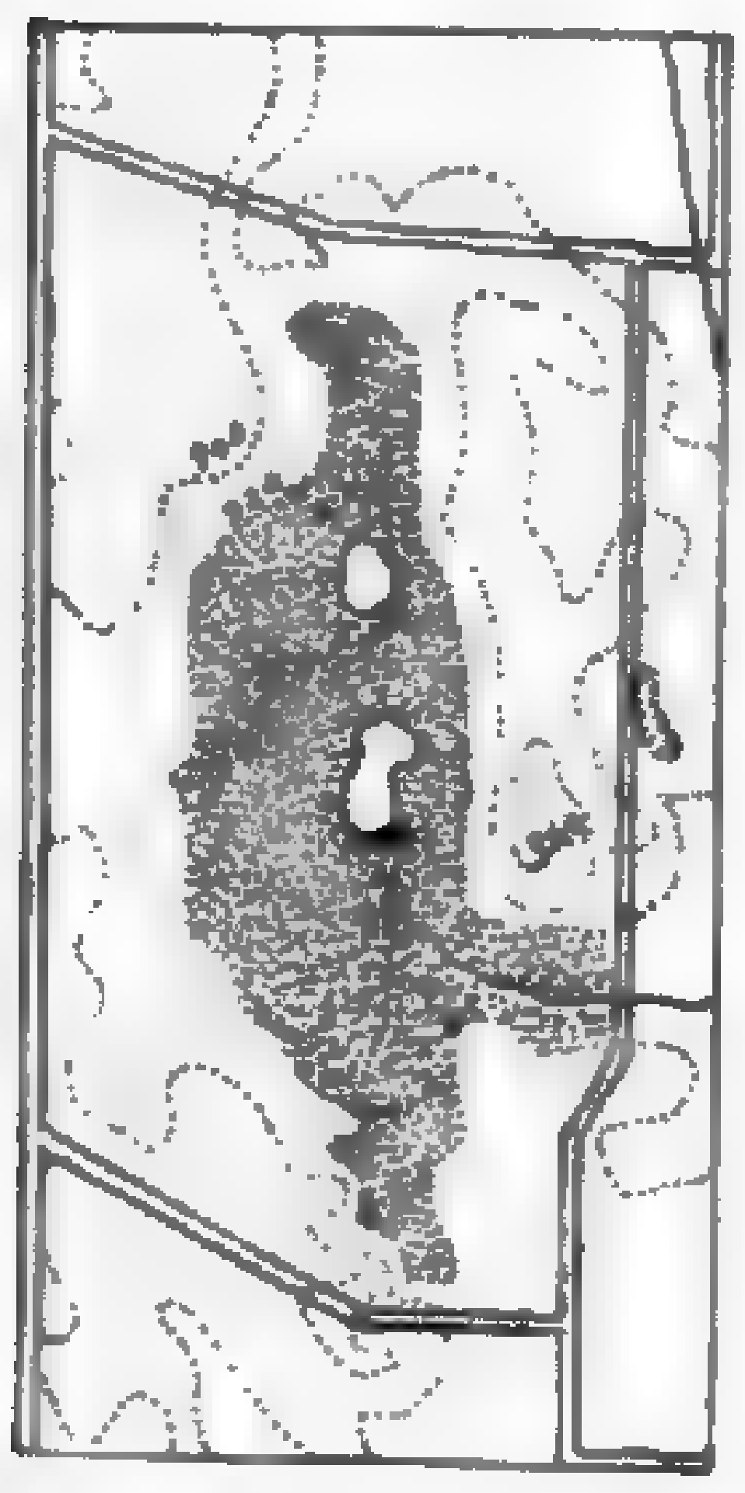

FIG. 7.—Delhi bog and adjacent topography. Scale 1:95,000 ($\frac{2}{3}$ inch = 1 mile).

BOG NORTH OF DELHI.

Two miles north of Delhi occurs an extensive bog which was formerly a mile and a quarter (2 ^{km}) long by a half mile wide (0.8 ^{km}) at its broadest part (*fig. 7*). The southwestern third has been cleared and is in part under cultivation. The eastern and northern parts have been somewhat interfered with by the cutting of timber, but areas occur which have been but little disturbed by these influences. Near the eastern margin are two small lakes, the last remnants of the larger lake which must have occupied this territory in early postglacial times. The basin is located in a clay moraine of the Erie ice-lobe, and probably owes its origin to unequal deposition by the glacier.

The plant societies found about the southeastern lake will give an idea of the whole vegetation (*fig. 8*).

Aquatic society.—The aquatic vegetation is represented almost wholly by the yellow water-lily, Nymphaea advena. This plant forms a broader zone completely encircling the lake and varying from 5 to 10 feet (1.5–3 ^{m}) in width. Accompanying it occur Brasenia purpurea, Ceratophyllum demersum, Lemna minor, and Spirodela polyrhiza.

Typha-cassandra-sphagnum society.—On the floating margin of the bog substratum occurs a zone which partially encircles the lake. Near its outer edge Typha latifolia is the characteristic plant, but in certain places it is wanting or extends the full width of the zone. Chamaedaphne calyculata, Sphagnum cymbifolium, S. subsecundum, S. recurvum, Carex filiformis, Eriophorum polystachyon, and Salix myrtilloides are the most frequent plants. The accessory species include Carex oligosperma, Menyanthes trifoliata, Comarum palustre, Triadenum virginicum, Osmunda regalis, Onoclea sensibilis, Rumex Britannica, Asclepias incarnata, Viola blanda, Cicuta bulbifera, Galium Aparine, Scutellaria galericulata, Rhus Vernix, Dulichium arundinaceum, Oxycoccus macrocarpus, Hypnum cordifolium, Hypnum Schreberi, Aulacomnium palustre, and Mnium.

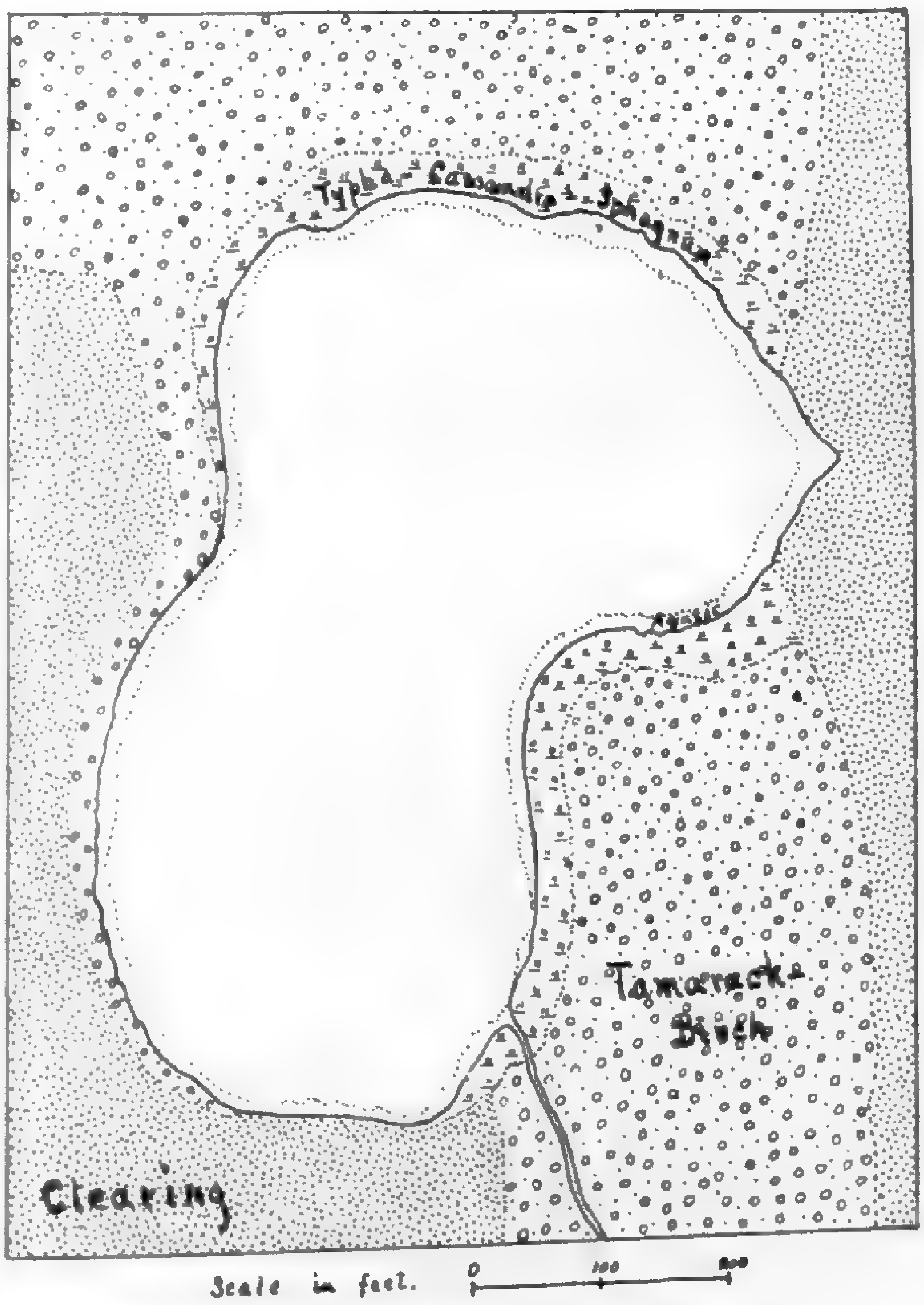

FIG. 8.—Portion of Delhi bog.

Vaccinium-aronia society.—Forming a narrow transition society between the low shrub zone just described and the tree society, occurs a dense line of tall shrubs. The dominant species are Vaccinium corymbosum, Gaylussacia resinosa, Aronia nigra, Ilicioides mucronata, Betula glandulosa, and Prunus serotina. The other species present are Acer rubrum, Sambucus pubens, Osmunda cinnamomea, Salix discolor, S. Bebbiana, Spiraea salicifolia, Ilex verticillata, Rosa Carolina, Sarracenia purpurea, Andromeda polifolia, Calamagrostis canadensis, and Eleocharis palustris glaucescens. These shrubs border the tamaracks and to varying distances extend back among them.

Tamarack-birch society.—Larix laricina and Betula lutea must have made up the great bulk of the original forest which occupied this area. The relative abundance of the latter has probably been increased by the cutting of the tamarack. The next most important tree is Acer rubrum, which occurs scattered throughout, but is especially abundant near the northeast side. Where isolated trees have been removed, the shrubs which occur among the undergrowth have made a rapid growth. Throughout the forest area are patches in which Aronia nigra, Vaccinium corymbosum, and Ilicioides mucronata stand so thickly as to be almost impenetrable. Where the forest has been but slightly disturbed and the tamaracks are more or less scattered, one finds a deep carpet of sphagnum with slender stems of cassandra, andromeda, and Eriophorum virginicum rising through it. Clusters of Sarracenia purpurea are common. The other plants found in this society are Trientalis americana, Unifolium canadense, Coptis trifolia, Rumex Acetosella, Rubus strigosus, Dryopteris spinulosa intermedia, Osmunda cinnamomea, Viola blanda, Impatiens biflora, Solanum dulcamara, Thelephora intybacea, Polytrichum juniperinum, Sambucus pubens, Agrostis alba, Blephariglottis lacera, Cornus candidissima, and Cicuta maculata.

Clearing society.—Surrounding the forest on the east, south, and west sides is a large area, in part dominated by sedges and grasses, and in part by a typical "slashing." It is impossible to characterize this plant association by any particular species. All that have been thus far mentioned occur in scattered clusters, the proportions and dominant plants varying from one locality to another. The notable facts are that on the east side Carex teretiuscula, C. vulpinoidea, C. riparia, C. filiformis, Scirpus cyperinus, Calamagrostis canadensis, Aster Novae-Angliae, Eupatorium perfoliatum, and Aster junceus have become the most abundant forms. To the west of the lake these plants are present, but the taller shrubs are in control. Salix discolor, Cornus stolonifera, Salix Bebbiana, S. sericea, and many others already mentioned as occurring among the tamaracks are present.

The second lake and the more northerly one is bordered by an exceedingly narrow zone of low-growing plants. The dominant species are Decodon verticillatus and Typha latifolia. Chamaedaphne calyculata, Carex riparia, Panicularia canadensis, and Bromus Kalmii are of secondary importance. The trees come almost to the water's edge. The proportion of red maples among the tamaracks and birches is considerably greater than in the vicinity of the other lake. Otherwise the tree society is essentially the same.

We have illustrated, then, in the bogs at West Lake, First Sister Lake, and Delhi, three stages in the filling of old lake basins. We have seen that, although there are minor variations in the species present, all of the bogs show a series of bog-sedge, shrub, and conifer societies which are genetically related. In the Delhi bog the filling is almost completed. In the bog about to be described we find this process finished, and what was formerly a ring of bog-sedges surrounding an open lake has become an irregular disk forming the central plant society of the area.

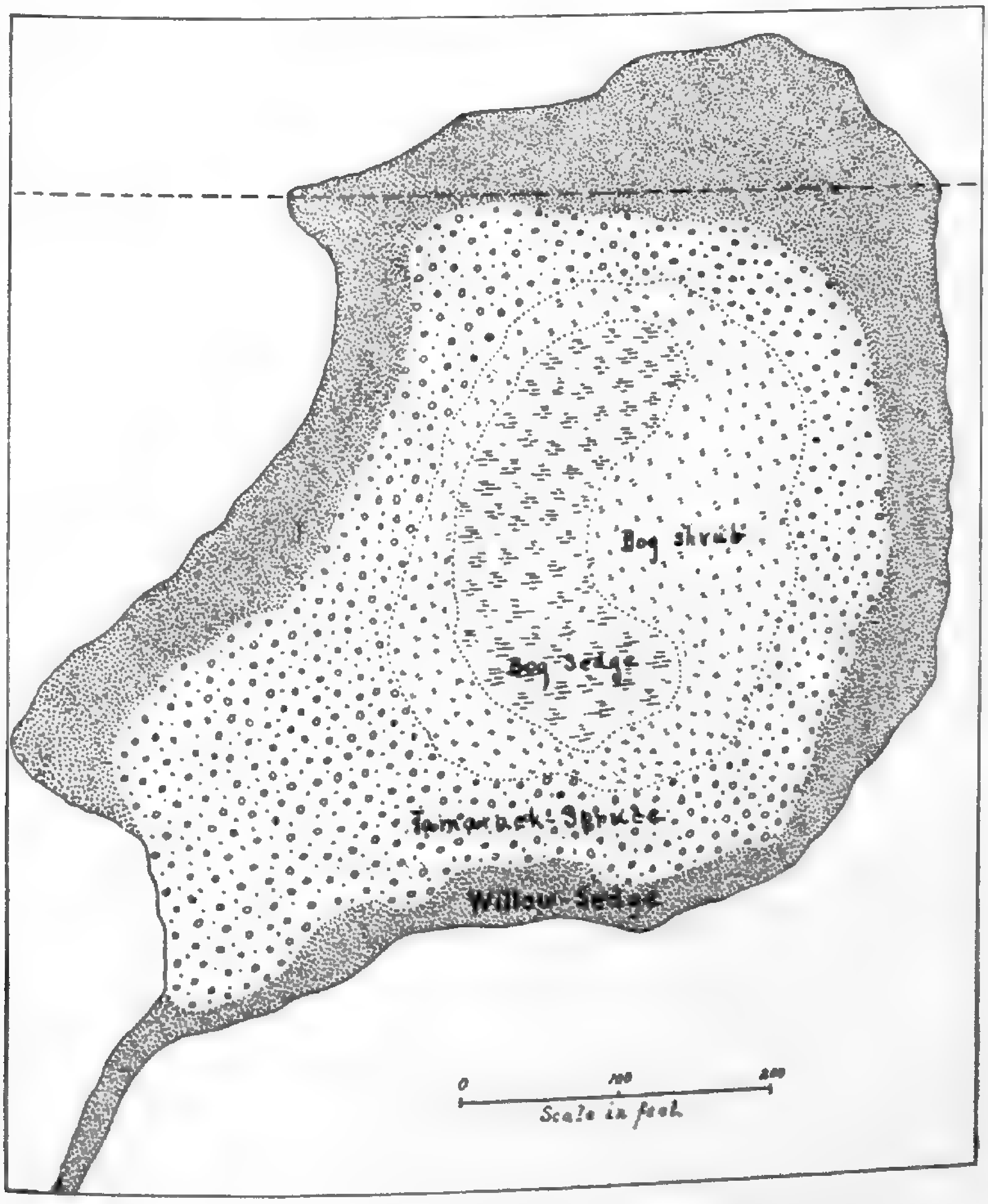

FIG. 9.—Bog near Oxford, Oakland county.

BOG NEAR OXFORD, OAKLAND COUNTY.

Near the northeast corner of Sec. 31, Oxford Tp., there is a bog (*fig. 9*) covering about 4.5 acres (1.8 hectares). Although it lies a few miles beyond the real boundary of the Huron River basin, it is included because it exhibits a flora somewhat different from the other areas, and may be considered as a near approach to the type of bogs occurring farther north. The basin is a depression in the outwash sands and gravels of the interlobate moraine. It is surrounded by hills 25 to 30 feet ($7.5–9^m$) in height above the bog level. During wet weather it has a shallow outlet to the southwest. The land surrounding it has all been cleared and is now under cultivation. As shown by other timber areas in the vicinity, it is probable that the original upland timber was made up in part of Pinus strobus, Quercus coccinea, and Betula papyrifera.

Bog-sedge society.—Toward the center of the bog is a considerable area in which the water level lies just at the surface. The sphagnum is for the most part submerged, and the dominant plants are Carex oligosperma and Scheuchzeria palustris. Occasional plants of the following society are scattered throughout.

Bog-shrub society.—While this zone is characterized by Chamaedaphne calyculata, Sphagnum cymbifolium, S. recurvum, and S. subsecundum, young and dwarfed specimens of the spruce, tamarack, and pine are present in large numbers. The surface formed by the sphagnum is exceedingly rough and marked by hummocks. Among the depressions Eriophorum virginicum, E. vaginatum, Andromeda polifolia, Sarracenia purpurea, and Oxycoccus macrocarpus are abundant.

Tamarack-spruce society.—This society forms a zone completely surrounding the shrub society, and is dominated by trees of Larix laricina and Picea Mariana. Occasional specimens of Pinus Strobus are found, especially toward the southwest corner, where the substratum is somewhat higher than elsewhere. Beneath the trees is an almost impenetrable tangle of shrubs, especially Vaccinium corymbosum and Ilicioides mucronata. The substratum is practically bare of lower vegetation. An occasional mat of Aulacomnium palustre may be found at the tree bases. That this society will come into possession of the central bog area is certainly indicated by the great numbers of young trees among the bog shrubs.

Willow-sedge society.—As usual in the clearing of the adjacent land, the larger trees of the bog margin were also removed, and in their stead has come up a growth of willows. The dominant plants of this zone are Salix sericea, Cornus stolonifera, Spiraea salicifolia, Salix discolor, Carex riparia, and C. stipata. Associated with these plants are Sambucus pubens, Salix nigra, Iris versicolor, Populus monilifera, Dryopteris spinulosa intermedia, Osmunda cinnamomea, Equisetum limosum, Cornus candidissima, Aronia nigra, Rosa Carolina, Juncus effusus, Calamagrostis canadensis, Rubus strigosus, Ilicioides mucronata, Comarum palustre, Carex filiformis, Panicularia canadensis, and Poa flava. Forming a high border about the tamaracks and spruces are numerous large plants of Vaccinium corymbosum and Ilicioides mucronata.

The very marked difference between the vegetation of the central and marginal parts of the bog are worthy of especial note. The former represents the original vegetation of the bog. The latter illustrates most forcibly that under present conditions a very different set of plants springs up and becomes dominant, in spite of the fact that the true bog plants were near at hand when the clearing occurred. This bog also illustrates that stage in the filling of a depression immediately following the disappearance of the lake.

In other bogs near Oxford, Dasyphora fruticosa and Chiogenes hispidula occur among the shrubby growth.

THE DELHI MUSKEAGS.

In the bog north of Delhi which has already been described occur two areas, somewhat to the west of the lakes, which seem to represent a later stage in the history of a bog than that shown by the lakes. These areas, if they were found in northern Michigan, would be termed "muskeags." They are surrounded by large tamaracks, and small tamaracks occur throughout, the smallest specimens toward the center. If the bog at Oxford were to continue its work of filling until the central society disappeared, we should have a bog area of much the same appearance. The small tamaracks stand far apart, and between them is a most luxuriant growth of cassandra and sphagnum. The hummocks rise between 3 and 4 feet (0.9–1.2^{m}) above the substratum. As one attempts to traverse these areas, he sinks knee-deep in the long, fibrous, peat moss.

The total number of species is very small, and includes, besides those already mentioned, Andromeda polifolia, Sarracenia purpurea, Oxycoccus macrocarpus, and a few specimens of Vaccinium corymbosum.

BOG ON CARPENTER ROAD

This bog is situated in the SW. ¼ Sec. 36, Ann Arbor Tp. Its basin is a small depression in the glacial moraine occupying about one-tenth of an acre (*fig. 10*). On the south, west, and north sides it is bordered by clay hills which rise 25 to 40 feet (7.5–12^{m}) above the bog level. The vegetation of the hills is dominated by Quercus velutina, Q. alba, and Q. rubra. With these trees occur Hicoria ovata, Hamamelis virginiana, etc.

On the north side the upland has been cleared, and the land is now under cultivation. From time to time tamaracks have been removed from the bog, until at the present time only the central area remains to indicate the original covering. Accompanying the clearing there has grown up about the tamaracks the usual thicket of shrubs and young trees. As elsewhere, the peat is more thoroughly decayed and the substratum level somewhat lower about the margin than toward the center. This fact is of importance in differentiating the willow-sedge society.

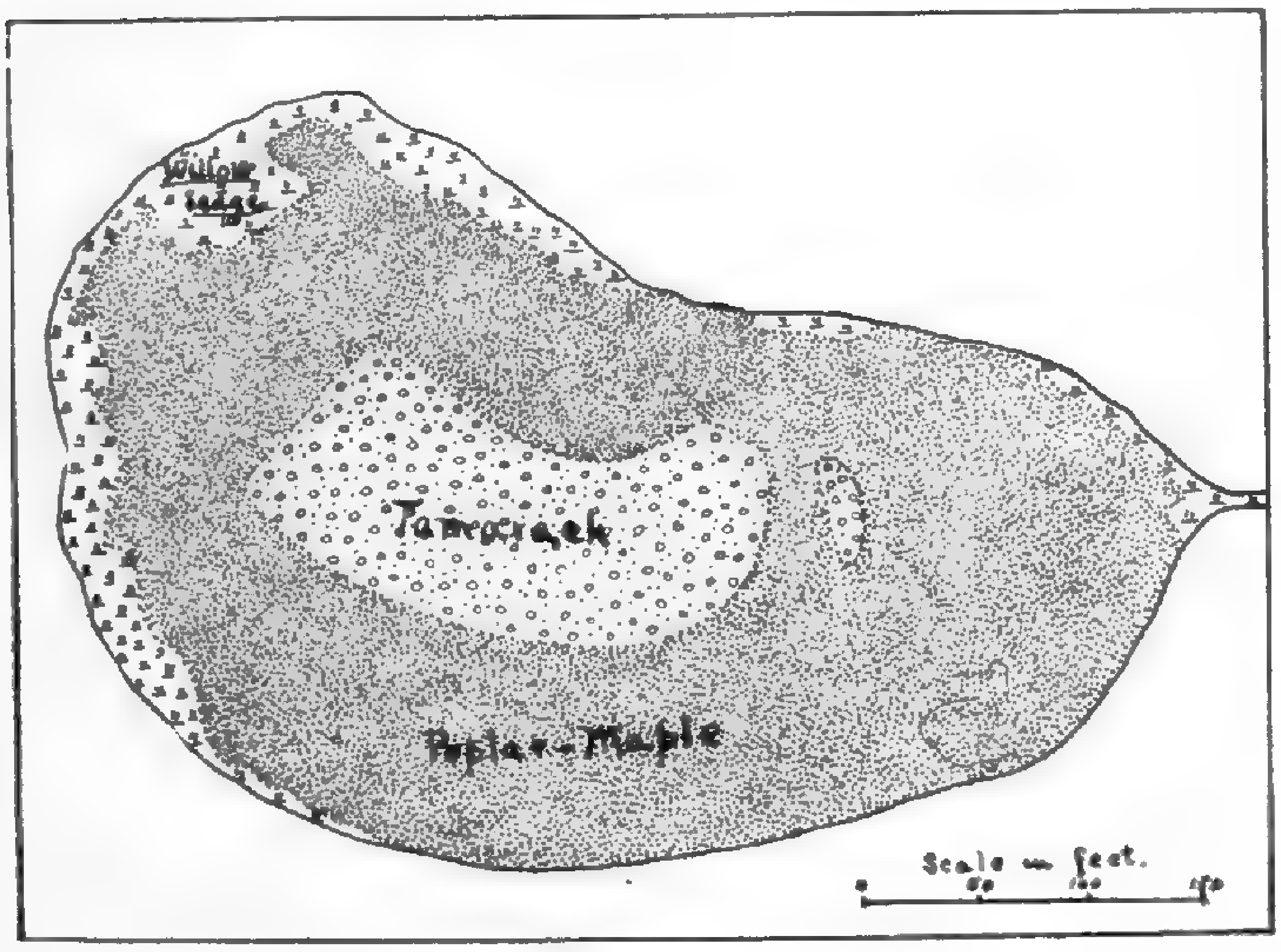

FIG. 10.—Bog on Carpenter road.

Tamarack society.—This society is dominated by the group of rather mature tamaracks. The substratum has the characteristic hummocky surface, marked by large exposed roots, common to such areas. It is overlaid by a loose covering of vegetable matter, made up principally of tamarack needles. The undergrowth is sparse, but most of the bog shrubs and herbs are represented. The more important species are Chamaedaphne calyculata, Sphagnum cymbifolium, S. recurvum, S. subsecundum, Eriophorum virginianum, and Lycopus virginicus. A very noticeable growth about the bases of most of the shrubs is produced by the fungus, Thelephora intybacea. The mycelium in developing its sporophores rises about the stems, frequently to a height of a foot (25^{cm}). From the cylinder thus formed, irregular fan-shaped pilei are developed, which gives the appearance of an elongated brown rosette about the stem bases. Clitocybe laccata and Boletinus porosus are also abundant in the autumn. The partially decayed stumps bear Peltigera canina. Other species occur in this area, but reach their dominance in the next society.

Poplar-maple society.—Here are brought together the remnant of the bog species, and those more characteristic of swamps and clearings. The trees are mainly Populus tremuloides, with a scattering of Acer rubrum. Elm seedlings occur. The shrubby plants, however, make up the bulk of the vegetation. Ilicioides mucronata, Ilex verticillata, Aronia nigra, and Vaccinium corymbosum have almost complete possession, and are struggling with one another for space. All these forms send up stems from the underground parts, so that among them the struggle is largely a mechanical one. However, where the red maple overtops them, the factor of shade enters, and the black choke-cherry and high-bush blueberry are the most tolerant. The mountain holly and black alder prevail elsewhere. The next most important plants are the willows, Salix sericea and S. discolor. Mixed with these are Cornus candidissima, Rubus nigrobaccus, Rosa Carolina, Cornus stolonifera, Spiraea salicifolia, and Rubus strigosus.

Willow-sedge society.—The area dominated by these plants is covered with water in the spring and during moist weather. Although this society is fast being crowded out by the next preceding, it is probable that only a small part of that area was ever occupied by these plants. These plants require a more moist substratum. The dominant species are Salix sericea, Carex riparia, C. stipata, Cornus stolonifera, and Osmunda cinnamomea. In the case of the cinnamon fern found in this bog there is a remarkable development of aerial roots. They are about an inch long and extend outward from the thick rootstock in all directions, forming a dense covering. The roots are thickly covered with root-hairs which have been persistent at least through one winter. The root-hairs are large and brown in color. The appearance of these rootstocks, as a whole, is very suggestive of certain tropical tree ferns. The other species present are Ranunculus abortivus, Polygonum sagittatum, Cicuta bulbifera, Prunella vulgaris, Rubus americanus, Rhus Vernix, Solanum dulcamara, Impatiens biflora, Eupatorium perfoliatum, Calamagrostis canadensis, Dryopteris thelypteris, D. spinulosa intermedia, Doellingeria umbellata, Lactuca spicata, Coptis trifolia, Boehmeria cylindrica, Onoclea sensibilis, Marchantia polymorpha, and Rosa Carolina.

The further development of these societies under present conditions will bring about a complete change. There can be no doubt that the poplars and red maples are the coming trees, with elm a close third. When these have become sufficiently large and numerous to overshade the shrubs, the latter will be killed out, and we shall have in their place the maple-elm forest common to the low grounds. The shrubs, however, are capable of persisting for a great length of time, because of the difficulty of tree seedlings obtaining a start beneath them.

THE CHELSEA BOG.

Of the bogs which have been subjected to clearing, burning, and ditching, by far the most interesting in this region is located just to the southeast of the town of Chelsea. It covers an area of about 50 acres (20 hectares), and the peat is reported to be 40 feet (12^{m}) thick at the deepest places. The divisions into societies, as indicated on the map (*fig. 11*), are based on the most general characters of the vegetation. There are gradations between all of the societies, and these are so gradual that it is difficult to determine definitely the boundaries. Further, owing to the tendency of many of the shrub species to form dense local growths by the development of stems from underground shoots, the smaller associations are very diverse in different parts of the same society.

Birch-vaccinium society.—This mixed society of bog shrubs occupies about one-fourth the area of the bog. Its substratum consists of peat standing about a foot above the average water level. The dominant plants are Betula pumila, Vaccinium corymbosum, Rubus frondosus, Aronia nigra, Vaccinium canadense, and Pteridium aquilinum. Just as common perhaps, but of lower growth, are Rubus hispidus, Spiraea salicifolia, S. tomentosa, Aralia hispida, Chamaedaphne calyculata, and Rumex Acetosella. The ground covering, except beneath the dense shade of the shrubs, is made up of Polytrichum juniperinum. There are many small areas of which this plant now holds exclusive control, and forms a rich carpet of green, yellow, and red, depending upon the season of the year. Where the moss is disturbed by the uprooting of plants, the substratum becomes exceedingly dry. The moss dies out, and in place of it there springs up a growth of Cladonia rangiferina, C. pyxidata, C. gracilis, C. verticillata, C. cristatella, and frequently a small admixture of Rumex Acetosella. These plants gradually close over the surface and aid in the conservation of the moisture. As the conditions become more favorable, the Polytrichum again closes over the area, driving out the lichens. About the borders of the shrubs

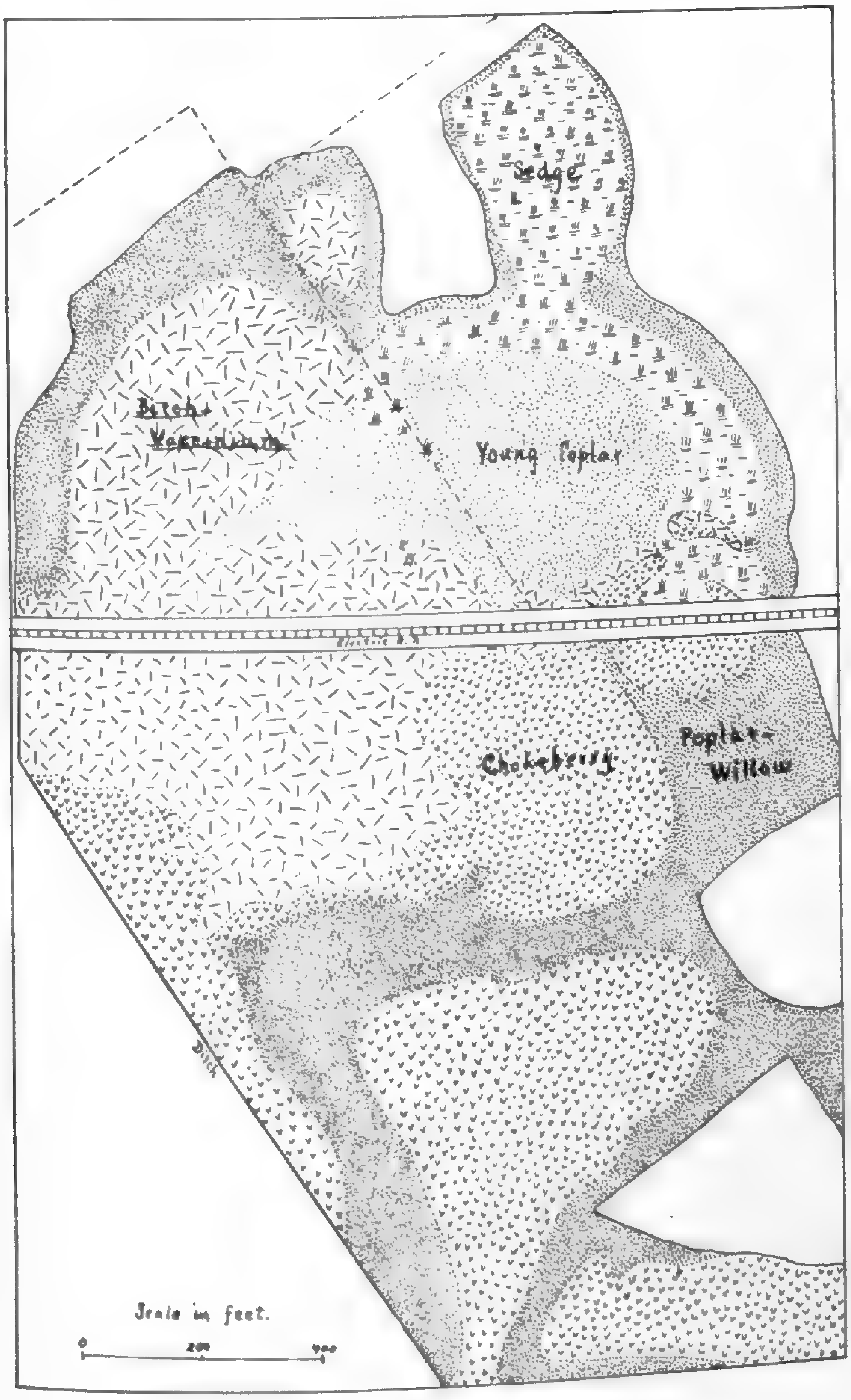

FIG. 11.—Chelsea bog.

the Polytrichum is killed out by the shade. Rumex Acetosella is better fitted to withstand such conditions, and consequently forms an inner border about each group of shrubs. Where depressions occur and are flooded for any length of time, the Polytrichum is replaced by Eriophorum virginicum and Scirpus cyperinus. Along the northwestern border Rubus nigrobaccus is making inroads upon this society. To the north of the railroad, however, the most important changes are being wrought by the development of Populus tremuloides and Quercus velutina. Young trees of the former are now scattered throughout, while the latter is present in small number. The plants of minor importance are Ilex verticillata, Viburnum lentago, Ilicioides mucronata, Amelanchier Botryapium, Euthamia graminifolia, Doellingeria umbellata, Bidens trichosperma tenuiloba, Dulichium arundinaceum, Poa flava, and Sphagnum cymbifolium.

Chokeberry society.—Aronia nigra forms the most dense and exclusive growth that occurs on the bog. Usually the substratum is somewhat lower and more subject to overflow than in the last society. It would seem from observation that this condition is in part due to the chokeberry itself. Owing to its dense growth, it protects the surface of the peat from drought and favors the processes of decay. At the same time it adds very little to the substratum in the way of débris. Where it attains its best development it is practically without undergrowth. About the borders it is mixed with Vaccinium corymbosum, Betula pumila, and Ilex verticillata. Of the smaller plants, Pteridium aquilinum penetrates to the greatest distance. Other species occurring about the borders are mentioned among the other societies.

Poplar-willow society.—About the borders of the bog, and extending to a greater or less extent into its interior, is a dense zone composed of Populus tremuloides, Salix discolor, Quercus velutina, Populus grandidentata, and Salix nigra. By far the most abundant form is the trembling aspen. The substratum varies from areas well above the water level to areas which are constantly submerged. The aspen is also the most important of the plants which are invading the shrub societies. In the relative proportion of the individual species there is the greatest variation at different places in this border zone. Of the more enduring species, Quercus velutina is the most abundant. The other species present are Salix Bebbiana, S. sericea, S. lucida, Prunus serotina, Quercus alba, Q. macrocarpa, Acer rubrum, Betula lutea, Amelanchier Botryapium, Viburnum pubescens, Spiraea salicifolia, S. tomentosa, Corylus americana, Sambucus pubens, Cornus candidissima, C. stolonifera, Cicuta maculata, Aster lateriflorus, Carduus altissimus, Galium asprellum, Osmunda cinnamomea, O. regalis, Ranunculus pennsylvanicus, Calamagrostis canadensis, Viola blanda, Euthamia graminifolia, Bidens frondosa, and Aster Novae-Angliae.

Sedge society.—On the northeast side of the bog is an area dominated by sedges. In the fall of the year it appears to be a uniform area of Scirpus cyperinus, but there are many other species mixed with it. The substratum is low and is mainly characterized by tussocks formed by the sedges. Throughout, occur small clumps of the willows already mentioned. The most abundant accessory species are Isnardia palustris, Calamagrostis canadensis, Carex teretiuscula, C. stipata, C. filiformis, C. fusca, C. oligosperma, C. riparia, and Aulacomnium palustris.

The future flora of this bog appears to be indicated by the rapid growth of the poplars, willows, and oaks. The few tamaracks remaining are approaching maturity and are not being reproduced. The means by which these tree species combat the shrubs is mainly by shading, while the latter in the same way interfere with the development of the tree-seedlings. The time involved in this struggle must be very great, but the ultimate outcome will be an oak forest, the intervening stages being filled in by poplar and willow growths. If, however, the decay of the peat beneath these trees brings the surface to the water level, the poplar-willow stage will be indefinitely prolonged.

GENERAL CONSIDERATION OF THE BOG FLORA.

Beside the trees mentioned in the preceding descriptions, note should be made of the occasional occurrence of the black ash, Fraxinus nigra, and swamp white oak, Quercus platanoides, in bog areas. It frequently happens, when the tamaracks are cut, that the black ash becomes abundant, as in the area one-half mile southeast of Kavanaugh Lake, where it is now associated with Ulmus americana and Acer rubrum. Another example occurs about a mile north of Chelsea in the NE. ¼ Sec. 1, Sylvan Tp. Here in a small area from which the tamaracks were removed, Fraxinus nigra, Quercus platanoides, Fraxinus americana, F. pennsylvanica, Acer rubrum, Ostrya virginiana, Tilia americana, and Liriodendron tulipifera are associated. The undergrowth consists of Solidago patula, S. neglecta, Aster lateriflorus, Mitella diphylla, Euonymus obovatus, Viola pubescens, Agrimonia hirsuta, Cornus florida, C. candidissima, Eupatorium perfoliatum, Rosa Carolina, Viburnum Lentago, Juniperus communis, and Spiraea salicifolia. The substratum is almost entirely occupied by mosses, including Hypnum fluitans, H. Schreberi, H. Blandovii, H. roseum, Thuidium recognitum, and Climacium americanum.

On the farm of James Barton (SW. ¼ Sec. 2, Lyndon Tp.) the black ash, red maple, and American elm have replaced a former growth of tamaracks and black ash.

In a previous publication (**55**: p. 403) the writer called attention to the absence of a genetic relationship between the bog plants and the surrounding vegetation in southern Michigan. This was explained on the basis that the bog vegetation is a relict of former climatic conditions; that it has a genetic relationship with the conifer forest formation of northeastern North America, as shown by studies in northern Michigan and Pennsylvania, and that in this region it has been surrounded by a more southern flora whose center of distribution is the southeastern United States. Consequently no order of succession between the tamarack and the oak floras is to be expected.

When, however, bog areas are cleared or their normal development disturbed, such trees as the black ash, white ash, red maple, and elm replace the tamarack, and a definite order of succession is established.

It was also maintained that present bog habitats are continuations of similar habitats which came into existence when a colder climate prevailed than at present. More recent observations tend to confirm and strengthen this statement.

The dominance of bog and swamp plants respectively in adjoining areas is to be explained largely by the time when the areas came to support their present ground vegetation. If the habitat has existed undisturbed since the time when a colder climate prevailed, the bog plants will be dominant. If it came into existence in recent times, or has been disturbed, it will be dominated by swamp species.

(*To be concluded.*)

BRIEFER ARTICLES.

TOLERANCE OF DROUGHT BY NEAPOLITAN CLIFF FLORA.

(WITH THREE FIGURES)

THE writer has already made mention of several of the most abundant species on the cliffs in the vicinity of Naples.[1] Some of these plants seemed to offer sufficient points of interest to be worthy of more detailed study, and a few notes in regard to their summer condition are here offered.

At Pozzuoli, where most of these observations were made, the strip of fertile soil which skirts the beach is bounded on the landward side by cliffs, in many places quite vertical, rising to a height of thirty to more than a hundred meters. These cliffs are occasionally of trachyte, but most frequently of gray or yellowish tufa, which in softness and porosity closely resembles the softest brick used in interior construction by American builders. Decomposed it makes a moderately rich and very warm soil. The chemical composition of two such tufas (from the little island of Vivara, 8.3 miles (13^{km}) from Pozzuoli, of the same volcanic series and not greatly different age from the Pozzuoli deposits) is as follows:

	Gray Tufa	Yellow Tufa
SiO_2	51.08	45.50
Al_2O_3	13.71	16.05
Fe_2O_3 FeO	13.16	11.69
MgO	4.72	3.20
CaO	7.09	5.03
Na_2O	2.94	2.28
K_2O	2.94	4.12
H_2O	4.58	9.36
CO_2	.....	1.50
Cl	.....	0.40
	100.22	99.13

On account of the porosity and the vertical extent of these tufas, the soil water sinks to great depths, springs (except profound volcanic ones) are unknown, and the southerly faces of the cliffs during the summer months appear perfectly dry.

	July	August
Mean daily temperature, ° C.	24.14	23.96
Mean precipitation, mm.	19.12	23.88

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[1] BOT. GAZETTE **35**: 360–362. 1903.

During the summer of 1904 the maximum temperature at 2 P. M. observed in the superficial layer of soil on the little local deposits of weathered earth on the faces of cliffs, was 57° C.

Occasionally the month of July is quite rainless.

Some experiments on the amount of moisture contained in the material of the faces of tufa cliffs and walls gave the following results:

1904		Loss of moisture at 100° C., per cent.
Aug. 15.	Top of Roman pillar of brick and tufa, portion about ultimate rootlets of *Medicago arborea*	2.1
Sept. 1.	Earth on face of cliff about ultimate rootlets of *Artemisia variabilis*	10.6
Sept. 8.	Earth on face of cliff about ultimate rootlets of *Matthiola rupestris*	13.4
Sept. 9.	Earth on face of cliff about ultimate rootlets of *Artemisia arborescens*	5.4
Sept. 10.	Tufa-like clay, surface of cliff, no vegetation except *Sedum* sp.	0.7

These determinations were made at a time when the autumn rains had not as yet set in, and the tufa and earth examined were nearly at their minimum as regards moisture-content. A few light sprinkles during late August and early September had not materially affected their condition.

In the cliff-side formations about Pozzuoli the most important woody species, arranged roughly in the order of their abundance, are:

1, Artemisia arborescens, L.; 2, A. variabilis, Ten.; 3, Helichrysum rupestre, DC; 4, Inula viscosa, Ait.; 5, Spartium junceum, L.; 6, Medicago arborea, L.; 7, Opuntia Ficus-Indica, Mill.; 8, Mesembryanthemum acinaciforme, L.; 9, Matthiola rupestris, Guss.

Number 5 of this list has been much discussed as a typical summer deciduous xerophytic shrub, and so it did not seem worth while to investigate further its equipment for resisting the difficulties of its environment. Numbers 7 and 8, the succulent members of the formation, are not indigenous and might better be studied in detail in their original habitats. Of the other members of this little flora it may be said that in general they have not the aspect of extreme xerophytes. It therefore seemed likely to be a profitable bit of work to look into the qualifications which enabled these six species to support the very high summer temperature to which they are exposed, with, in general, an inadequate supply of water.

In external appearance the only obvious characteristic common to most of the shrubs considered is the tufted form of the plant. Helichrysum and Matthiola show this well in the shape of the plant as a whole (*fig. 1*) and the Artemisias in the shape of the separate branches. It seems probable that this mode of growth is of use in removing the foliage of the plants as far as possible from the intensely heated cliff surfaces.

The plants in question show few adaptations for extraordinary collection or storage of water. The roots of the Artemisias are often twice or more than twice as long as their stems, but the other four species have comparatively short roots. In all six species the means of checking foliar transpiration are only moderately developed. Most of them during the rainy season transpire abundantly. The loss per hour per 100 square centimeters of leaf surface (reckoning lower surfaces only) for Matthiola is 661^mg^, Helichrysum 750^mg^, Medicago 1200^mg^, and Inula 1431^mg^, at a temperature of about 30° C., when the moderately xerophytic leaves of the olive lose 450^mg^ per hour. The leaf areas for the finely dissected leaves of the Artemisias were difficult to calculate, so twigs of these were compared with olive twigs by weight, and the loss per gram per hour of both species of Artemisia was found to be about 190^mg^ when the loss of an olive twig was 60^mg^.

FIG. 1.—*Helichrysum rupestre* (left), *Matthiola rupestris* (right). May condition.

Putting the means of checking transpiration in tabular form, they may be indicated as follows:

	Leaves summer deciduous	Leaves withering	Leaves paraheliotropic	Leaves sulcate or revolute	Leaves very hairy or sericeous	Leaves aromatic with essential oil
Artemisia arborescens	..	×	..	..	×	×
Artemisia variabilis	..	×	..	..	..	×
Helichrysum rupestre	..	×	..	×	×	×
Inula viscosa	..	×	..	..	..	×
Medicago arborea	×	..	×	..	..	..
Matthiola rupestris	..	..	..	×	×	..

No one of the nine cliff species enumerated is without some xerophytic characteristics, but it is noteworthy that only two of the non-succulent species have ample and obvious protection from injury by drought. The Spartium, leafless during the drier months and with thick wax-coated epidermis and sunken stomata, endures months of rainless heat without injury. The Medicago (*figs. 2, 3*)[1] has a far less xerophytic aspect, but it flourishes not only on the nearly vertical surfaces of tufa cliffs, but also on the bare tops of ancient Roman walls and pillars. It is, indeed, the characteristic shrub of the meager flora of these latter localities, often at a height of 10–20^{m} above the ground and far beyond the reach of any moisture from the soil. Its roots are short and scanty, and the plant contains no mechanism for special storage of water, but the complete shedding of the leaves in early summer renders the shrub secure against fatal desiccation afterward. Unfortunately I was not able to make as many determinations of the rate of transpiration of *M. arborea* under various conditions, as would have been desirable, so the following values are far from exact; still they may serve to explain the tenacity of life of the species. The total transpiration per hour at 30° C. of a twig 8^{cm} long was about as follows:

May 1, leafy twig in water	180^{mg}
May 14, leafy twig in water	120
June 17 leafy twig in water	70
September 14, leafless twig, not in water	5

In the first case above given, the leaves were in the height of their activity; May 14 they looked as green and fresh as at first, but had lost a little of their power to transpire. By June 17 all the leaves had turned yellowish and had taken up permanently their paraheliotropic position. On September 14 the twigs were (and had long been) entirely leafless and appeared rather destitute of moisture. The figures speak for themselves, and the final rate of transpiration, less than 3 per cent. of the maximum,

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[1] For these figures the author is indebted to Mrs. HERBERT S. JENNINGS.

indicates an extremely high degree of adaptiveness to variations in temperature and water supply. The greatly lessened loss of water from the leafless twig of September 14 was certainly in great measure due to its comparatively desiccated condition at the beginning of the half-hour during which it was allowed to transpire. Twigs in vigorous leafy condition (May 14) lost about 7 per cent. as much water through the cortex alone as through leaves and cortex taken together.

It is evident that *Medicago arborea* depends for protection against the excessive transpiration mainly upon its summer-deciduousness. This is shown not only by the lessened loss of water after defoliation, as above stated, but also by the fact that in damp soil, as under large trees of *Quercus Ilex* at Lake Fusaro, where during the larger part of the day in summer the illumination is only from 1 to 5 per cent. of the total, the leaves of this species are hardly at all deciduous during the summer. The aspect of these shade plants (*fig.* 2) is notably different from that of those growing on cliff sides. The former are much taller and relatively more slender, with leaves fewer, larger, and longer petioled. Twigs of shade plants gave about one and one-half times as much leaf area as those of equal length from sun plants. Leaves on individuals growing in deep shade were less numerous than on those growing in

FIG. 2.—*Medicago arborea*, shade form, grown in a situation with one to five per cent. illumination. ×¾.

the sun, but each leaf of the former class was about twice as large as one of the latter.

Like those of a good many other Leguminosae, the leaves of this Medicago take a paraheliotropic position (*fig. 3*) during the hours when they are exposed to bright sunlight. This is identical with the nocturnal position. The movements of the leaflets are so sluggish that it is difficult to ascertain definitely the percentage of illumination necessary to induce the position. As already stated, the leaves take this attitude permanently for some time before they are shed for the summer.

FIG 3.—*M. arborea*, mesophytic form grown in full sunlight; leaflets in paraheliotropic position. ×¾.

Of the other woody non-succulent plants under discussion, the Matthiola alone at the end of the dry season has suffered no material injury. It is difficult to see how this plant, with its not inconsiderable rate of transpiration and its leaves destitute of unusual epidermal protection and with loose, soft mesophyll, maintains itself so successfully during the Mediterranean summer. Its most xerophytic characteristic is the manner in which the leaves are folded together upward along the midrib.

The Helichrysum has a decidedly xerophytic aspect. Its cylindrical looking linear leaves are 30–70^{mm} long and usually only 1.4–1.5^{mm} wide; sometimes 3^{mm} wide. Both surfaces, but especially the lower, are covered with an abundant coating of felted, cobwebby hairs, and in leaves of the narrower type the spaces between the midrib and the recurved leaf margins are quite filled with a mass of hair. But this apparent provision against excessive transpiration, as already shown, does not prevent rapid loss of water, and indeed the poorly developed epidermis and loosely packed cells of the mesophyll are ill adapted to retain water. Helichrysum and Inula both lose more than half of their foliage by drying up before the end of the summer, and many of their branches die to the ground. The Artemisias also lose by drying *in situ* sometimes more than two-thirds of their leaves, but the branches generally remain alive.

All four of these species appear to occupy their cliff-side stations rather because the latter are somewhat free from other competing shrubs than because here is found an ideal environment. Indeed, the Artemisias and the Inula in good soil have a robuster habit and more abundant foliage than along the faces of the tufa cliffs where their presence is most characteristic.

Summing up the results of the observations made upon the nine species dealt with in this paper, the members of this flora may be classed according to their qualifications to endure high temperature with deprivation of water as follows:

Succulents, extremely resistant . . .	*Opuntia Ficus-Indica* *Mesembryanthemum acinaciforme*
Uninjured by drought, retaining all foliage	*Matthiola rupestris*
Summer deciduous, highly resistant . .	*Spartium junceum* *Medicago arborea*
Leaves and branches often dying *in situ*, moderately resistant	*Artemisia arborescens* *Artemisia variabilis* *Helichrysum rupestre* *Inula viscosa*

—J. Y. Bergen, *Naples, Italy.*

A NEW GENUS OF OPHIOGLOSSACEAE.

(WITH ONE FIGURE)

During the spring of 1903 the writer discovered the gametophytes of *Botrychium obliquum* Muhl., and later announced the fact in a catalogue of the pteridophytes of Minnesota.[1] Since that time both sporophyte and gametophyte of this and other species of Botrychium have been subjected to careful study. The gametophytes of *Botrychium virginianum* have been found in large numbers, and a few gametophytes of *B. simplex* and *B. matricariaefolium* were found in 1904. While the results of the investigation are not ready for final publication, it seems at the present time desirable to call attention to the embryo of *Botrychium obliquum*, as it affords evidence bearing on a question now being agitated by others. In two recent papers Campbell[2] has disputed Bower's contention that the Ophioglossaceae are allied to the Lycopodiales. Campbell would derive them directly from the Bryophyta.

The gametophytes of *Botrychium obliquum* are subterranean and destitute of chlorophyll. They grow by a distinct apical meristem, are

[1] Minn. Bot. Studies **3**:249. 1903.

[2] (1) American Naturalist **38**:761–775. 1904; (2) *ibid.* **39**:273–285. 1905.

flattened dorsiventrally, and possess many long rhizoids. They are monoecious. The reproductive organs are developed on the flattened dorsal side and in their organization differ essentially from those of *Botrychium virginianum* as described by JEFFREY.[3]

The oosperm upon segmentation does not develop directly into a spherical protocorm, as is the case in all other ferns which have been studied, but *first gives rise to a long suspensor*, which burrows into the tissue of the gametophyte in the manner characteristic of certain lycopod embryos. At the tip of this suspensor a spherical protocorm is organized, out of which the stem and root apices are shortly differentiated. The axis of the metacorm transfixes the protocorm and all the tissue of the latter, except the suspensor, becomes a permanent part of the metacorm. The embryo does not, therefore, possess a lateral cotyledon (nursing-foot) as does *Botrychium virginianum*. The root grows downward and *emerges from the under side* of the gametophyte, and at a later period the first leaf breaks through the upper surface. The relation of the members in the young embryo and its orientation in the gametophyte are well illustrated by the accompanying figure.

FIG. 1.—Photomicrograph of a section through a gametophyte and young sporophyte of *Sceptridium obliquum*. The section is vertical, and transverse of the gametophyte. The root is already protruded from the under side of the gametophyte, while the position of the first leaf was marked by a pronounced elevation on the upper side. *a*, archegonium; *s*, suspensor; *t*, stem tip; *l*, first leaf; *r*, root. ×60.

A study of the mature sporophytes of the ternate species of Botrychium

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[3] Univ. of Toronto Studies **1**: 1–32. 1898.

discloses unique characters which alone mark them as a natural group entitled to generic rank. Considering, in addition, the anomalous character of their embryos as illustrated by *Botrychium obliquum*, it appears at once desirable to segregate them as a distinct genus.

The writer would therefore suggest the name **Sceptridium** (from σκῆπτρον), in allusion to the scepter-like sporangiophore.

SCEPTRIDIUM, a new genus of Ophioglossaceae.

Stem subterranean, short, erect, with many clustered roots. Sporophyll *dividing near the stem* into a long petioled sporangiophore and a shorter petioled sterile segment. Sporangiophore erect, bi-, tri-, or even quadripinnate, bearing naked, spherical sporangia in two rows. Sterile segment inserted obliquely near or at the surface of the ground, ternately divided or compound. Gametophyte tuberous, subterranean, saprophytic, monoecious. Embryo *with a suspensor* and without a pronounced lateral cotyledon; its axis straight, *the root emerging from the lower side* of the gametophyte.

To this genus should be referred the following described but ill-defined species and varieties:

Sceptridium australe (R. Br.).—*Botrychium australe* R. Br., Prodr. Fl. Nov. Holl. 164. 1810.

Sceptridium biforme (Colenso).—*Botrychium biforme* Colenso, Trans. New Zeal. Inst. **18**:223. 1886.

Sceptridium biternatum (Lam.).—*Osmunda biternata* Lam., Encyc. Meth. Bot. **4**:650. 1797. *Botrychium biternatum* (Lam.) Underw., Bot. Gazette **22**:407. 1896.

Sceptridium californicum (Underw.).—*Botrychium californicum* Underw., Torreya **5**:107. 1905.

Sceptridium Coulteri (Underw.).—*Botrychium Coulteri* Underw., Bull. Torr. Bot. Club **25**:537. 1898.

Sceptridium daucifolium (Hook. & Grev.).—*Botrychium daucifolium* Hook. & Grev., Ic. Fil. **2**: *pl. 161.* 1831.

Sceptridium decompositum (Mart. & Gal.).—*Botrychium decompositum* Mart. & Gal., Mém. Acad. Sci. Bruxelles **15**:—(15). *pl. 1.* 1842.

Sceptridium dissectum (Spreng.).—*Botrychium dissectum* Spreng. Anleit. **3**:172. 1804.

Sceptridium japonicum (Prantl).—*Botrychium daucifolium β japonicum* Prantl, Jahrb. Bot. Gartens Berlin **3**:340. 1884. *Botrychium japonicum* (Prantl) Underw., Bull. Torr. Bot. Club **25**:538. 1898.

Sceptridium Jenmani (Underw.).—*Botrychium Jenmani* Underw., Fern Bull. **8**:59. 1900.

Sceptridium matricariae (Schrank).—*Osmunda matricariae* Schrank, Baier. Fl. **2**:419. 1789. *Botrychium matricariae* (Schrank) Spreng., Syst. Veg. **4**:23. 1827.

Sceptridium obliquum (Muhl.).—*Botrychium obliquum* Muhl., Willd. Sp. Pl. **5**:62. 1810.

Sceptridium obliquum elongatum (Gilbert & Haberer).—*Botrychium obliquum elongatum* Gilbert & Haberer, Fern Bull. **11**:89. 1903.

Sceptridium obliquum Habereri (Gilbert).— *Botrychium obliquum Habereri* Gilbert, Fern Bull. **11**:88. 1903.

Sceptridium obliquum intermedium (Underw.).—*Botrychium obliquum intermedium* Underw., Our Native Ferns, ed. 6, 72. 1900.

Sceptridium obliquum oneidense (Gilbert).— *Botrychium ternatum oneidense* Gilbert, Fern Bull. **9**:27. 1901.

Sceptridium pusillum (Underw.).—*Botrychium pusillum* Underw., Bull. Torr. Bot. Club **30**:50. 1903.

Sceptridium robustum (Rupr.).—*Botrychium rutaefolium* var. *robustum* Rupr., Milde Nov. Act. Acad. Caes. Leop.-Carol. **26**:763. 1858. *Botrychium robustum* (Rupr.) Underw., Bull. Torr. Bot. Club **30**:51. 1903.

Sceptridium Schaffneri (Underw.).—*Botrychium Schaffneri* Underw., Bull. Torr. Bot. Club **30**:51. 1903.

Sceptridium silaifolium (Presl).—*Botrychium silaifolium* Presl, Rel. Haenk. **1**:76. 1825.

Sceptridium subbifoliatum (Brack.).—*Botrychium subbifoliatum* Brack., U. S. Expl. Exped. **16**:317. 1854.

Sceptridium tenuifolium (Underw.).—*Botrychium tenuifolium* Underw., Bull. Torr. Bot. Club **30**:52. 1903.

Sceptridium ternatum (Thunb.).—*Osmunda ternata* Thunb., Fl. Japon. 329. 1784. *Botrychium ternatum* (Thunb.) Sw., Schrader's Journ. Bot. **1800^2**:111. 1801.

Sceptridium Underwoodianum (Maxon).—*Botrychium Underwoodianum* Maxon, Bull. Torr. Bot. Club **32**:220. 1905.

—HAROLD L. LYON, *University of Minnesota.*

CURRENT LITERATURE.

BOOK REVIEWS.

Photomicrographs of plant rusts.

THERE is a difficulty in studying microscopic fungi, from which the student of phanerogamic plants is exempt. It arises from the minuteness of the parts, making it necessary to prepare a slide and place it under the microscope, and sometimes more than one slide, before the essential characters can be seen. As only one slide can be examined at a time, the student must carry a mental picture of the various forms previously examined which he desires to compare with the one under examination. He cannot lay his two or more objects side by side and have them both or all equally under consideration at the same time.

One of the best known means for reducing this difficulty to a minimum is the use of photomicrographs. When skilfully prepared under uniform conditions and magnification they are of great assistance in making close comparisons between a few forms, and immensely facilitate the rapid review of a large series.

Recognizing these facts, together with the additional one that many species are so rare that the student can not hope always to secure a specimen, Professor E. W. D. HOLWAY, of the University of Minnesota, has undertaken to publish a complete series of photomicrographs of the spores of the North American rusts.[1] The work starts out with the genus Puccinia, taking the species up systematically according to hosts. The first number begins with the order Ranunculaceae, having seventeen species, followed by nine other orders. The 45 species of this first number are illustrated by 62 figures, all but one representing the spores as seen in the field of a microscope under a magnification of 250 diameters. The photogravure plates show almost the same perfection of detail as the original photographs, both being of superior quality.

The text accompanying the plates is of the nature of a monograph. Each species is fully described, with synonymy, distribution, and citation of *exsiccati*. The work is all founded upon the specimens and treatises in the herbarium of the University of Minnesota, and is carried out with much critical insight.

The number forms a highly valuable addition to the literature of the plant rusts, and especially so on account of the illustrations, few botanists having such skill in the production of photomicrographs as the author.—J. C. ARTHUR.

Luther Burbank.

THOSE who know Mr. Burbank personally admire his gentle and simple character; they who know his work acclaim him as a genius in plant breeding

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[1] HOLWAY, E. W. D., North American Uredineae, Vol. I, part 1. 4to. pp. iii + 32. *pl. 1–10.* Minneapolis, 1905. $2.00.

and marvel at his dauntless and unselfish devotion thereto; they realize that he has operated on a grand scale, producing, by his acute judgment and his keen insight, even more than by skilful and ingenious manipulation, remarkable and valuable results. He is a great man—doubtless the greatest—in his chosen field; granting that he is now worthy a biography, he is most unfortunate in his biographer.[2]

To describe the personality of a great man one must not only be enamored of the man, but be able to sketch him in attitudes of mind and soul that carry conviction of greatness. To exhibit the work of a great man, one must not only be conversant with the details of the work, but be able to make manifest its nature and its bearings, its problems, and its triumphs.

Mr. HARWOOD is convinced that LUTHER BURBANK is a superlatively great man; but he cannot compel his readers to believe this by mere reiterated assertion. He is sure that the work is marvelous and of surpassing value; but as he obviously knows nothing of horticulture and less of botany, he is incompetent to explain it. He insists *ad nauseam* that Mr. BURBANK is a scientific luminary of the first magnitude; but our author has no inkling of the meaning of scientific training, nor does he know the criteria of a man of science; he does not even perceive that his liberal (and presumably literal) quotations convict his hero of some lack of the scientific spirit, which is even more important than the errors they embody.

Given reasonably clear English and a logical presentation, the actual information in this book could be condensed into a magazine article. It is surprising that a house like the Macmillan Co. should lend its imprint to a volume with the style and English of a sensational newspaper, not to mention consistent misspelling which cannot be laid at the door of the compositor.

As to the work of BURBANK little need be said. Its economic value is unquestionable, even though many of the most wonderful things are not yet quite perfected. And no one will doubt the devotion and few will question the altruism of this man, who like AGASSIZ, has been too busy to make money, except for further prosecution of his work. But withal it must be recognized that he is no "wizard of horticulture;" he has no secrets but skill and insight derived from long experience; he has devised no unusual methods and developed no essentially new ideas in plant breeding. Naturally when he claims to have disproved this scientific theory or that, one hears his opinion and, without doubting his sincerity, remains incredulous until the proof is adduced. If that can be done none sooner than scientific men will recognize and acclaim it. But incredulity is only aggravated by assertion without evidence, and distrust can only be intensified by such absolute misconception of so clear a theory as that of DEVRIES.—C. R. B.

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[2] HARWOOD, W. S., New creations in plant life. An authoritative account of the life and work of Luther Burbank. 12mo. pp. xiv+368. New York: The Macmillan Co. 1905. $1.75.

Organography

THE LARGE English edition of the second part of GOEBEL'S *Organography of plants* has now appeared.[3] The first part has become so indispensable to students of experimental morphology that the translation of the second has been awaited with much interest, and with some impatience as time wore on. As the German edition was reviewed in this journal shortly after its appearance in 1900,[4] little need now be said about the subject matter. The work, as a whole, is an attempt to present the configuration of plants from the point of view of function and environment. While the first part is primarily a discussion of principles, the second is devoted to a more detailed presentation of the structures and variations of the Bryophyta, Pteridophyta, and Spermatophyta. The wide experience of the author in experimental work, and more especially his great wealth of first-hand observation of plants under most diverse conditions, has enabled him to present a mass of detailed information that is of very great value and suggestiveness.

The translation has been accurately done by Professor BALFOUR. "Spermophyta" will strike everyone as a novel form, but it has classical usage as justification and its brevity will probably cause it to displace the more familiar Spermatophyta. The translator has taken wise liberties with the typographical form, by making headings and subheadings that present the matter more clearly to the eye. When he alters the order of figures, however, we think he goes a bit too far. Other points of make-up are open to objection. If the translation had been made into two volumes of nearly equal size, by dividing at the section on Pteridophyta and Spermophyta the work would have been more convenient to handle than in one thin (270 pages) and one thick (708 pages) part. The separate pagination, and calling the volumes "parts," together with the separate numbering of figures seem to us distinct bibliographical mistakes.

The index is very complete and adds greatly to the value of this translation. The index to illustrations should have been made a part of it. Two indexes are never as good as one.—W. B. MCCALLUM.

Mosses and ferns

THE EXHAUSTION of the edition of CAMPBELL'S *Mosses and ferns* and the continuing demand for it have given opportunity for a thorough revision,[5] made necessary by the researches of the last decade. With the experience gained from a first edition, the author who undertakes a second, unhampered by "plates,"

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[3] GOEBEL, K., Organography of plants, especially of the Archegoniatae and Spermophyta. Authorized English edition by ISAAC BAYLEY BALFOUR. Part II. Special Organography. Imp. 8vo. pp. xxiv+708. *figs. 417*. Oxford: Clarendon Press. 1905. $7.00.

[4] BOTANICAL GAZETTE **31**:204. 1901.

[5] CAMPBELL, D. H., The structure and development of mosses and ferns (Archegoniatae). 8vo. pp. vii+657. *figs. 322*. New York: The Macmillan Co. 1905. $4.50.

may reasonably be expected to perfect his book to the limit of his powers, embracing the opportunity not only to bring the work up to date, but also to eliminate crudities of design and execution, well-nigh inseparable from a first edition.

These expectations, unhappily, are not fully met in the revision of *Mosses and ferns*. This is the more disappointing in that the volume is indispensable, both because it is unique in its field, and because of certain undeniably excellent features. These have become well known, and we do not recount them because they are so. They are transmitted, undiminished, to the present edition.

That the book is fairly brought up to date goes without saying, though one may differ from the author as to relative values among some of the newer researches, and may wish that some of the old figures had been replaced by new and better ones. In the bryophyte portion there is less change than among the chapters on pteridophytes, because among the mosses the researches have been fewer and less important. This is shown by space comparisons:

	Pages		Approximate percentage increase	Figures		Approximate percentage increase
	1st Ed.	2nd Ed.		1st Ed.	2nd Ed.	
Bryophyta	217	228	5	107	123	7
Pteridophyta	290	333	15	155	199	25
Totals	519	606	16¾[6]	266	322	21

In the bryophytes there are no notable changes of view;. in the pteridophytes there are some; but on the whole the author believes that later investigations have confirmed his earlier views. The Isoetaceae have been removed from their association with the Marattiaceae and placed after the Lycopodineae, but other large groups hold the same position as in the first edition. The most extensive revision appears in the section on the eusporangiate ferns, where particular attention is paid to the work of Bower.

Some new material is here published for the first time, but it is mostly taken (with due acknowledgment to others) from papers previously published. A new chapter on the nature of alternation of generations discusses the probable origin of the liverwort thallus, the origin and evolution of the sporophyte, and presents the arguments for homologous and for antithetic alternation, the author giving his adherence to the latter theory. He reiterates the opinion also, that the weight of evidence is in favor of a genetic connection of Pteridophyta with Bryophyta, through Anthocerotes. There is also a new chapter on fossil archegoniates, in which Scott's results figure largely.

Some inaccuracies of the first edition are corrected and some persist. Thus, in an attempt to correct the curious error as to the annulus of the moss capsule, the author doubles it on p. 210, but leaves it in the adjacent figure and on p. 213 in its Simon-pure form. The obviously misleading account of the megaspo-

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[6] Greater than either part on account of added chapters.

rangium of Azolla is also retained (p. 414). "Recent" still appears in referring to papers, recent when the first edition was issued in 1895 (*e. g.*, Waldner 1887, Guignard 1889, Buchtien 1887), but now rather ancient.

In style and method of presentation the second edition has no advantage over the first. So far as typography affects it, there seems to be almost ingenuity in selecting for chapter headings and especially for subheads, the most confused and, to a novice, confusing forms. Thus, interpreted by accepted typographical canons, *The biology of the Marchantiales* is a subhead under MONOCLEA; and THE ACROGYNAE is a subhead under ANACROGYNAE, and coordinate with ANELATEREAE and ELATEREAE. Citation of bibliographical references in subheads is awkward and is a new blemish, *e. g.*,

LYCOPODINEAE (*Potonie (3)*; *Scott (1)*; *Solms Laubach (2)*).

The bibliography, to whose enlargement and completeness the author refers in the preface, would have profited by greater care. Not only are there numerous mistakes in the text-references, one paper being cited when another is meant, but there are papers cited in the text which do not appear in the bibliography at all. Five such cases came to light by pure chance—GARBER, PORSILD, ASHWORTH, BAUKE, and GRAND' EURY; how many could be found by searching we know not. As a minor, but not trifling, matter may be mentioned the unsystematic mode of writing citations; *e. g.*, in the same page four of BOWER'S *Studies in the morphology of spore-producing members* are cited thus:

Roy. Soc. Phil. Trans., vol. clxxxv: 1894, p. 473.
London, 1896. [Nothing more.]
Phil. Trans. Roy. Soc., series B, vol. 189: 35–81, 1897.
Phil. Trans., ser. B., vol. 192: 29 138, 1899.

A like variety can be found in the citation of journals. There are traces of a self-consistent system, however, which hardly goes beyond the adoption, from the one most widely used in America, of its most unimportant feature—the colon following the volume number!

Proof-reading throughout the volume has been very bad, for much of which the printing office and the publishers are blameworthy, but not for all.

The index is really absurd. It is charitable to believe that the author farmed this out to an inexpert hand, and what he did not do to spoil it by sins of omission and commission, the compositor did by ingenious disarrangement of a too complex system of indention. *E. g.*, "Hepaticae" (a curious entry when there are 150 pages about them) has thirty-nine bare entries; its subordinate phrase "germination of spores" has one, and "spores" one (the same), while the spores and their germination are referred to dozens of times in the text. "Acrogynae" has five entries, but "Acrogenous liverworts" in the next line has one, and that is not among the five! "Affinities" has only two sub-references, Matonia and Monoclea, whereas almost every large group has under it in the text a conspicuous subhead, like *Affinities of the Musci*, and so on.

In fact, the revision everywhere shows evidences of haste, and as the author signs his preface April 1905, just before he sailed for Europe on his way to South Africa, it seems likely that he was working under pressure that prevented—most unfortunately, indeed—that "careful revision" of which he speaks.

Spite of defects that, by a little more care, the author could easily have avoided, we welcome the new edition and commend it to every botanist as a necessary reference work, even though he have the first.—C. R. B. and C. J. C.

MINOR NOTICES.

IN AN ELEGANT work on the Bahama Islands,[7] published by the Geographical Society of Baltimore, there is an interesting ecological presentation of the vegetation by W. C. COKER, the result of an expedition undertaken in the summer of 1903. The discussion of the plant formations follows accounts of previous botanical work in the Bahamas, the composition and relationships of the flora, and the economic plants. On New Providence Island the author found a sand strand formation made up of the following associations successively inward: *Ipomoea pescaprae* with Paspalum and Sporobolus, Uniola and Tournefortia, Pithecolobium and Salmea, Erithalia and Reynosia, and the silver palm. There are wet and dry pine barrens, the former with an undergrowth of *Inodes palmetto*, the latter with a Coccothrinax. Other formations are those of the salt marsh, the fresh marsh, the coppice, and the rocky shore. On Watlings Island Suriana, Chrysobalanus, and Lantana are prominent on the sand strand, and there are mangrove formations with Conocarpus. The paper closes with a list of the plants collected. There are plates of typical formations, and of some economic plants, and there is a colored plate of Bougainvillea.—H. C. COWLES.

A POPULAR account of all the pteridophytes except the homosporous Filicales, with special attention to ranges, habitat, time of fruiting, manner of growth, folk lore, etc., is given by CLUTE in a new book entitled *The fern allies of North America*.[8] The field notes, which show an intimate acquaintance with the life histories of the various forms, will interest the botanist as well as the layman. The seven keys, by which the genera and species may be identified are as untechnical as an efficient key can be made. Necessary technical terms are defined in a glossary. Both common names and scientific names are given. No attempt is made to treat internal anatomy or morphology.

The illustrations, more than 150 in number, are by IDA MARTIN CLUTE. Details which are of taxonomic importance have been drawn with particular accuracy, so that many of the species might be identified by the illustrations alone.—CHARLES J. CHAMBERLAIN.

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[7] COKER, W. C., Vegetation of the Bahama Islands. The Bahama Islands. pp. 185–270. New York. 1905.

[8] CLUTE, W. N., The fern allies of North America north of Mexico. 8vo. pp. xiv + 278. New York: Frederick A. Stokes. 1905. $2.00 net.

BELIEVING that insufficient attention has been given to the higher fungi as a cause of disease in animals, GUÉGUEN[9] has compiled a volume containing descriptions of all fungi which have been reported parasitic on man and other animals. The material, including the Myxomycetes, is arranged in the following order: Myxomycetes, Oomycetes, Basidiomycetes, Ascomycetes, and Fungi Imperfecti. To the description of each species are added notes on the pathology of the organism so far as known. All fungi that have been reported on animals, even the lowest, are included. Full references to literature are given at the end of each chapter. The volume as a whole will be of greater interest to pathologists than to botanists.—H. HASSELBRING.

HALLIER[10] has published a résumé of the more important features of his natural system of classification[11] with some corrections and additions, which are here noted. The Hydnoraceae and Balanophoraceae are held to be derived through parasitism from epiphytic Cactaceae; the Gnetaceae do not belong to the gymnosperms, but are reduction forms near the Loranthaceae, Myzodendraceae and Santalaceae; and Casuarina is nearly related to Betula and Alnus.—C. J. CHAMBERLAIN.

NOTES FOR STUDENTS.

IN A NOTE in the Comptes Rendus,[12] RÉNÉ MAIRE summarized the results of his cytological study of the mitosis in the ascus of *Galactinia succosa*, describing the existence of "protochromosomes," or chromatic granules formed during the prophases of the first division, and which united during the metaphase into the four chromosomes of the equatorial plate. In a more recent publication,[13] based upon a more detailed study of Galactinia as well as several other Ascomycetes, MAIRE has endeavored to explain the significance of the protochromosomes and to recognize certain specific characters of the first division in the ascus. He believes this division to be heterotypic, comparable to the heterotypic division of higher plants. The secondary nucleus of the ascus at the time of its greatest size shows long, fine, much intermixed chromatic filaments, which have been furnished to it by the two primary nuclei. Later these chromatic filaments approach and fuse two and two. It has been impossible to determine whether or not this bivalence is a result of a folding of a single thread or of the union of two different filaments. At this time the filaments are collected to one side of the nucleus into a compact synaptic ball, which later undergoes complete dissolution into chromatic granules or protochromosomes. At the time the centrosomes and the

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[9] GUÉGUEN, F., Les champignons parasites de l'homme et des animaux. 8vo. pp. 299. *pls. 10.* Paris: A. Joanin & Cie. 1904. 20fr.

[10] HALLIER, H., Neue Schlaglichter auf das natürliche System der Dikotyledonen. Phylogenetische Betrachtungen. Imp. 8vo. pp. 15.

[11] BOT. GAZETTE **35**: 223. 1903.

[12] Compt. Rend. Acad. Sci. Paris **137**: 769. 1903.

[13] MAIRE, RÉNÉ, Recherches cytologiques sur quelques Ascomycétes. Ann. Mycol. **3**: 123–154. *pls. 3–5.* 1905.

internuclear aster appear, these protochromosomes leave the achromatic substance, being attracted about four centers to form the four definite chromosomes. Each of the four definite chromosomes undergoes a longitudinal fission, the two halves of which separate at the metaphase, undergoing a new longitudinal splitting during their passage to the poles. This second split is often very distinct during the anaphase of this division, when eight chromosomes may be counted. During the prophases of the second division eight chromatic elements reappear, which unite two and two to form the definite chromosomes of the equatorial plate. The two halves of each chromosome separate, four passing to each pole. The first division of the ascus MAIRE believes therefore to be preceded by a true synapsis, very similar to that described by STRASBURGER for *Thalictrum purpurascens*. He believes the protochromosomes should be interpreted as the gamosomes of STRASBURGER. The segregation and re-collection of the chromatin of two primary nuclei assures a complete rearrangement of the chromatin in the definite chromosomes of the secondary nucleus. MAIRE designates the fusing nuclei as primary and the resulting fusion nucleus or ascus nucleus as secondary. These phenomena, together with the longitudinal splitting preceding the metaphase of the first division, and the longitudinal fission during the metaphase of the second division, which split is much more complete than in phanerogams, all show that the first mitosis in the ascus is heterotypic, analogous to the first division of all normal spore mother-cells, while the characters presented by the second mitosis are those of a homotypic division. MAIRE further believes that the third division is a typic one, where the spirem directly segments into the four chromosomes, which only divide at the metaphase. The proof that the first division in the ascus is heterotypic certainly favors the view that the numerical reduction of chromosomes occurs immediately after the fusion which produces the nucleus of the ascus. This hypothesis finds support in the fact that the number of chromosomes in the mitoses in the ascus and in the ascogenous hyphae is the same as in *Pyronema*. MAIRE has not been able to count the chromosomes of the ascogenous hyphae. He admits the fact that the number of chromosomes may vary in different species of the Ascomycetes, just as this number varies in higher plants, instead of being always four as he has previously maintained. In *Galactinia succosa* the centrosomes and the spindle have an intranuclear origin, while the polar radiations have an extranuclear origin, developing independently of the intranuclear part of the achromatic figure. The ascus presents the cytological characters of secreting cells. In the epiplasm are found basiphile granules entirely distinct from the metachromatic granules, and often a sort of latex. The nucleus is able to take an active part in the elaboration of certain secretory products.—J. B. OVERTON.

A RECENT paper by FISCHER[14] on the Cyanophyceae, while reaffirming in the main his earlier conclusions,[15] presents some further additions to the cytology

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[14] FISCHER, A., Die Zelle der Cyanophyceen. Bot. Zeit. **63**^{1}:51–130. *pls. 2.* 1905.

[15] FISCHER, A., Untersuchungen über den Bau der Cyanophyceen und Bakterien. Jena. 1897.

of this group, a subject which is already overburdened with the results of much speculation rather than careful and accurate observation.

FISCHER'S results on the microchemical detection of certain substances in the cell are far from convincing, since a comparison with the opposed results of other authors leads rather to a realization of our needs of trustworthy microchemical tests for distinguishing certain carbohydrates and proteids than to FISCHER'S conclusions It is not at all demonstrated that FISCHER is able even to distinguish with certainty between a carbohydrate and a proteid substance, although he seems to be perfectly sure of his test.

A new test is given for glycogen, which FISCHER designates as the "tannin-safranin stain." He regards glycogen as the first visible product of assimilation. This is produced in the Cyanophyceae in such large quantities that, although in some instances 75 per cent. of the cells of a filament may be using up this food-substance in active division, there is always left a surplus which is stored up in the "central body." In large species, *e. g.*, *Oscillatoria princeps*, the central body is large enough for the storage of a considerable amount of unchanged glycogen, which in the treated sections assumes the form of large granules and irregular masses.

FISCHER'S test for glycogen in this instance may be called into serious question, since the majority of writers on this subject interpret these same bodies as of a proteid nature and not carbohydrate. We are left in serious doubt, in fact, as to whether FISCHER'S glycogen granules are to be referred to the albuminous "slime globules," or to the "chromatin granules" of earlier authors, both of which bodies may be readily detected in the "central body" of the larger Oscillatorias.

FISCHER concludes on the other hand, that in the smaller forms, the limited room for storage necessitates the condensation of the glycogen, hence it is here converted into another carbohydrate, "anabaenin," which is stored up in the central body, either in the form of *Zentralkörnern* or as "pseudomitotic" loops. The number of these twisted rods is in some instances apparently constant, and, further, their similarity to chromosomes and their equal division between the two daughter cells arises, according to FISCHER, from the striving, not after an equal distribution of valuable material, but only the distribution of "lästigen Ballast"!

The author thinks that it is probable that this "carbohydrate mitosis" may be the forerunner of the nuclear mitoses of such low forms. At first it is merely a ballast-divider; but later, nuclein might be deposited, and then the central body would assume the true nuclear character. But FISCHER denies emphatically that the central body as it is at present is a nucleus; nevertheless he would agree that nuclein-like substances also occur in the Cynophyceae, but holds that they exist in a finely divided state in the cytoplasm and are not yet formed in special bodies. He thus returns to the old, much-exploited view of the scattered or distributed nucleus. Such scattered nuclein bodies he fails to show, however, in any of his figures.—EDGAR W. OLIVE.

ITEMS OF TAXONOMIC INTEREST are as follows: N. L. GARDNER (Univ. Calif. Publ. Bot. **2**:169–180. *pl. 18.* 1905) has described a new genus (*Nigrosphaeria*) of ascomycetous fungi, parasitic on Pseudhydnotria, one of the Tuberaceae.—N. L. BRITTON (Bull. N. Y. Bot. Garden **4**:115–127. 1905), in a second paper entitled "Contributions to the flora of the Bahama Islands," has described new species of Coccolobis, Caesalpinia, Canavalia, Hibiscus, Heliotropium (2), Lantana (2), Cestrum, Stemmodontia, and Anastraphia.—W. A. MURRILL in his twelfth paper on the Polyporaceae of North America (Bull. Torr. Bot. Club **32**:469–493. 1905) has described twelve new genera of this family (*Irpiciporus, Dendrophagus, Spongiporus, Rigidiporus, Earliella, Cubamyces, Coriolellus, Microporellus, Flaviporellus, Aurantiporellus, Aurantiporus, Pycnoporellus, Phaeolopsis*), making new names for species formerly referred to Boletus, Polyporus, Fomes, or Trametes. Earliella alone is possibly new.—K. K. MACKENZIE (*idem* 495–506) describes three new varieties and creates two new specific names under Onosmodium, and refers *O. Thurberi* to *Macromeria Thurberi.*—In a sixth paper on Crataegus (Rhodora **7**:162–164. 1905) C. S. SARGENT describes two new species of Tomentosae.—M. L. FERNALD (*idem*) refers the common *Symphoricarpos racemosus* Auct., with leaves glabrous beneath, to the new var. *laevigatus;* those with leaves pilose beneath to the type, and those with leaves whitened beneath to var. *pauciflorus.*—A. BORZI establishes (Nuova Notarisia **16**:20. 1905) two new genera of Chrococcaceae, *Planosphaerala* and *Bacularia.*—W. A. SETCHELL describes (*idem* 59–63) a new genus, *Peyssonneliopsis*, a parasitic alga distributed under a manuscript name in 1903, as no. 649 of the Phycotheca Boreali-Americana.—MAX FLEISCHER (Hedwigia **44**:301–329. 1905) describes as a new genus of the Indian Archipelago, *Aerobryopsis*, to receive ten species mostly belonging to a section of Neckera, Eriocladium, which, though preoccupied, was raised to generic rank by DUSÉN. A dozen new species, all issued in Exsicc. Musci Archipel. Ind. Series VII. 1904, are also described.—F. BUBÁK and E. KABÁT (*idem* 350–358) describe new species of fungi from Bohemia; Phyllosticta (3), Vermicularia (1), Ascochyta (3), Diplodina (1), Leptothyrium (4), and Ramularia (1).—H. CHRIST (*idem* 359–370) publishes the list of ferns collected by ULE in the Amazon region, including one new species each of Elaphoglossum, Polypodium, Pteris, Lindsaya, Asplenium, Aspidium, Alsophila, and Danaea.—The whole of the first part of vol. 38, Engler's Bot. Jahrb., is devoted to descriptions of new species of African plants. The following new genera are established: by R. SCHLECHTER (Bot. Jahrb. **38**:1–56. 1905) *Auxopus, Genyorchis* (Orchidaceae), and *Neoschumannia* (Asclepiadaceae); by H. HARMS (*idem* 74–79) *Platycelyphium* and *Stemnocoleus* (Leguminosae); by A. ENGLER (*idem* 94–101) *Dicraeanthus, Winklerella* (Podostemonaceae) and *Tridesmostemon* (Sapotaceae).—C. R. B.

IN THE large literature on Bordeaux mixture, secondary physiological effects on plants, not due to the fungicidal action of the mixture, have frequently been described. These effects are of two kinds: first, a stimulating effect, resulting in darker green, thicker foliage, with increased starch production and decreased transpiration; second, direct toxic action on the foliage and fruits. The whole question, on which many conflicting views have been published, has been critically examined by SCHANDER.[16] Many writers have attributed the stimulating action of Bordeaux mixture to the entrance of small quantities of copper into the plant, both through the cuticle and through the stomata. SCHANDER finds that leaves injected with a solution of $CuSO_4$, 1 part in 10,000,000, and allowed to lie in the solution 24 hours, showed poisonous effects, while much more concentrated solutions were unable to penetrate the uninjured epidermis when applied externally. The argument is that the cuticle prevents the penetration of very dilute solutions of copper, such as might result from solution of the particles of copper compounds applied to the leaf, but if any copper enters the cells the results are injurious, never stimulating. By growing plants in water cultures with dilute solutions of copper, it was found that the young roots were gradually killed, whereupon another crop of roots was formed, which also was finally killed, etc. Here again there was no stimulating action, although the top of the plant remained uninjured, showing that the copper was accumulated by the root cells, even from very dilute solutions, but was not passed on into the vascular system. In soils, a more concentrated solution of copper was required to produce toxic effects on account of their absorption. By appropriate experiments it is also shown that neither the lime compounds nor the traces of iron produce stimulating effects. The true explanation of the phenomena is found in the physical action of the coating itself. The same results were produced by shading plants with glass to which a spray of Bordeaux mixture had been applied, also by the use of thin paper or dust. Good results were obtained only in bright sunny weather, while injury resulted during cold rainy seasons. This, no doubt, explains the conflicting reports of various investigators. The toxic effect of the mixture is found to be due to solution of the copper, caused by the secretions of glandular hairs as in the peach, phaseolus, and sunflower.—H. HASSELBRING.

THE FINAL sections of DAVIS'S *Studies on the plant cell*[17] have appeared. Section IV deals with cell unions and nuclear fusions. The subject is treated under three heads: (1) protoplasmic connections between cells, (2) sexual cell unions and nuclear fusions, and (3) asexual cell unions and nuclear fusions. The writer says, "The test of a sexual act must lie with the history of the elements which fuse. If they are shown by their morphology and developmental history to be sexual cells or gametes, then their fusion becomes a sexual process." Asexual unions and nuclear fusions are treated under three heads: (1) cell fusions which have apparently no sexual relations, (2) cell fusions which are substitutes for a normal ancestral sexual process now suppressed, and (3) extraordinary modifications of

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[16] SCHANDER, R., Ueber die physiologische Wirkung der Kupfervitriolkalkbrühe. Landw. Jahrb. **33**:517–584. 1904.

[17] DAVIS, B. M., Studies on the plant cell. Amer. Naturalist **39**:217–268, 449–499, 555–599, 695–740. 1905.

what may have been originally sexual processes but which at present serve some peculiar and special function.

Section V deals with cell activities at critical periods of ontogeny in plants. The literature is discussed under the headings, apogamy, apospory, hybridization, and xenia. Historical accounts are given, but most of the space is devoted to cytological papers of the last three or four years. About 150 papers are cited in the bibliography. Section VI, which concludes the series, is entitled "Comparative morphology and physiology of the plant cell." The material is treated under the heads: the simplest types of plant cells, comparisons of the structures of some higher types of plant cells with simpler conditions, some apparent tendencies in the evolution of mitotic phenomena, the essential structures of the plant cell and their behavior during ontogeny, and the balance of nuclear and cytoplasmic activities in the plant cell.

The series as a whole contains a fuller treatment of the subject than that given in KOERNICKE'S recent paper, *Der heutige Stand der pflanzlichen Zellforschung.*[18] The writer's personal views are expressed freely throughout the work. The bibliography of recent literature is quite complete.—C. J. CHAMBERLAIN.

LANG[19] has studied the structure and development of Cyathodium, a tropical genus of Marchantiaceae. The few species occur in the deep shade of tropical forests, in dark caves, in the crevices of walls, or even on paths in more exposed positions. The two forms studied (*C. foetidissimum* Schiffn. and *C. cavernarum* Kunze) were collected in the Malay Peninsula and the material was preserved in alcohol. One interesting feature of the investigation was that it made possible a comparison between one of the least reduced and the most reduced form in the genus. The antheridia are borne on small disk-shaped antheridiophores, developed from the lower surface of the thallus, and at maturity are essentially similar to those of other Marchantiaceae. LEITGEB'S surmise that the antheridial wall is not formed of a layer of cells was definitely set aside for both species. In both species the archegonia stand on the morphologically upper surface of the thallus, in *C. cavernarum* actually retaining this position, but in *C. foetidissimum* becoming displaced so as to appear to be borne upon the under surface. The development of the sporogonium in the main resembles that of other Marchantiaceae, the sporogenous tissue and the greater part of the wall of the capsule being derived from the epibasal cell, and the foot and the base of the capsule wall being derived from the hypobasal cell. The four cells at the base of the foot grow out into a number of relatively long tubular processes, each of which may branch once or oftener, thus greatly increasing the absorbent surface of the foot. The conclusion is reached that the supposed close relationship of the genus with Targionia is confirmed; and that it is probably a reduction group of species,

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[18] See BOT. GAZETTE **39**:30–31. 1905.

[19] LANG, WILLIAM H., On the morphology of Cyathodium. Annals of Bot. **19**: 411–426. *pls. 21–22.* 1905.

derived from a form not unlike Targionia by adaptation of the gametophyte to shady and damp situations, and by changes in the sporogonium induced by the alterations in the gametophyte.—J. M. C.

Drimys, a genus of the Magnoliaceae, and a neighboring genus, Trochodendron, have long been known to resemble gymnosperms in the structure of their wood, which consists entirely of tracheids with bordered pits. Hallier, in his recent scheme of phylogeny, places Drimys in the Drimytomagnoliaceae, an hypothetical group of the Magnoliaceae derived from the Bennettitales or nearly related Cycadales. A paper by Strasburger[20] gives the results of a study of the ovule, embryo sac, fertilization, and endosperm and early stages in the development of the embryo of *Drimys Winteri*. In all these particulars the development is that of a typical angiosperm, with not the slightest suggestion of gymnosperm characters!

Strasburger takes this occasion to express his views as to the nature of the endosperm and embryo-sac structures. The formation of endosperm is still regarded as a continuation of an interrupted development of the prothallium, the fusion of polar nuclei which precedes it being a secondary phenomenon. In the usual development of the embryo sac the two polar nuclei lie in a mass of cytoplasm surrounded by a common plasma membrane. Under such conditions it is usual for nuclei to fuse. The synergids are not regarded as eggs, but rather as cells of the prothallium. The condition found in the ovules of Gnetum is not regarded as a forerunner of the condition found in the embryo sacs of angiosperms. Gnetum is rather the last member of a line of development.—Charles J. Chamberlain.

Wiesner has recently written several papers on leaffall,[21] one of which, on summer leaffall, has been reviewed in the Botanical Gazette.[22] A second paper deals with *Trieblaubfall*, or leaffall in connection with the development of leaf buds, and of course found only in evergreens. This type of leaffall is associated with ombrophily, a habit characteristic of essentially all evergreens. The external factors which so strongly influence leaffall in summergreens are of little account here. The third paper treats of frost leaffall. If the absciss layer freezes, the leaf drops at once, but if the rest of the leaf freezes, while the absciss layer remains unfrozen, leaffall occurs more slowly. In some cases leaffall is due to high turgescence in the cells of the absciss layer. The final paper is a presentation of the biological significance of leaffall, and the author's conclusions are the result of many years of investigation. Leaffall is absent in plants where

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[20] Strasburger, E., Die Samenanlage von *Drimys Winteri* und die Endospermbildung bei Angiospermen. Flora **95**:215–231. *pls. 7–8.* 1905.

[21] Wiesner, J., Ueber den Treiblaubfall und über Ombrophilie immergrüner Holzgewächse. Ber. Deutsch. Bot. Gesells. **22**:316–323. 1904. Ueber Frostlaubfall nebst Bemerkungen über die Mechanik der Blattablösung. *Idem* **23**:49–60. 1905. Die biologische Bedeutung des Laubfalles. *Idem* **23**:172–181. 1905.

[22] Bot. Gazette **38**:153. 1904.

leaves and stems die simultaneously, as in ephemerals, most annuals and biennials, and monocarpic plants generally. Leaffall is absent in most herbs, and present in most woody plants, especially in those which require much light in connection with bud development; this light is secured when the leaves have fallen. Leaffall is less pronounced or even absent in woody plants whose buds never lack sufficient light. Leaffall occurs in woody plants after injury or death, or when they develop in conditions where normal functions cannot be performed.—H. C. COWLES.

CHANDLER[23] has examined the "seedlings" of a number of ferns, mostly belonging to Polypodiaceae. In nearly all the cases studied a protostele was found to pass into the condition of siphonostele or dictyostele by the appearance, inside the xylem of the central cylinder, first of phloem, then of endodermis, and lastly of fundamental tissue which communicates at the foliar gaps with the fundamental tissue of the cortex. Usually several leaf traces are given off before the central cylinder incloses fundamental tissue, and at this level the core of the central cylinder consists of phloem. The writer concludes that "the primitive type of vascular system in the ferns is a solid rod of vascular tissue, which may be a solid xylem strand surrounded by phloem, or an amphiphloic strand." The writer follows JEFFREY in considering the parenchymatous pith of the central cylinder to be of the same morphological nature as the cortex; curiously enough he hesitates to apply this generalization to certain species of Osmunda, though he considers the rule to hold good for *O. cinnamomea.* The results of the investigation seem to confirm the view that the ontogeny of the vascular system resembles what has probably been its phylogeny. The change from a solid to a tubular central cylinder is attributed to the necessity for an efficient attachment of the leaf traces. The mode of origin of double leaf traces in several genera is carefully described, and well represented in the plates accompanying the paper.—M. A. CHRYSLER.

Within the past few years, Dr. LUJO ADAMOVIČ has published a number of papers dealing with the plant geography of Servia. A recent contribution[24] has to do with the sand steppes of that country. This is not a single unified formation, but comprises a group of formations, similar in ecology, distribution, and life-history. Meadows contain hygrophiles, grasses which form close mats, and there are but few annuals or coarse herbs; steppes, on the contrary, contain xerophiles, and there are many annuals and coarse herbs; heaths are in places where soil and air are wet, and they contain half-shrubs, among which a single species often dominates. The life-history of the sand steppes is interesting. Sand commonly encroaches on vegetation, but the reverse is the case in wet years.

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[23] CHANDLER, S. E., On the arrangement of the vascular strands in the "seedlings" of certain leptosporangiate ferns. Annals of Bot. **19**:365–410. *pls. 18–20.* 1905.

[24] ADAMOVIČ, L., Die Sandsteppen Serbiens. Engler's Bot. Jahrb. **33**:555–617. 1904.

The pioneer plant of the drifting sand is the delicate annual, *Polygonum arenarium;* a Veronica and a Tragopogon are other early plants. No grasses appear among the pioneers, though a Festuca appears the second year, with a Euphorbia; before long, these later species form mats and exclude the first named. When the dunes have become well covered with vegetation, and rather thoroughly established, they are termed *Sandpussten.* Plants found exclusively in sand are termed psammophytes, while those found elsewhere but preferring sand are termed psammophiles. The photographs accompanying the paper well illustrate the dunes and the *Pussten.*—H. C. COWLES.

A SERIES of five papers by BROWN and ESCOMBE record the fundamental researches made by these investigators at Kew during a period of three years. The paper here cited[25] is the largest of the series and to it the others are supplementary. Part I is descriptive of apparatus devised by the authors for accurately determining the amount of CO_2 in air before and after photosynthesis. The rate of photosynthesis as determined by the direct measurement of CO_2 entering was found to be one-third to one-fifth that found by SACHS with his method of increase in dry weight. When all sources of error were accounted for, the discrepancy was reduced to 50 per cent. An investigation of SACHS's method shows that the errors are cumulative, so that it is very unreliable. The estimation of foliar respiration as made by the authors agrees with that made by BLACKMAN. An investigation of the "energetics" of the leaf shows that only a small part of the radiant energy incident upon a leaf is used for photosynthesis, the "economic coefficient" being only 6.5 per cent. in full sunshine. Even in moderate light the supply of photosynthetic energy is far greater than the leaf can use. The surplus of energy which the leaf is compelled to absorb is dissipated by the vaporization of water in transpiration and by the thermal emissivity required in the constant adjustment of the temperature of the leaf to that of the surrounding air.—RAYMOND H. POND.

AT THE suggestion of Professor WITTROCK, HESSELMAN[26] undertook the completion of an investigation begun by STENSTRÖM, but broken off upon the latter's death in 1901. Having noticed that in Sweden southern slopes are often covered by pines, and northern slopes by spruce, and that birch woods ascend higher on sunny than on shady mountain slopes, STENSTRÖM determined upon a careful study of the distribution of plants on slopes of various directions. He chose for this study railway embankments, because they present similar soils and all kinds of slopes. The results obtained were very uniform, southern slopes having chiefly xerophiles or weeds (such as *Anthemis tinctoria*, *Convolvulus arvensis*, *Barbarea vulgaris*), and northern slopes having a more closed and

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[25] BROWN, H. T., and ESCOMBE, F., Researches on some of the physiological processes of green leaves, with special reference to the interchange of energy between the leaf and its surroundings. Proc. Roy. Soc. B. **76**:29–112. 1905.

[26] HESSELMAN, H., K. O. E. Stenström's Studier öfver Expositionens Inflytande på Vegetationen. Arkiv för Botanik **4**:1–54. 1905.

mesophytic vegetation (with *Aira cespitosa, Ranunculus acris,* etc.). No differences of moment were observed between east and west slopes. Although no close study of factors was made, it was clear that the direct influence of radiation, or its influence on moisture and temperature, is the controlling element. A figure is given of a valley in Lapland with a wood of birch with scattered pine and spruce on the southern slope, and a tundra with *Salix herbacea, Andromeda hypnoides,* and other characteristic forms on the northern slope.—H. C. COWLES.

SALMON has extended his investigations on the specialization of parasitism in the Erysiphaceae to include the ascospores of several forms.[27] In former experiments with conidia it was found that conidia from *Bromus commutatus* would infect *B. hordeaceus* but not *B. racemosus* or *B. mollis. B. hordeaceus,* however, acts as a "bridging species," so that if conidia from *B. commutatus* are used to inoculate *B. hordeaceus,* the conidia produced on *B. hordeaceus* will in turn infect *B. mollis.* A similar specialization occurs in the ascospores. Ascospores from *B. commutatus* infect *B. hordeaceus,* but not *B. racemosus.* The conidia produced from the former infection were then used to infect *B. mollis.*

Another series of experiments was performed in order to see whether *E. graminis* from wheat, which also infects *Hordeum silvaticum,* could by continuous culture on *H. silvaticum* be made to lose its power of infecting wheat. The fungus was cultivated for five generations on Hordeum, but showed no signs of losing its power of infecting wheat. Successive generations of the fungus on Hordeum seemed to show a weaker power of infecting that plant, but this is probably explained by the fact that only the younger leaves of Hordeum are susceptible to infection.—H. HASSELBRING.

OLIVER and TANSLEY give a detailed account of their methods for surveying vegetation, applicable where the ground is reasonably flat.[28] The two methods employed, the method of squares and the gridiron method, are related, and their especial advantage is to exhibit the characteristics of an area where the vegetation is complex and yet definitely related to physiographic features. These methods have been employed in the salt marshes of the north coast of Brittany, and in some respects resemble the quadrat methods used by CLEMENTS. The method of squares is employed for mapping on the scale of 1:250 or 1:500, squares one hundred feet each way being made from a base line; such squares correspond to a five-inch square in the notebook. The gridiron method is used for detailed work, an area twenty-five feet square being measured out; this area is then divided off by tapes into smaller areas, 5×25 feet. Here six inches correspond to one-tenth of an inch in the notebook, so that great accuracy can be secured. The methods could be advantageously modified by the use of metric units and relations.

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[27] SALMON, E. S., On specialization of parasitism in the Erysiphaceae. III. Ann. Mycol. **3**:172–184. 1905.

[28] OLIVER, F. W., and TANSLEY, A. G., Methods of surveying vegetation on a large scale. New Phytol. **3**:228–237. 1904.

On the maps, samples of which are given, physical features are represented by continuous lines, plant associations by dotted lines, and contour lines by alternating dots and dashes.—H. C. COWLES.

THE RELATIONS of *Arum maculatum* with insects, as described by HERMANN MÜLLER and others, have become so much a part of the literature of entomophily that it is a distinct shock to read the testimony of GERARD,[29] as given at a recent meeting of the Linnean Society. The current account is contradicted as follows: "The obstruction caused by the hairs is not such as of itself to prevent the insects escaping;" for "the hairs are not stiff or sharp; they do not point consistently downwards; frequently they are not in the narrow throat of the tube; they are so far apart as to leave ample room for such small insects [as those that habitually visit the plant] to pass between them; they never extend to the walls of the chamber, leaving a free passage in that direction;" and, besides, insects may be observed to escape. That many insects do not escape is evident, which the observer explains as follows: "The truth seems to be that the plant drugs the insects, reducing them to a state of imbecility, which is the true cause of their inability to get away; and that finally they not only die from the effects of the treatment, but their succulent portions are absorbed by the Arum, which thus claims to rank as carnivorous."—J. M. C.

IN A PAPER entitled *Evolution of cellular structures* COOK and SWINGLE discuss some of the fundamental problems of plant cytology.[30] The treatment is interesting for their arrangement of the material, and for the development of a terminology covering the various phases of the life histories of plants based upon the nuclear conditions. Whether such elaborate systems of nomenclature really tend to clearness of expression may be open to question. They are apt to give the framework of a subject a degree of rigidity, which is found to be impracticable because it cannot yield. In a number of points their outline seems open to criticism. The statement that "there has been no evolution away from sexuality" is surprising, when one recalls the wonderful development of the kelp family, of Caulerpa, and of numbers of forms whose reproductive processes are entirely asexual, together with the remarkable extent of apogamy. The establishment of apogamy in such large and successful genera as Alchemilla, Hieracium, Antennaria, Taraxacum, and Thalictrum, indicates the possibility of apogamy in higher plants to an extent that is probably scarcely suspected.—B. M. DAVIS.

DETTO has joined the army of investigators who are taking up anew the floral color problem as related to insects.[31] In view of the experiments of FOREL,

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[29] GERARD, JOHN, *Arum maculatum* and its relations with insects. Jour. Botany **43**:231–233. 1905.

[30] COOK, O. F., and SWINGLE, W. T., Evolution of cellular structures. Bull. 81. Bureau Plant Indus., U. S. Dept. of Agric. 1905.

[31] DETTO, C., Versuche über die Blütenorientirung und das Lernen der Honigbiene. Flora **94**:424–463. 1904.

ANDREAE, GILTAY, and BUTTEL-REEPEN, he regards color attraction as established in the case of Apis and Bombus. However, the experiments of GILTAY and BUTTEL-REEPEN show that color becomes less and less a source of attraction, when bees become acquainted with the neighborhood which they frequent. Again the visits of bees to flowers that are not showy indicate that high coloration is not absolutely necessary to secure the visitation.

WERY also has attempted to find out the exact value of color as source of attraction for bees.[32] She finds that flowers with colored organs attract bees more than do flowers of the same species without colored organs, that honey does not serve to attract bees, that artificial flowers attract bees as well as do natural flowers, and that perfume attracts but little. The author thinks that she has demonstrated that color and form together offer four times as much attraction to bees as pollen, perfume, and nectar combined.—H. C. COWLES.

ADAMS has published[33] another paper on postglacial migration, in which he discusses the successive "waves" of life from the close of the Ice Age until now. After the first or tundra wave, there followed a wave from the western and northeastern centers, consisting of peat bog and conifer forest plants and animals. The third wave was from the southeastern and southwestern centers, migration taking place from the former along the coastal plain and the Mississippi River; from the southwestern center there came desert plants and animals. The paper concludes with general remarks concerning the definiteness of the laws of migration. Invading elements enter a new region at definite places, and they remain in definite associations. The succession of ecological associations is similar even in diverse regions, where the biotic components are different. A particular merit of this paper is that animals and plants are considered together, forming a biota, rather than a fauna or a flora.—H. C. COWLES.

BESSEY has continued his studies on the encroachment of the forest upon the Nebraska prairies.[34] After a general discussion of the factors involved in migration, instances are given of recent natural enlargements of the forest area. Such advances of the forest are to be observed especially where protection is afforded from fires and grazing animals. An especially favorable place for the effective germination of tree seeds is along a forest border in a moist valley, where tall weeds readily develop and choke out the prairie grasses. The forest border may advance from a few feet to several hundred feet in a single year. The paper is accompanied by maps showing the distribution within the state of each of the native Nebraska trees.—H. C. COWLES.

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[32] WERY, J., Quelques expériences sur l'attraction des abeilles par les fleurs. Bull. Acad. Roy. Belgium **1904**:1211–1261.

[33] ADAMS, C. C., The postglacial dispersal of the North American biota. Biol. Bull. **9**:53–71. 1905.

[34] BESSEY, C. E., Plant migration studies. Univ. Nebraska. Studies **5**:1–27 1905.

PAMMEL[35] has given an interesting account of the Iowa species of Gymnosporangium whose aecidium or roestelia stage causes the rust of apple leaves. The species described are: *Gymnosporangium globosum, macropus, clavipes, nidus-avis*, and *clavariaeforme*. A considerable number of inoculation experiments are here reported, showing the genetic relationship between the teleutosporic stage on the red cedar and the roestelia stage on apple and other rosaceous plants. PAMMEL has not secured as good results in combating the apple rust by Bordeaux spraying as was reported by EMERSON.[36] The removal of the cedar-apples is again recommended as the best method of preventing injury from the apple rust.—E. MEAD WILCOX.

SHELDON[37] has published an account of his investigations in West Virginia of the anthracnose of the watermelon, due to *Colletotrichum lagenarium*, and minor notes regarding a few of the other diseases of cucumbers and melons. The anthracnose was successfully combated by spraying with the usual Bordeaux mixture, but the cupram did not give so good results. In a later bulletin,[38] in a way a preliminary hand-book of the diseases of that state, he presents brief notes regarding some of the more important diseases of cultivated plants observed in West Virginia during 1903 and 1904.—E. MEAD WILCOX.

MINSSEN holds[39] that the experiments of BLANCK[40] were faulty in method and his data consequently incorrect, invalidating his conclusion that the diffusion of water in humus soils is retarded by the presence of free humus acids. MINSSEN finds, on the contrary, that neither free humus acids nor other organic or mineral acids in dilute solutions can diminish the rate of diffusion of water or of salt solutions. The physiological dryness of humus soils, then, cannot be due to the free humus acids, nor can these influence plant growth in this particular. —C. R. B.

IN THE *Report of the Botanist*[41] of the Hatch Experiment Station of Massachusetts for 1904 there is given a bibliography of great value to the plant pathologist. It includes, as the title states, "Some important literature relating to dis-

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[35] PAMMEL, L. H., The cedar apple fungi and apple rust in Iowa. Bull. Iowa Exp. Stat. 84:1–36. *figs. 1–11*. 1905.

[36] EMERSON, R. A., Apple scab and cedar rust. Bull. Neb. Exp. Stat. 88:1–21. *figs. 1–9*. See BOT. GAZETTE **40**:149. 1905.

[37] SHELDON, J. L., Diseases of melons and cucumbers during 1903 and 1904. Bull. W. Va. Exp. Stat. 94:119–138. *pls. 1–5*. 1904.

[38] SHELDON, J. L., A report on plant diseases of the state. *Idem* 96:69–99. *pl. 6* (not numbered).

[39] MINSSEN, H., Ueber die Diffusion in sauren und neutralen Medien, insbesondere im Humusboden. Landw. Versuchs-Stat. **62**:445–476. 1905.

[40] BLANCK, Ueber die Diffusion des Wässers im Humusboden. *Idem* **58**:145. 1901.

[41] STONE, G. E., Rept. 17, Mass. Hatch Exp. Stat. **1904**:31–34. 1905.

eases, etc., of crops, not generally believed to be caused by fungi and insects." This constitutes a supplement to the similar list of the literature of diseases due to parasites that was published by STURGIS.[42] Both lists should be bound together for more convenient reference by the working pathologist.—E. MEAD WILCOX.

HANS HALLIER[43] has published a curious, personally flavored account of his scheme of classification of seed plants. It is a statement of his right to be heard, a complaint that his views have been given scant attention or none at all, and a general outline of his scheme. Of course it will be taken up or discarded on its merits, without any reference to personal rights or feelings.—J. M. C.

COOK and HORNE,[44] in the first bulletin of the new Cuban Experiment Station, give the results of a year's study of the insect enemies and certain diseases of tobacco in Cuba: the seed-bed disease due to a species of *Rhizoctonia;* mosaic disease; leaf-spot due to *Cercospora nicotiana;* and an injury due to the parasitism of *Orobanche ramosa.*—E. MEAD WILCOX.

ANDREWS finds,[45] contrary to the results of DEMOOR,[46] that the nucleus cannot divide independently of the protoplasm, and that if the protoplasm is killed or temporarily disabled, the nuclear activity is soon (sometimes immediately) affected.—C. R. B.

TO THE LIST of plants which form chlorophyll in darkness Miss BITTNER adds[47] *Fegatella conica,* various mosses, the reduced leaves on fern rhizomes, the spores of Osmunda regalis, and scales of Selaginella.—C. R. B.

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[42] STURGIS, W. C., Literature of plant-diseases. Rept. 24, Conn. Exp. Stat. **1900**:255–297. 1901.

[43] HALLIER, HANS, Provisional scheme of the natural (phylogenetic) system of flowering plants. New Phytologist **4**:151–162. 1905.

[44] COOK, M. T., and HORNE, W. T., Insects and diseases of tobacco. (English edition.) Bulletion Estación Central Agronómica de Cuba 1:1–23. *figs. 1–20.* 1905.

[45] ANDREWS, F. M., The effect of gases on nuclear division. Annals of Bot. **19**:521–530. 1905.

[46] DEMOOR, Contribution à l'étude de la physiologie de la cellule. Archives de Biol. **13**:30–54. 1894.

[47] BITTNER, KAROLINA, Ueber Chlorophyllbildung im Finstern bei Kryptogamen. Oesterr. Bot. Zeits. **55**:302–312. 1905.

NEWS.

Macmillan and Company announce for publication before Christmas a textbook on plant pathology by Dr. D. T. MacDougal and F. S. Earle.

Professor R. Thaxter, of the Cryptogamic Laboratory of Harvard University, is spending his sabbatical year in a collecting trip in South America.

Oakes Ames, R. C. Leavitt, and A. A. Eaton of the Ames Botanical Laboratory, left October 10 for a period of study in British and European herbaria.

Dr. Forrest Shreve, Bruce Fellow in the Johns Hopkins University, sailed from Baltimore on October 13 for Jamaica, where he will spend the year in work on the anatomy and physiology of epiphytes.

The twenty-first annual meeting of the Indiana Academy of Science was held at Shortridge High School, Indianapolis, December 1, 1905, under the presidency of John S. Wright. The program contained twenty papers on botanical topics.

Professor B. L. Robinson has returned to his duties at the Gray Herbarium after spending several months in Europe, where he attended the Vienna Congress and made brief studies in various herbaria. Mr. M. L. Fernald has been promoted to an assistant professorship.

Mrs. A. G. Helmer, of Helmer, Georgia, is prepared to send by mail small boxes showing the products of the cotton plant for school and home study. The box contains photographs of the flower, pod, and leaf; a ripe pod with seeds *in situ;* samples of seed after ginning, hulls, meal, crude and refined oil; and a miniature bale of cotton.

Professor W. A. Kellerman will leave before the holidays for Guatemala to continue his mycologic studies begun there last winter. He reports a rich harvest of parasitic fungi and hopes to publish next summer some of the results of the two seasons' work. Several new species are on hand and special phases of the subject are under investigation. Minor commissions of specialists will be gladly executed, so far as feasible; requests should be made immediately.

Dr. J. C. Arthur, of Purdue University, Lafayette, Indiana, is preparing the manuscript upon the plant rusts of North America for early publication in the *North American Flora.* As this is the first attempt to present the uredineous flora of North America with reasonable completeness, much difficulty is naturally experienced in securing material enough to show approximately the geographical distribution of species. Any assistance, through the gift of duplicate specimens or the loan of herbarium sheets, will be greatly appreciated. The commonest, as well as the rarer species, are desired.

At the Desert Botanical Laboratory, Tucson, Arizona, Professor F. E. Lloyd, of Columbia University, spent June and July in a continuation of his studies on the physiology of the stomata of desert plants. Dr. V. M. SPALDING has returned for his third winter's research work at this laboratory, and is extending his studies on the absorption of water and water vapor by representative shrubs and trees. The resident investigator, Dr. W. A. CANNON, is observing the transpiration of certain salt-loving plants which are growing in the vicinity of Tucson, and continuing his work on the anatomy of *palo verde* (Parkinsonia) and other plants.

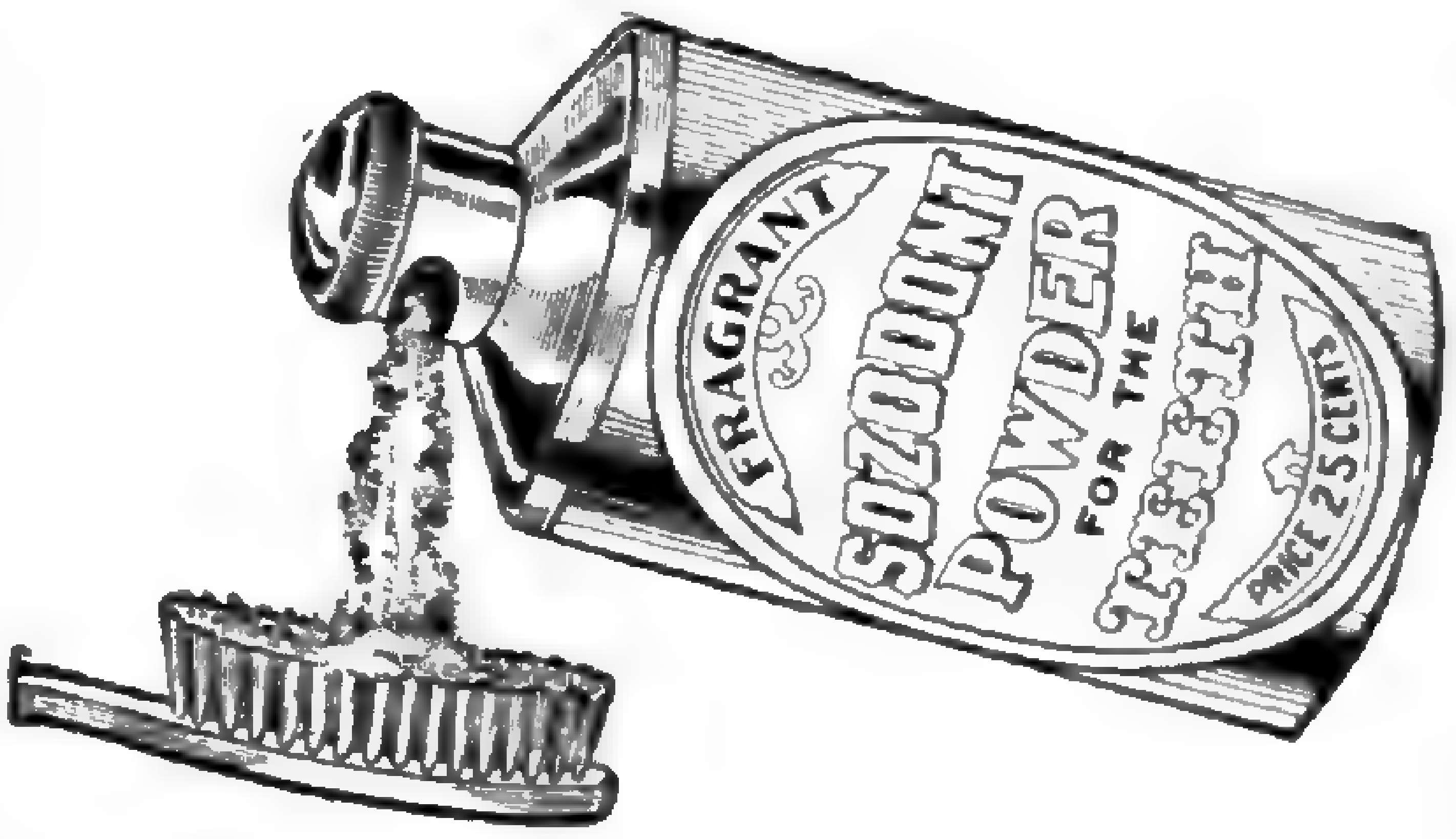
ON JULY 15 appeared the first number of the semi-monthly *Repertorium novarum specierum regni vegetabilis*, under the editorial direction of Dr. FEDDE, and from the publishing house of GEBRÜDER BORNTRAEGER. The earlier numbers each contain sixteen pages, filled with diagnoses of new species, some original (South American collections mainly), some reprinted. It is the purpose to reprint in this journal the scattered descriptions of new species from all journals and floras, as published, and to publish original papers of the same kind. The subscription price at present is *M* 10 per year; or for an edition printed on one side only, for card catalogue use, *M* 15.

THE UNIVERSITY OF TEXAS has recently improved its equipment for courses in mycological and bacteriological technique. For the present, only elementary mycology and bacteriology for sanitary engineers are given, but it is intended later to offer advanced courses. Professor W. L. BRAY, head of the School of Botany, is preparing an elementary plant geography of Texas, to be issued as a bulletin of the University of Texas for the affiliated schools. The major part of the bulletin will deal with the factors influencing distribution and the phenomena of adaptation. He is also continuing his study of the forest conditions of the "Big Thicket" country of southeastern Texas. A. M. FERGUSON, instructor in botany, has been endeavoring by experiments on an extensive scale to improve the quality and yield in southern corn, and is investigating the acclimatization of corn races.

DURING the month of September, Professors OLIVER, TANSLEY, and BLACKMAN conducted a field expedition to the Bouche D'Erquy in Brittany, somewhat on the lines of a previous expedition, but more thoroughly carried out, and embracing more points of attack. The place selected both in 1904 and 1905 was an extensive area of salt marshes. The party was divided into three sections: (1) under charge of Professor OLIVER, continuing and contouring the general map of the area, begun in 1904; (2) under charge of Mr. TANSLEY, charting the vegetation, in which work CLEMENTS'S quadrat and transect methods were employed, in addition to the grid system of OLIVER and TANSLEY; (3) under charge of Dr. BLACKMAN of Cambridge, determining the physical factors of the habitats, especially the salt and water factors. It is planned to continue these expeditions in succeeding years, and permanent quadrats have been plotted to facilitate the study of vegetation changes. This study is one of the most practical and systematic yet attempted, and the division of labor amongst the members of the party, each section being under charge of a competent specialist, is particularly commendable.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties are printed **in bold-face** type; synonyms in *italics*.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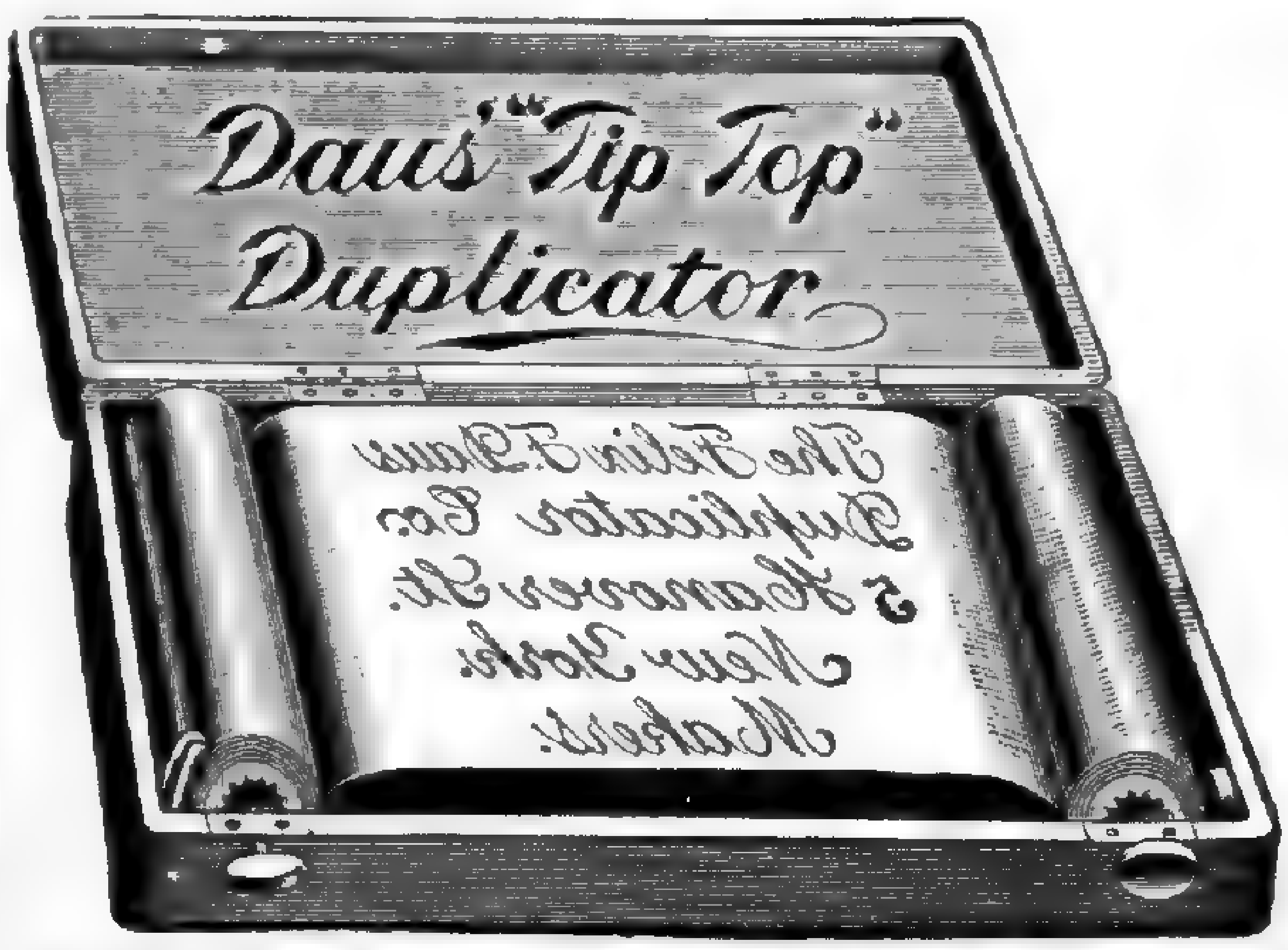
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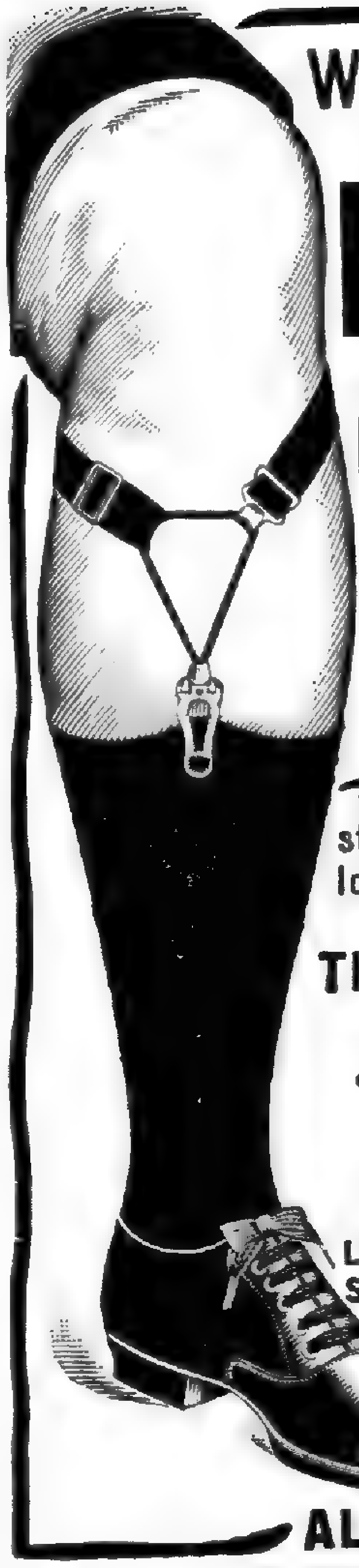


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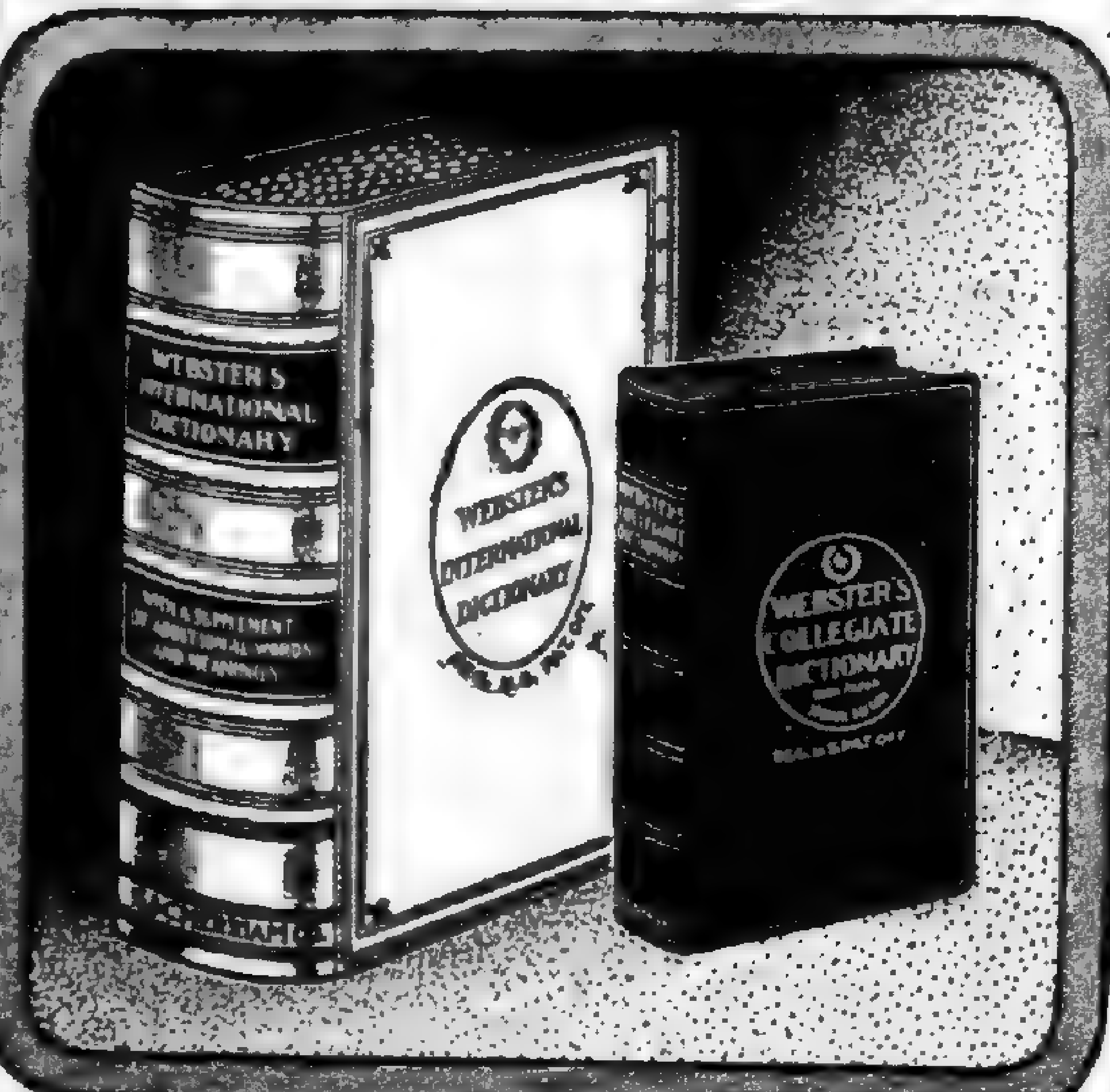

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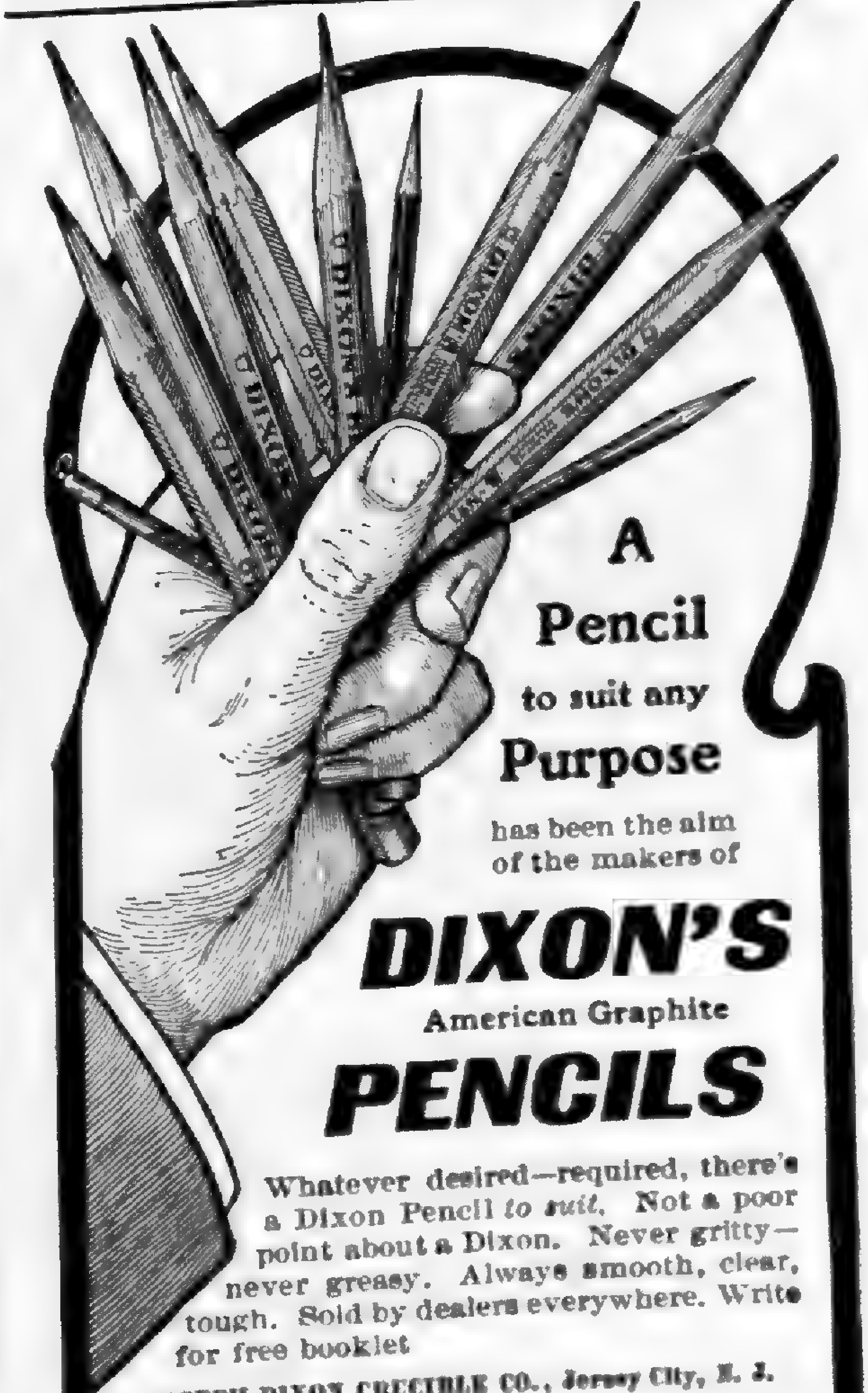

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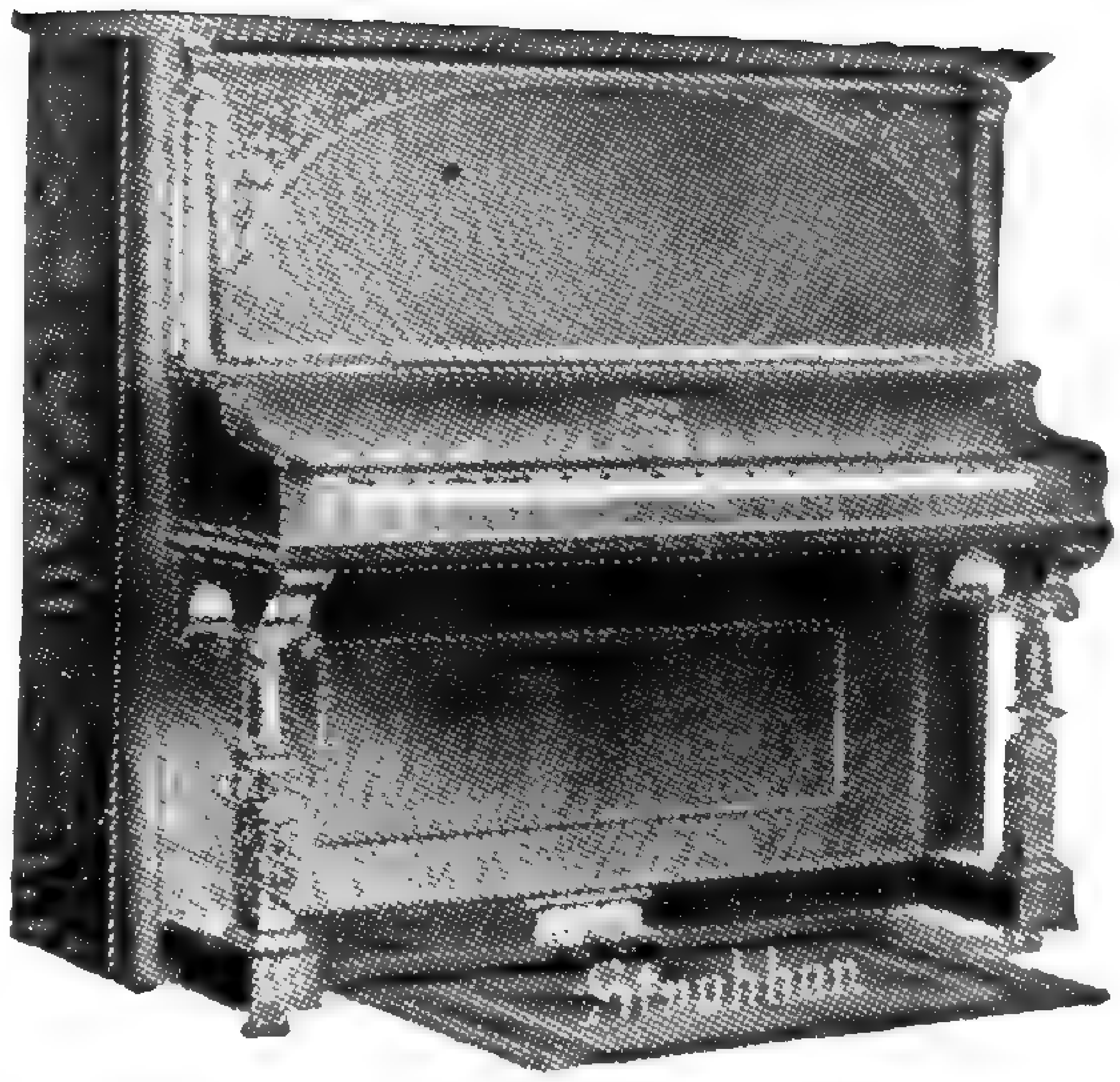


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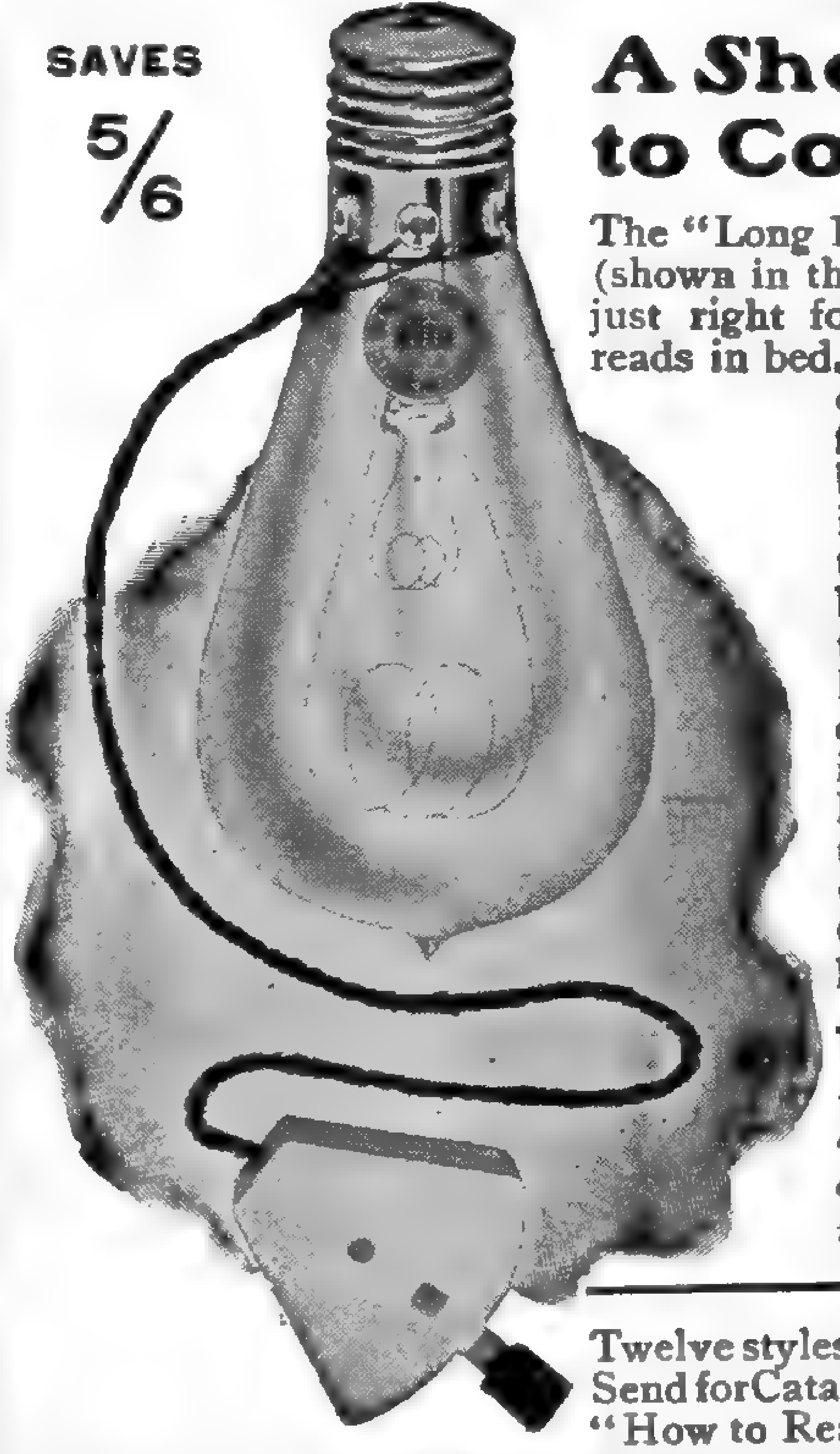

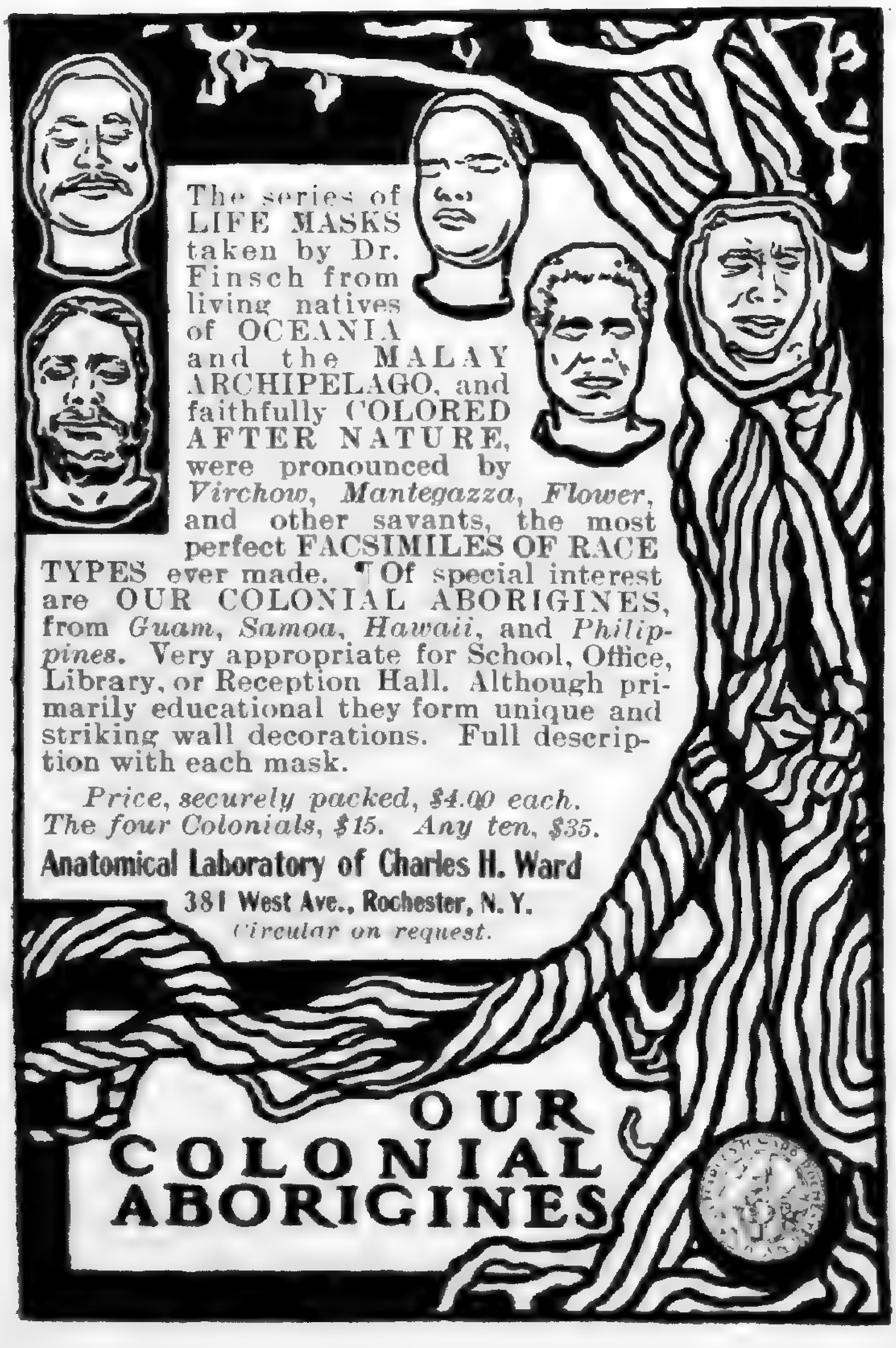

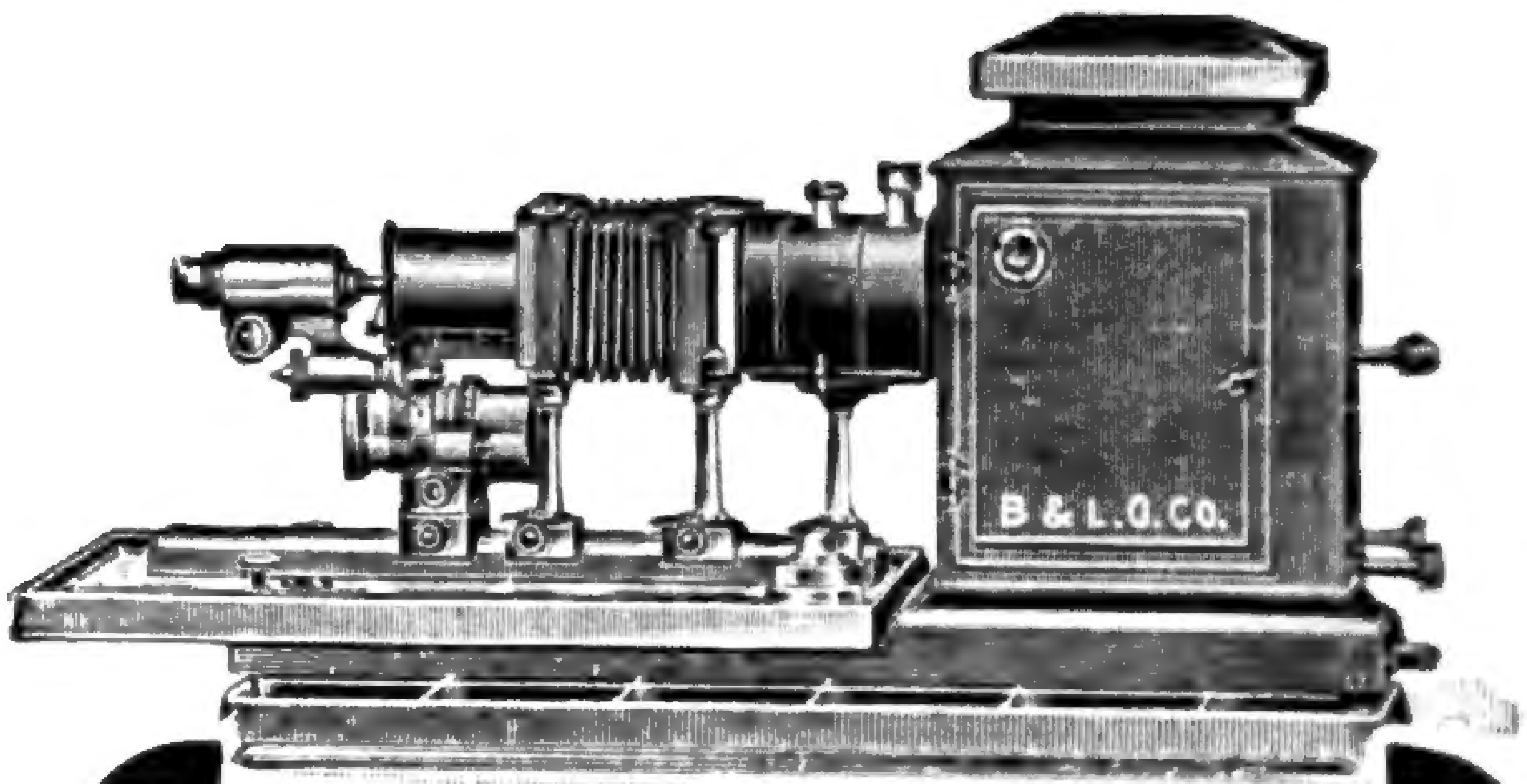
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