BOTANICAL GAZETTE

THE

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No. 1, July 28; No. 2, August 15; No. 3, September 17; No. 4, October 15; No. 5, November 19; No. 6, December 22.

ERRATA.

P. 151, line 6, for Kawin read Kaurin.

P. 223, line 6 from below, for *merite* read *mérite*.

P. 235, line 3 from below, after reduced insert to.

P. 239, line 2, for Fulmer read Fullmer.

P. 240, line 5 from below, for nucleoli read nuclei.

P. 279, line 4, for 1896 read 1898.

P. 296, line 12 from below, for is read was.

P. 296, line 11 from below, for this issue read the October number.

P. 310, line 18, after lucida dele comma.

P. 375, line 14, after him. insert — W. M. CANBY.

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VOLUME XXVI NUMBER 1

BOTANICAL GAZETTE

JULY 1898

ON THE LEAF AND SPOROCARP OF PILULARIA.

DUNCAN S. JOHNSON.

(WITH PLATES I–III)

DURING the course of some work on the development of the foliar structures of *Marsilia quadrifolia* L., the results of which have been published elsewhere ('98), a brief examination was also made of the same structures in the related Pilularia. Certain features observed here suggested the desirability of making a more careful study of the latter genus, and following out in detail all stages of the development for comparison with the same stages in Marsilia.

Through the kindness of Professor Eugenius Warming, Dr. Ostenfeld Hansen, of Copenhagen, collected for me in July 1897 a considerable quantity of fruiting material of *Pilularia globulifera* L. With this material the work embodied in the present paper has been prosecuted at the biological laboratory of the Johns Hopkins University, while holding the Adam T. Bruce fellowship for 1897–8.

The material was fixed in 95 per cent. alcohol, which seemed to give very good results except in the older stages, where the preparation of certain tissues of the capsule for the gelatinization, which causes the bursting of the capsule, had already begun. In this stage the sporocarps were often considerably shrunken, as happens in Marsilia after using other fixing agents unless great care is used in running up through the alcohols.

Sections of the structures studied were cut in paraffine, stained rather lightly in Mayer's haemalum, and then strongly with Bismarck brown in saturated solution in 70 per cent. alcohol.

THE LEAF.

The leaves of Pilularia arise, in acropetal succession, on the right and left sides alternately of the upper surface of the stem. Each leaf originates in a large cell from which a typical two-sided apical cell is cut out by curved anticlines. The apical cell thus formed has its longer axis directed toward the stem apex (*L, fig. 1*), as was shown by Bower ('84).

This apical cell swells out beyond the general surface of the stem and cuts off segments, alternately toward the right and left of the latter and of the leaf itself. The number of segments formed is probably about fifteen pairs. In several young leaves where the segments could be counted the number was found to be ten or eleven on each side of the apical cell, but in older leaves where the segments could not be satisfactorily counted the number was apparently considerably greater, at least as many as fifteen.

By the growth and division of these segments a papilla-like organ is formed, which soon begins to curve in ventrally (*L, fig. 3*) toward and above the stem apex. This circinate coiling continues with growth of the leaf until, when a centimeter long, the tip may form a flat spiral of two turns or more, of which the inner projects out laterally beyond the plane of the outer, so that median sagittal sections cannot be obtained through the whole length of the leaf.

Up to quite a late period the apical cell can be distinguished, but whether its fate is finally like that to be described for the apical cell of the sporocarp was not determined. The shape of this is never three-sided, as described by Campbell ('93) in *P. Americana*, but is two-sided as stated by Meunier ('87), though the segments are not cut off toward the dorsal and ventral sides of the leaf as seems to be indicated in Meunier's figures, but to the right and left alternately as we have seen.

The primary division of the semicircular segments or "primary marginal cells" is quite regular and at first resembles exactly that described by Poirault ('90) and myself for Marsilia. The first wall formed is a longitudinal and radial anticline (*I, figs. 3, 4*) cutting off about one-third of the segment toward the dorsal side to form what we may call a section. The second is a similar wall (*II, figs. 2–4*) forming a second section next to the median wall of the leaf (or inner border of the segment), and leaving a "tertiary marginal cell" (*m* c^3, *fig. 4*). Then a transverse anticline (*t* a^1, *figs. 2, 3*) divides this marginal cell into two, an upper and a lower one. In each of these tertiary marginal cells a third longitudinal anticline appears (*III, figs. 3, 5*) nearly parallel to wall I. At this point the similarity to Marsilia ceases, for instead of forming two more sections, as in that plant, each marginal cell of the fourth grade is here divided by a pericline (*d w, fig. 6*), thus ending its function as a marginal cell.

The four primary divisions formed in each segment (leaving out of account the transverse anticlines which do not appear in a cross section of the leaf) develop in a way very like that found in the six primary divisions in the segments of the leaf of Marsilia. Section I very early cuts off by a pericline near the inner end (*p l w, fig. 4*) a cell which is to function as procambium. The outer end of the section is soon cut in halves by a longitudinal anticline (*h a, fig. 4*). Then sections II and III and the marginal cell form procambium at their inner ends (*p l w, fig. 6*), while at the outer ends of all the sections periclines, corresponding to that in the marginal cell, separate the protoderm and ground meristem layers which encircle the procambium (*figs. 6, 7*). No second portion of procambium is ever formed in section I, as happens in Marsilia.

The protoderm layer soon divides by periclines into epidermis and hypodermis (*e p* and *h y, figs. 7–9*) and the cells of these then divide by anticlines to form many cells, but each layer remains of a single cell in thickness even at maturity, as no more periclines are ever formed. The procambium throughout breaks up by numerous longitudinal walls and fewer transverse ones to form the elongated cells of the axial vascular bundle (*a b, figs. 6–9*). Of the cells arising thus, one of the four first formed in the procambium of section II (*t r, figs. 6–9*) develops without further division by longitudinal walls into the large trachea of each side of the bundle. Whether transverse anticlines are formed in this in its later development could not be made out with certainty, but it agrees apparently with the trachea of the same bundle in Marsilia in remaining the full length of the segment. As the bundle progresses in its development the outer layer of the cells formed from the procambium becomes specialized as an endodermis or bundle sheath (*b s, figs. 8, 9*). The fact that the first wall formed in the procambium of section I does not correspond exactly with the halving anticline in the outer end of this section (*fig. 5*) makes it easy to distinguish procambium and ground meristem at this point (*figs. 6–8*). The leaf of Pilularia thus forms an exception to the general rule holding in the ferns, that the endodermis is formed from the ground meristem surrounding the bundle (Haberlandt, '96, p. 336); and agrees rather with the Juncaceæ and Cyperaceæ which have been studied by Haberlandt. I am inclined also to believe that Marsilia agrees with Pilularia in this respect, though it was not possible to determine this with absolute certainty as in the present case.

We may now turn to follow briefly the development of the ground meristem layer The two primary cells of this layer in section I and the single cell of each of the other three main divisions of the segment divide by a single pericline in each. The inner layer of cells thus formed, ten in number, constitutes the mesophyll layer (*m p, figs. 7–9*), which remains of this number (as seen in cross section) until maturity, being one cell thick and having no tannin sacs like those of Marsilia. Of the ten outer cells (*p c, figs. 7–9*), of which there are at this time several in the length of a segment, each gives rise to its part of one of the ten longitudinal partitions which separate the ten longitudinal air canals (*a c, figs. 7, 9*), in the leaf of Pilularia (Bischoff, '28). These air canals arise very early as small intercellular spaces between the cells of the ground meristem and those of the hypodermis (*a c*, *figs. 7–9*) on the line of the median wall, of each section wall, and on the halving anticline of section I. The primary partition cells divide by periclines and thus increase in a radial direction as the leaf increases in diameter. At certain points the tips of these cells remain in contact with those of their fellows in adjoining sections laterally (as at the median wall and halving anticline in *fig. 8*). When viewed in tangential section (*pc*, *fig. 10*) it is seen that each cell of the partition elongates tangentially and forms thus a protuberance at the upper end on one side and at the lower end of the cell on the other side. Then when the next transverse anticline is formed it is slightly oblique and forms two wedge-like cells, each with a protuberance on one end and none at the other (*fig. 10*). These cells soon elongate with the growth in length of the leaf, and cells are cut off from each which are not in contact with their fellows laterally (*fig. 11*). Thus arise the longitudinal partitions which separate laterally the adjacent air canals. The protruding ends of the partition cells, which separate the divisions, at first short, of the same longitudinal canal from each other, are finally cut off by oblique anticlines (*c p*, *fig 11*) and form thus transverse partitions two cells broad from one longitudinal partition to the next. These cells do not divide further, as in Marsilia to form transverse partitions many cells in width, but elongate very greatly as the longitudinal partitions separate by the growth in circumference of the leaf. The latter, however, are closer together at the point where joined by the transverse partitions, and thus each longitudinal partition, as seen in tangential section, has a zigzag course from the base to the apex of the leaf. Both kinds of partitions remain one cell in thickness throughout, and both are perforated by pores, the "meats" of Meunier, which allow the free circulation of the enclosed air to all parts of the leaf.

The stomata which are present on both the leaf and the sporocarp and the peculiar trichomes which cover all the younger parts (Mettenius '46) have been carefully studied and figured by Meunier, and for the sake of simplicity have been omitted from nearly all drawings in the present paper. We may note, however, that the origin of the trichome from a portion cut from the acroscopic end of an epidermal cell is practically the same as in Marsilia, though the regularity is not so striking.

As is well known (Bischoff '28), the mature leaf of Pilularia has no lamina whatever. We may consider it as quite probable, however, that the immediate ancestors of Pilularia and Marsilia had leaves possessing a lamina, which still persists in the latter genus, and we might expect to find some remnant or trace of this in Pilularia in the mode of division of the segments if not in the outward form. Keeping in mind then the mode of development of the lamina in Marsilia, by the continued activity of the marginal cells near the apex of the leaf, many segments in this region of the leaf of Pilularia were examined in search of any irregularity in the formation of cell walls, or of continued activity of the marginal cells. The results were always negative, and we must therefore conclude that the development of the leaf of Pilularia gives no indication that it has ever possessed a lamina.

THE SPOROCARP.

The sporocarp of Pilularia was considered by Hofmeister ('62) as a modified branch arising as an accessory bud at the base of the leaf. Alexander Braun ('70) and his pupil Russow ('72) dissent from this view, and on theoretical grounds consider it a segment or branch of the leaf; while Juranyi ('80) and Goebel ('82) confirm this latter view as a result of the study of the development of the sporocarp and the relation of its tissues to those of the neighboring leaf. Meunier ('87), however, while holding that the latter view is probably the correct one, thinks the evidence adduced is at fault, as the vascular bundle of the sporocarp, according to his observations, does not fuse first with that of the leaf, but with that of the stem itself. He then points out that the best evidence for this view will be the proof that both arise from the single apical cell of a foliar structure at first unbranched. This he was not fortunate enough to obtain, and it was left for Campbell ('93) to show that this was the case in *P. Americana*, where he found the sporocarp arose from a single cell at the base of the leaf. In the development of the capsule of the sporocarp in Pilularia, Juranyi thought the soral cavities arose by a splitting of the internal tissues of the young capsule, as Russow had described for Marsilia. Goebel on the contrary held that these cavities were external in origin, and this view was later confirmed by the work of Meunier and Campbell.

According to Meunier's work the young sporocarp is developed from a two-sided (possibly a three-sided) apical cell which soon ceases to function as such, and growth is continued by the activity of four cells occupying the four corners of the tip of the sporocarp. Each of these cells was supposed to give rise to one of the four valves of the mature capsule with its sorus.

Meunier's figures of the vascular bundle system of the capsule and of the stalk show that the sporocarp is bilaterally symmetrical, and that the plane of symmetry separates the sori into a right pair and a left pair and does not pass through the middle of diagonally opposite sori as do the longitudinal sections figured by Meunier.

The latest work on the development of the capsule (Campbell '93 and '95) indicates that one of the valves or lobes of the young capsule is developed directly from the apical cell of the sporocarp, being thus terminal in position, while a second appears lower down on the median line of the side toward the leaf, and the third and fourth on the right and left of this line respectively. This of course means that the plane of symmetry must pass through the upper and lower sori and between the other two, which does not agree well with the structure of the mature capsule of Pilularia as given by Meunier, or with the mode of development that I found in Marsilia. It was this difficulty in seeing how the structure of the mature capsule as given by Meunier could be developed in the manner described by Campbell that led me to take up the present work.

According to my own observations the sporocarp of Pilularia arises on the inner and anterior side of the leaf, just above the axillary bud which is always present. As in Marsilia, a fertile branch of the stem has a sporocarp on nearly every leaf, but there is never more than one on the same leaf in Pilularia, or could any rudiment of a second be found.

The young sporocarp owes its origin to the formation of a two-sided apical cell in one of the marginal cells of the fourth grade in (probably) the first segment of the anterior side of the leaf (*F*, *fig. 12*). The difficulties of orientation were such that transverse sections of the leaf in this region were not frequently obtained, and it cannot be definitely stated therefore that the sporocarp arises in the quaternary marginal cell, rather than the tertiary one, but the evidence obtained seems in favor of the former. The fusion of the outer tissues of the leaf with the stem makes it impossible also to state positively from which segment the sporocarp arises, but I believe it to be the first rather than the second, and certainly it cannot be a younger one than this.

The apical cell of the sporocarp has its longer axis across the leaf, and cuts off segments toward the base and apex of the leaf alternately, to the number of seven or more on each side (*figs. 13, 14*). The exact number of segments formed could not be determined with certainty, but in several cases six and seven pairs were counted, and in others very little older, as shown by their size, apical growth had ceased, and the number of segments was certainly much smaller than in Marsilia, where I found more than twenty pairs of segments. The activity of the apical cell as such is ended when the sporocarp is about a tenth of a millimeter long, by the appearance in it of several irregular anticlines, dividing it up into small cells which soon become indistinguishable from those derived from its later segments, as can be readily seen in a surface view of this part of the capsule (*fig. 15*).

The fate of the segments of the apical cell in the sporocarp is at first exactly like that of the leaf segments (*figs. 13, 14, 16, 17*), but while in the leaf wall III is followed by a pericline that cuts off the protoderm in the marginal cell, it is here followed by three more section walls. Wall IV is dorsal to the marginal cell and nearly parallel to wall III (*fig. 18*), wall V is on the ventral, and VI on the dorsal side of the marginal cell (*figs. 18, 19*), and the ultimate marginal cell is thus of the seventh grade, just as in the capsule of Marsilia (Johnson '98).

THE STALK.

The type of primary division just given is the one found in most of the later segments of the sporocarp, but in those at the base, which form the stalk, wall IV is often followed immediately by a pericline in the marginal cell which ends its activity as such (*fig. 20*). The further fate of the various sections and the marginal cell is quite similar to that found in the leaf. Procambium, ground meristem and protoderm layers are formed in all ; the latter gives rise to epidermis and hypodermis (*e p*, *h y*, *figs. 20, 21*), and the ground meristem to the two or three-layered mesophyll and to the partitions separating the small and irregular air canals. We find a notable difference in the fate of the procambium, for the eccentric vascular bundle of the stalk is developed entirely, or nearly so, from the procambium of section I (*a b*, *fig. 20*), while most of the procambium of the other divisions is devoted to the formation of the large stereome bundle which lies ventral to and partially surrounding the vascular bundle (*s c l*, *figs. 21, 31–33*). This fuses below with the central stereome of the stem, but ends abruptly above at the basal wall of the capsule. In the mature sporocarp the stalk is sharply curved in ventrally, is smaller at the lower end and considerably enlarged at the upper end where it joins the capsule, at which point also it is peculiarly modified on the dorsal side, as will be described in detail in speaking of the wall of the capsule.

The vascular bundle of the stalk, as Meunier has pointed out, does not fuse with that of the leaf in the way described by Goebel, but usually, according to my own observations, fuses first with the bundle of the axillary bud, and then this composite bundle reaches that of the stem at or near where the leaf bundle joins the latter.

THE CAPSULE.

In the terminal segments of the sporocarp, which form the capsule, the number of primary divisions is seven, as we have seen. Of these the six sections immediately divide up to form the three meristem layers, while the marginal cells, or at least a pair of these on each side, do not (*figs. 19, 22*). There are four ultimate marginal cells in each segment arising from the division of each of the two quaternary marginal cells by a transverse anticline (*fig. 14*). On each side of the capsule we find that two of these cells, in different but successive segments, become considerably larger than their fellows (*fig. 14*), and each finally gives rise to the sporangia of one of the four sori. In several cases these sporangial marginal cells, as we may call them, seemed to be the upper ones of the segments, as in the case figured (*fig. 14*), but the material at hand of this stage was not sufficient to allow me to determine whether this is always true. Neither can I assert positively that all of the sporangia of a sorus come from one marginal cell, but the evidence obtained is such that I feel practically satisfied that further study will show this to be the case. The essential thing, however, and one which is quite certain, is that the sporangia come from marginal cells, in a way that we shall find to be similar to that found in Marsilia, though differing in some details.

In describing further the development of the various structures of the capsule, we shall find it best to take them up separately, and may conveniently begin with the wall developed from the protodermal layer. Soon after apical growth ceases in the young sporocarp, the portion near the tip, that is the region including the four sporangial marginal cells, begins to swell out ventrally and laterally to form the globular capsule (*figs. 25, 31*), and these marginal cells at the same time begin to divide up to form the many sporangial cells of the sori. No tendency to a circinate coiling of the young sporocarp is seen at any time, but growth soon becomes more rapid on the lower side of the ventral protuberance and the original apex is thus pushed far around dorsally (*A*, *figs. 31–33*), and the sori, which originate in cells having a lateral position (*fig. 14*), come later to have a position such that the soral canals open nearly terminally *figs. 31–33*), thus making the longitudinal axis of these canals nearly parallel to that of the stalk.

On the dorsal side of the sporocarp in the meantime there is formed a small protuberance at the upper end of the stalk (*l t*, *figs. 31, 32*), which is later found to be supported by a mass of thick-walled cells extending inward nearly to the vascular bundle (*fig. 33*). This protuberance, as was pointed out by Russow in *P. minuta*, is apparently homologous with the lower tooth of the capsule of *Marsilia quadrifolia*. Just above this tooth there is a rather narrow, but deep depression (*b p*, *figs. 31, 34*), which according to Russow corresponds to that found between the upper and lower teeth in *M. quadrifolia*, but there is no marked increase in height of the epidermal cells above this that might represent the upper tooth of the Marsilia capsule (see Russow '72, and Johnson '98).

It was this bending backward of the young capsule, perhaps, which led Meunier to think that the sori were primarily terminal in position, and this may account also for the view of Campbell that one of the valves is developed from the apical cell of the sporocarp, but it is not very difficult to follow out the details of development satisfactorily if the unchanging sagittal plane is used as a guide.

During this change in the general form of the capsule the protodermal layer throughout, beginning on the dorsal side just above the basal pit, divides by periclines into epidermal and hypodermal layers, and then the latter divides again to form inner and outer hypodermis (*e p*, *h y*, *figs. 30, 31*). These layers soon surround the whole capsule (Mettenius '46, Hanstein '66) except for the stomata, most of which are near the base of the capsule. At these openings both hypodermal layers are wanting, the guard cells being as usual derived from the epidermis (*s t*, *fig. 33*).

The development of these highly specialized tissue layers has been very carefully studied by Meunier, and I will therefore give only a brief account of their mature structure. The brown walled cells of the epidermis are prismatic in shape, varying in height from one-half to three or four times their diameter, the highest being those at the base of the capsule near the ventral side (*fig. 33*). In the basal pit the epidermis is made up of several layers of irregular thin-walled cells (*figs. 32, 33*), while just above this on the wall of the capsule it consists of a single layer of very short cells (*fig. 33*). On either side of this narrow pit the epidermal cells are quite high, as was shown by Meunier, but, though this author figures transverse sections of this region of the capsule, he does not appear to have discovered the pit in longitudinal sections, and hence apparently failed to appreciate its significance. Scattered about among the epidermal cells of the ripe capsule are many of the persistent basal cells of the deciduous trichomes (*tc, fig. 33*).

The outer hypodermal layer consists of cells with the clear yellowish walls so thickened that the cavity is entirely obliterated except at the ends (hy^1, *figs. 33–35*). These cells are of quite uniform length and have the thick walls peculiarly modified at about the middle of their length, by the deposit, as Meunier thinks, of a more albuminous substance in this portion of the wall, to form the most prominent of the several "light lines" characteristic of this layer (*ll, figs. 33, 34*). The inner hypodermal layer consists of rather longer prismatic cells with thick walls, and are occasionally divided into inner and outer cells by obliquely transverse walls (hy^2, *fig. 33*). In the region between the stalk and capsule it is noticed, quite early in the development, that the cells are somewhat smaller than the surrounding ones (*bw, figs. 25, 31*), and the larger number of nuclei makes this quite striking in stained sections of a stage like that from which the latter figure is drawn, even when the power used is so low that the cell walls are not distinguishable. Finally, quite late in the development, one layer of these cells in the lower part of this basal wall become modified in the same manner as the outer hypodermis of the capsule (*fig. 33*), and is continuous with this hypodermis laterally and ventrally (*figs. 33, 34*). For a narrow space in the dorsal region, however, the outer hypodermis from the dorsal wall of the capsule is seen in sagittal section to continue on down into the stalk, making a sharp bend and becoming much thickened just opposite the basal pit, while the similar layer of the basal wall laps over on to this above and abuts against the thin inner hypodermis (*fig. 33*). Horizontal sections (*fig. 35*) show that the region of overlapping is a very narrow one, and that this arises from the transverse division here of cells which are elsewhere undivided. Whether this division gives rise to an open slit is difficult to determine, but I believe that at maturity there is an actual opening here which may have the function, attributed by Russow to the similar structure in Marsilia, of allowing an interchange of air between the capsule and the air canals of the stalk.

Russow noticed the thinness and the bulging outward of the outer hypodermis just above the basal pit, as shown in horizontal section (*fig. 34*), but was unable to study it thoroughly from lack of material. The course of the light line at the point of overlapping is worthy of special notice. It moves toward the inner surface of the hypodermis (*ll, figs. 33, 34*) and finally passes over into the basal wall (*figs. 33, 35*), and the thickening of the walls of the cells in these layers is seen to be definitely related to this line, the cell cavity increasing in size with the distance out from this line toward the end of the cell (*figs. 34, 35*), while where two layers are present (*fig. 35*), the cells of the outer one, in which the light line is wanting, have very slightly thickened walls. At the stomata also the light line is seen to bend outward to the guard cells, so that we may conclude that this line indicates the distribution of some material which makes the hypodermis impervious to air or moisture, and is therefore present only where needed for this purpose.

At the base of the capsule the inner hypodermal layer is wanting, and is replaced by several layers of brown-walled cells which form the inner portion of the basal wall (*fig. 33*). Next to the prismatic outer layer of this wall these cells are closely packed together, but farther up many small intercellular spaces occur. These spaces open into the larger spaces between the rounded parenchyma cells surrounding the vascular bundle under the base of the sori, and these in turn connect with the still larger canals in the mesophyll which surrounds the capsule just within the hypodermis (*fig. 33*).

In the region near the basal pit the inner hypodermis seems to be pretty sharply separated from the cells of the inner portion of the basal wall (*fig. 33*), running down from the dorsal side of the capsule as a very thin layer which abuts against the overlapping edge of the outer layer of the basal wall. The cells of the inner portion of the basal wall in this region are thin-walled and have small intercellular spaces between them, suggesting thus the tissue that was described by Russow as filling the "lens-shaped space" in this part of the capsule of Marsilia. There is, however, no indication of a duplication of the hypodermis to shut off these cells from the rest of the capsule (see Russow '72 or Johnson '98), nor is there any trace of the rod of brown cells described by Russow as occupying the anterior end of this lens cavity.

THE VASCULAR BUNDLE SYSTEM.

This system has been carefully studied by Meunier, and since my own work confirms his in all essential points, I have, with his consent, reproduced several of his figures (*figs. 36–38*) of its mature anatomy.

In the development of the vascular system we have already seen that the axial bundle of the stalk comes from section I entirely, and this is true also of the simple continuation of this bundle into the capsule (*a b, fig. 24*). The rapid modification in shape and position of the various parts of the capsule, however, makes it practically impossible to trace out the origin of the many branches in the capsule with reference to segments and meristem layers, as it was possible to do in Marsilia.

After penetrating unbranched nearly to the base of the sori (*fig. 33*), the axial bundle divides, sending one branch to the right side of the capsule and one to the left, forming a short transverse bundle perpendicular to the main trunk (*tb*, *figs. 36, 37*). Each end of the transverse bundle soon divides again, sending one branch upward and dorsally in each case, and the other downward and ventrally (*figs. 32, 33*). Then each of these four branches, which correspond to what I have called the "lateral branches of the dorsal bundle" in Marsilia, divides to form the three peripheral bundles of its respective valve (*l b f*, *figs. 30, 36, 37*). Of these bundles, the middle one of each valve gives rise, a short distance above its base, to a short branch (*p a b r*, *fig. 36*) that turns abruptly into the capsule to join the placental bundle which runs through the length of the placenta just back of the sporangia (*p a b*, *figs. 30, 36*). Of the other two main branches in each valve, one runs along close to each edge of the latter (*l b f*, *figs. 27–30*), and all three fuse again at the tip of the valve (*figs. 36, 38*). There is never a fusion of bundles from upper and lower sori on the same side of the capsule as occurs in Marsilia, and the absence of this allows the separation of upper and lower valves on each side, just as the absence of fusion across the median plain in Marsilia allows the separation of the wall of the capsule into right and left valves.

THE SORI.

In the young soral segments the growth in a tangential direction of sections II and V is comparatively slight, while the sections dorsal to the marginal cell grow vigorously and thus push this cell around into a nearly ventral position (*m c*^{7}, *fig. 19*), After increasing considerably in size, the marginal cell divides into halves by an anticline parallel to the median wall (*s p c*, *fig. 22*), and then these halves are divided further by walls parallel to the first (*figs. 23–26*) and by others perpendicular to these (*figs. 27–29*), giving rise thus to the large number of sporangium mother cells of the sorus. During the growth and division of these derivatives of the marginal cell they are turned over, by the continued growth of the dorsal sections, so that the originally outer surface finally faces toward the cells of section V, which have been turned in a similar way to face laterally outward (*s p c*, *fig. 23*). The slight depression thus formed on the ventral surface (*s c*, *figs. 23*, *24*) is the beginning of the soral canal, which grows constantly deeper as the capsule develops (*figs. 24–26*), becoming crescent-shaped in cross section (*figs. 27–30*), and finally closing at the outer end, by the growing together of sections V and VI, to completely inclose the sporangial cells (*figs. 26–32*).

By the striking change in the external form of the capsule already mentioned, the position of the sori within this is considerably affected. From their origin (*fig. 14*) we might expect the sori to face the median wall, as in Marsilia, but this is not the case, for in accommodating themselves to the globular form of the capsule, the sori of the upper pair soon come to face inward and downward, while those of the lower pair face upward and inward (*figs. 27–29*), or, in other words, all four face toward the central axis of the capsule.

When fully developed to sporangium mother cells the derivatives of the marginal cells are elongated perpendicularly to the surface of the sorus, densely filled with contents, and have large nuclei in which, in the resting stage, the chromatin is collected in a few rounded masses (*figs. 26–28*). The number of sporangium mother cells in the length of the sorus is ten or more (*fig. 26*), while the number seen in transverse sections varies from four to five at the base or top (*figs. 27*, *30*) to as many as twelve at the middle (*fig. 29*).

The basal cells of the sorus are the first to form sporangia (*fig. 26*), and this begins in each of them by the occurrence of inclined walls, cutting out a tetrahedral apical cell (*s p*, *figs. 26*, *28*, *29*). One or more series of segments are cut off from this, and then a pericline appears at the outer end, completing the sporangium wall and forming the archesporium, which later cuts off the tapetum in the usual way (*s p*, *figs. 28–30*). According to Meunier, who has carefully described the development of the sporangia, the microsporangia and macrosporangia are just alike up to the time of formation of the mother cells. This view is confirmed by Campbell, and I believe it to be true, though I have not been able to follow out in detail this part of the development.

Among the cells at the base of the sorus, where the first sporangia are formed, are a few cells which do not develop sporangia until much later, so that the sporangia in this region differ greatly in age, and hence in size (*s p*, *fig. 30*). In the middle and upper portions of the sorus there seems to be much less disparity in the size of the sporangia, as all of the sporangial cells form sporangia at about the same time (*fig. 29*). From the similarity in distribution in the sorus of the sporangia first formed to that of the macrosporangia of the mature sorus, one is tempted to believe that these primary sporangia near the base of the sorus are the only ones that develop to macrosporangia, while the backward sporangia, including a few at the base and all those of the upper part of the sorus, give rise to microsporangia only, but this view could not be definitely confirmed.

I can corroborate Campbell's statement that no stalk cell is regularly formed in the development of the sporangia, and whether the cell sometimes seen at the base of the sporangial cell (*fig. 29*) is the homologue of the stalk cell of the Polypodiaceæ seems open to question.

We have seen that while the indusium which separates the sori of the laterally opposite pairs from each other is formed by the ventral outgrowth of sections II and V, that which separates the upper and lower sori of the same side must be derived principally from the sterile marginal cells. The presence of intercellular spaces along the median wall is noticed very early (*i s c*, *figs. 25–27*), and these finally run together to complete the separation of the indusia of the opposite sori. A similar splitting apart begins a little later between the upper and lower sori of the same side.

The fact that these layers of tissue surrounding the individual sori are not originally separate is used by Goebel as evidence for the view that it is not an indusium morphologically, but it seems to me that, just as in Marsilia, the mode of development by the outgrowth of surface cells favors the opposite view, as has been pointed out by Meunier.

SUMMARY AND CONCLUSIONS.

The leaf of Pilularia develops, like that of Marsilia and many other leptosporangiate ferns, by a two-sided apical cell arising on the right and left sides alternately of the dorsal surface of the stem, near the apex.

The eleven or more pairs of segments formed by this apical cell divide primarily into three sections and a quaternary marginal cell, instead of five and a marginal cell of the sixth grade, as in Marsilia. Each of these four divisions takes part in the formation of all three meristem layers. The sheath of the axial bundle is derived from the procambium and not from the ground meristem as in other ferns. The mesophyll of the mature leaf is of a single layer. Outside of this are the ten air canals, separated both laterally and transversely by perforated partitions, and surrounded externally by the epidermis and hypodermis developed from the protoderm.

No indication of a rudimentary lamina could be found by carefully following the details of division in the terminal segments of the circinately coiled leaf.

The sporocarp of Pilularia is a branch of the leaf, arising in an anterior marginal cell at the base of the latter. It grows by a two-sided apical cell which cuts off six or more pairs of segments, and is then divided up by irregular anticlines. These segments, like those of the sporocarp of Marsilia, form seven primary divisions.

This plan of division found in both genera must, I think, be regarded as a characteristic of the spore-bearing portion of the leaf in their common ancestor. From the absence of a lamina in the sterile leaf of Pilularia, it might be suggested that the sporocarp, which also possesses no lamina, had been derived from a leaf of this type. For phylogenetic reasons, however, we must believe that the leaf of the Leptosporangiatæ, from which the Marsiliaceæ are derived, possessed á lamina, developed in the same manner as in many other families of the group, and had a petiole more like these same forms in the number of divisions of its segments (see Sadebeck '74). Pilularia, on the contrary, has no lamina, and has a smaller number of divisions in the leaf segments, resembling in this respect certain petioles of Marsilia (Johnson '98), where the number of sections is reduced below the normal. Again, the type of division in the capsule seems to be easily derivable from that of the leaf of Marsilia, for the interpolated section IV of the former seems so plainly to assist in pushing the marginal cell around to the ventral surface, that we can readily believe it to have been added to a leaf of this type for this particular purpose. When all of these facts are considered, it seems evident that, so far as the structure of the leaf indicates, Marsilia is the less modified of the two genera, and resembles the other leptosporangiate ferns more closely, while Pilularia has a leaf very much reduced from the ancestral type. Whether the capsule of Pilularia is derived from one with more numerous sori cannot, perhaps, be profitably discussed until we know the details of development in such forms as *Marsilia polycarpa*, or *M. Aegyptiaca*, and *Pilularia minuta*, where the number of sori is reduced in each genus below that in the forms already studied, but from my own study of *P. globulifera* and *M. quadrifolia*, I am inclined to think the capsule of the latter, like its leaf, is the more primitive of the two. It seems to me that detailed study of the leaf development throughout the Leptosporangiatæ may be expected to give more light on the exact affinities of the Marsiliaceæ with the other families of the group.

In the segments forming the stalk of the sporocarp the protoderm gives rise to epidermis and hypodermis, and the ground meristem to mesophyll and the irregular partitions separating the small air canals, while the procambium gives rise in section I to the vascular bundle and in the other sections to the ventrally placed stereome bundle.

The remaining younger segments of the sporocarp are devoted to the formation of the capsule. In this region two of the ultimate marginal cells on each side are devoted to the formation of sporangia, all of those of each sorus arising from one of these four sporangial marginal cells. The sori thus arise in right and left pairs, one above the other on each side, and are not terminal in origin, as described by Meunier, nor with two sori on the median plane, as indicated by Campbell. These sporangial marginal cells give rise in a way somewhat similar to that found in Marsilia, to the large number of sporangium mother cells of the sori, and are in the meantime surrounded by the more vigorous growth of the other portions of the ventral side of the capsule. By the more rapid growth at the base of the capsule on the ventral side, the openings of the soral canals thus formed are pushed around from a lateral position to become nearly terminal in the mature sporocarp.

The macrosporangia and microsporangia are not derived from different marginal cells, as in Marsilia. The earliest evidence of differentiation found here is in the fact that the first sporangia formed, most of them near the base of the sorus, seem to develop macrosporangia, while the upper and younger ones become microsporangia. Except in this matter of location, the two kinds of sporangia are just alike up to the formation of the spore mother cells.

The outgrowth of the cells of the ventral surface of the capsule gives rise not only to the wall surrounding all of the sori, but also to the so-called indusium which separates the different sori from each other. It seems to me that Meunier is right in saying that the development of this tissue here (as in Marsilia also) is sufficient warrant for calling it an indusium. But we cannot agree with Campbell in regarding these indusia as the inturned edges of leaflets enclosing the sori, since we have no evidence that any structure homologous with the lamina occurs in the capsule.

Of course, the whole question of homology is complicated by the fact that the sporangia of the Marsiliaceæ seem to arise on the ventral surface of the leaf. But if we pass from forms like Asplenium, with sporangia borne near the middle of the dorsal surface of the leaf, through forms like Adiantum, with sporangia near the edge on the same surface, to Lygodium, where, according to Prantl ('87), the sporangia actually arise from marginal cells, the transition to the Marsiliaceæ, with several sporangia arising from each marginal cell, does not seem to be so very abrupt. The indusium of Lygodium also seems to have a striking resemblance to that of the Marsiliaceæ in some features of its development, and may repay further investigation from this point of view.

The axial vascular bundle entering the base of the capsule divides into two, one branch going to the right and the other to the left side of the latter. Each of these again divides, forming four branches, each of which furnishes the three main bundles of a sorus. The middle one of the three in each case develops a placental branch which connects with the placental bundle present in the axis of the placenta. The three bundles of each sorus fuse together at the tip of the valve, but there is no fusion of the bundles of the upper and lower sori on the same side like that found in Marsilia.

The firm wall of the globular capsule of Pilularia is made up, like that of Marsilia, of an epidermis of thick brown-walled cells with trichomes and stomata scattered among them. Within this are two hypodermal layers, the outer of very thick-walled, regularly prismatic cells, and an inner layer of larger, more irregular, brown-walled cells. Across the base of the capsule is formed the thick basal wall, the outer layer of which is continuous with and exactly like the outer hypodermis and has the same "light line" running through it. Near the dorsal side of the capsule there is a narrow slit through this wall, corresponding to the air passage which opens into the lens-shaped space in Marsilia, but, though a tissue similar to that found in this space is present in Pilularia, it is not cut off from the rest of the capsule by a duplication of the hypodermis.

Just opposite the basal wall there is a depression in the dorsal surface of the sporocarp, and just below this, at the upper end of the stalk, is an outgrowth corresponding to the lower tooth of the capsule of Marsilia. The upper tooth, which in Marsilia consists simply of elongated epidermal cells, is entirely wanting in Pilularia.

In conclusion, the sporocarp of *Pilularia globulifera* is essentially the equivalent of a Marsilia sporocarp in which the number of sori has been reduced to two pairs, and will probably be found to correspond even more closely in development with those Marsilias, like *M. polycarpa* or *M. Ægyptiaca*, which also have a small number of sori. Morphologically, then, we must in both cases consider the capsule as equivalent to a branch of the leaf in which the marginal cells have been devoted to the formation of sporangia instead of a lamina.

BALTIMORE, MD.

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EXPLANATION OF PLATES I–III.

Abbreviations used.— *A*, apex ; *ab*, axial bundle ; *ac*, air-canal ; *arc*, archesporium ; *bp*, basal pit ; *bs*, bundle sheath ; *bw*, basal wall ; *cp*, transverse partition ; *D*, dorsal ; *d*, protoderm ; *dw*, protoderm-wall ; *ep*, epidermis ; *F*, sporocarp ; *ha*, halving anticline ; *hy*, hypodermis ; hy^1, outer hypodermis ; hy^2, inner hypodermis ; *id*, indusium ; *isc*, intersoral cavity ; *L*, leaf ; *lb*, lateral branch of vascular bundle ; *lbf*, fork of the lateral branch ; *ll*, light line ; *lp*, longitudinal partition ; *lt*, lower tooth ; *mc*, marginal cell ; mc^1, mc^2, etc., marginal cell of the first, second, etc., grade ; *mp*, mesophyll ; *mw*, median wall ; *pa*, placenta ; *pab*, placental bundle ; *pabr*, placental branch ; *pb*, ground-meristem ; *pc*, partition cell ; *pl*, procambium ; *plw*, procambium-wall ; *pp*, pores in partition ; *S*, stem ; *sc*, soral cavity ; *scl*, stereome bundle ; *sp*, sporangium ; *spc*, sporangial cells ; *st*, stoma ; *sw*, segment wall ; ta^1, first transverse anticline ; *tc*, trichome ; *tp*, tapetum ; *tr*, trachea ; X, apical cell ; I, II, etc., first, second, etc., section walls.

All figures are camera drawings from microtome sections, except *figures 36–38*, which are copied from Meunier.

PLATE I.

FIG. 1. Transverse section of stem through apical cells of two young leaves. × 400.

FIG. 2. Ventral surface of tip of young leaf. × 400.

FIG. 3. Lateral surface of same. × 400.

FIG. 4. Part of transverse section of young leaf. × 400.

FIG. 5. Similar section of an older leaf. × 400.

FIG. 6. The same still older. × 400.

FIG. 7. The same older than the last. × 400.

FIG. 8. The same still older than the last. × 400.

FIG. 9. Similar section of nearly mature leaf. × 75.

FIG. 10. Part of tangential section of a young leaf through the partitions and air-canals. × 200.

FIG. 11. Similar section of older leaf. × 200.

FIG. 12. Part of transverse section of stem showing ventral surface of a young leaf and the mother cell of a sporocarp. × 400.

FIG. 13. Dorsal surface of tip of a young sporocarp. × 400.

FIG. 14. Ventral and lateral surface of the same. × 400.

FIG. 15. Surface view of the apex of an older sporocarp, showing the fate of the apical cell. × 400.

FIG. 16. Part of a section of the tip of a young sporocarp, which cuts the segment on the right parallel to the upper and lower segment-walls and the segment on the left perpendicular to these. × 400.

FIG. 17. Part of a transverse section of a young sporocarp. × 400.

FIG. 18. Similar section of slightly older sporocarp. × 400.

FIG. 19. Part of transverse section of a capsule showing ultimate marginal cell. × 400.

PLATE II.

FIG. 20. Transverse section of stalk of sporocarp. × 400.

FIG. 21. Similar section of an older stalk. × 300.

FIG. 22. Transverse section of a capsule older than that shown in figure 19. × 400.

FIG. 23. Similar section slightly older than the last. × 400.

FIG. 24. The same still older, though lower sori. × 400.

FIG. 25. Approximately horizontal section through upper pair of sori of a capsule considerably older than that shown in figure 31. × 200.

FIG. 26. Part of similar section slightly older, showing formation of sporangia. × 400.

FIG. 27. Part of a section transverse to the sori of a capsule of the age shown in figure 31, near the ventral surface. × 400.

FIG. 28. Similar section of right upper sorus a little older. × 400.

FIG. 29. Similar section near the middle of left upper sorus still older. × 175.

FIG. 30. Similar section, near the base of lower right hand sorus, older than last. × 175.

PLATE III.

FIG. 31. Approximately sagittal section of a young sporocarp, just at the right of the median plane. × 400.

FIG. 32. A similar section of a much older sporocarp. × 200.

FIG. 33. Nearly median sagittal section of a mature sporocarp. × 30. (At *lbf*, in dotted lines, the vascular bundles which would be seen in a section a little farther from the median plane than this.)

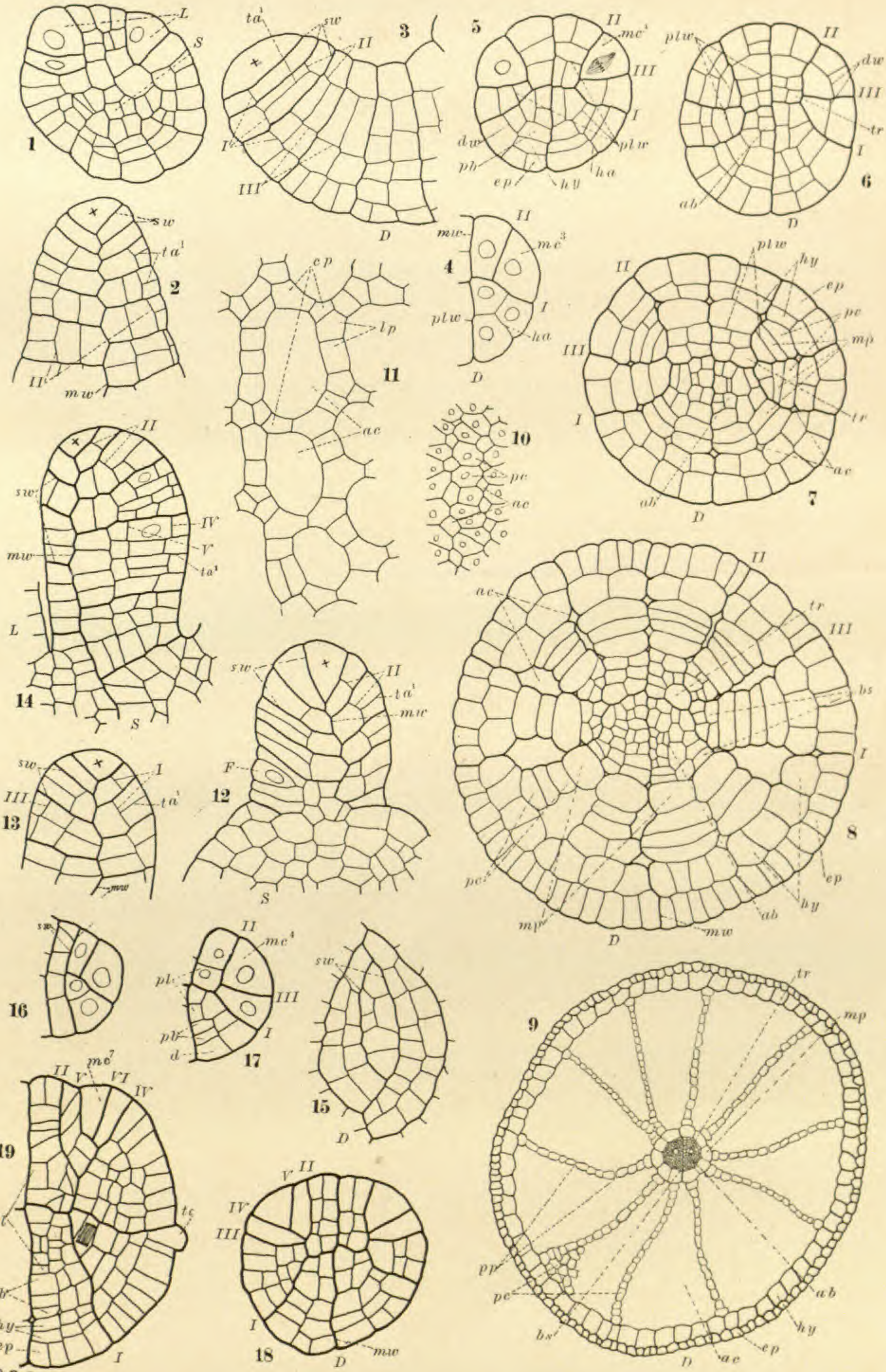
FIG. 34. Horizontal section through pit and base of mature capsule, just dorsal to slit in basal wall. × 175.

FIG. 35. Section parallel to last through slit in basal wall. × 175.

FIG. 36. View from the ventral side of the vascular bundle system of the mature capsule. × 15. (The arrow indicates the direction of the median plane.)

FIG. 37. View from above of the transverse bundle at the base of the capsule and its branches. × 15.

FIG. 38. View from above of the bundles at the top of the capsule. × 15.



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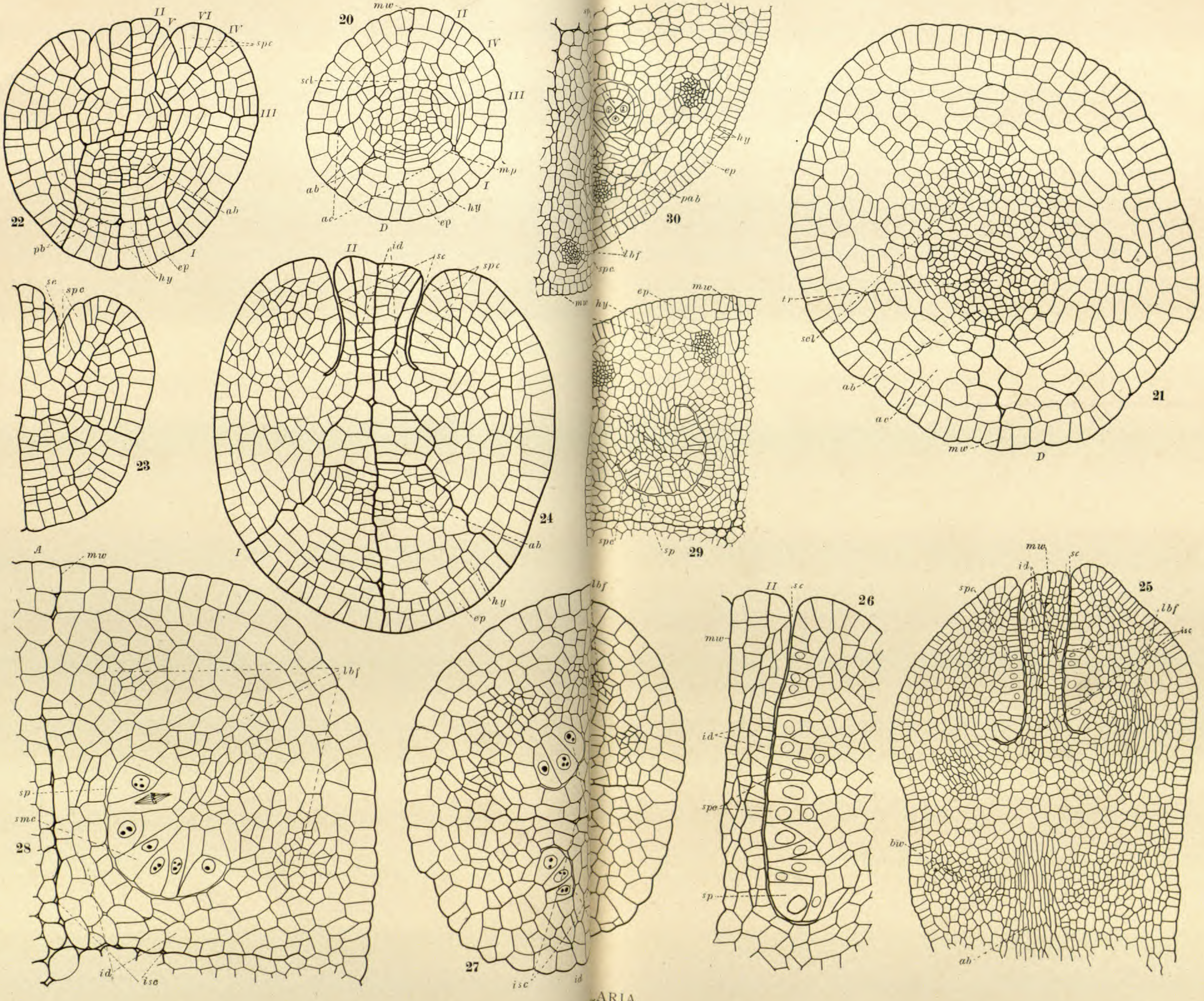
JOHNSON on PILULARIA.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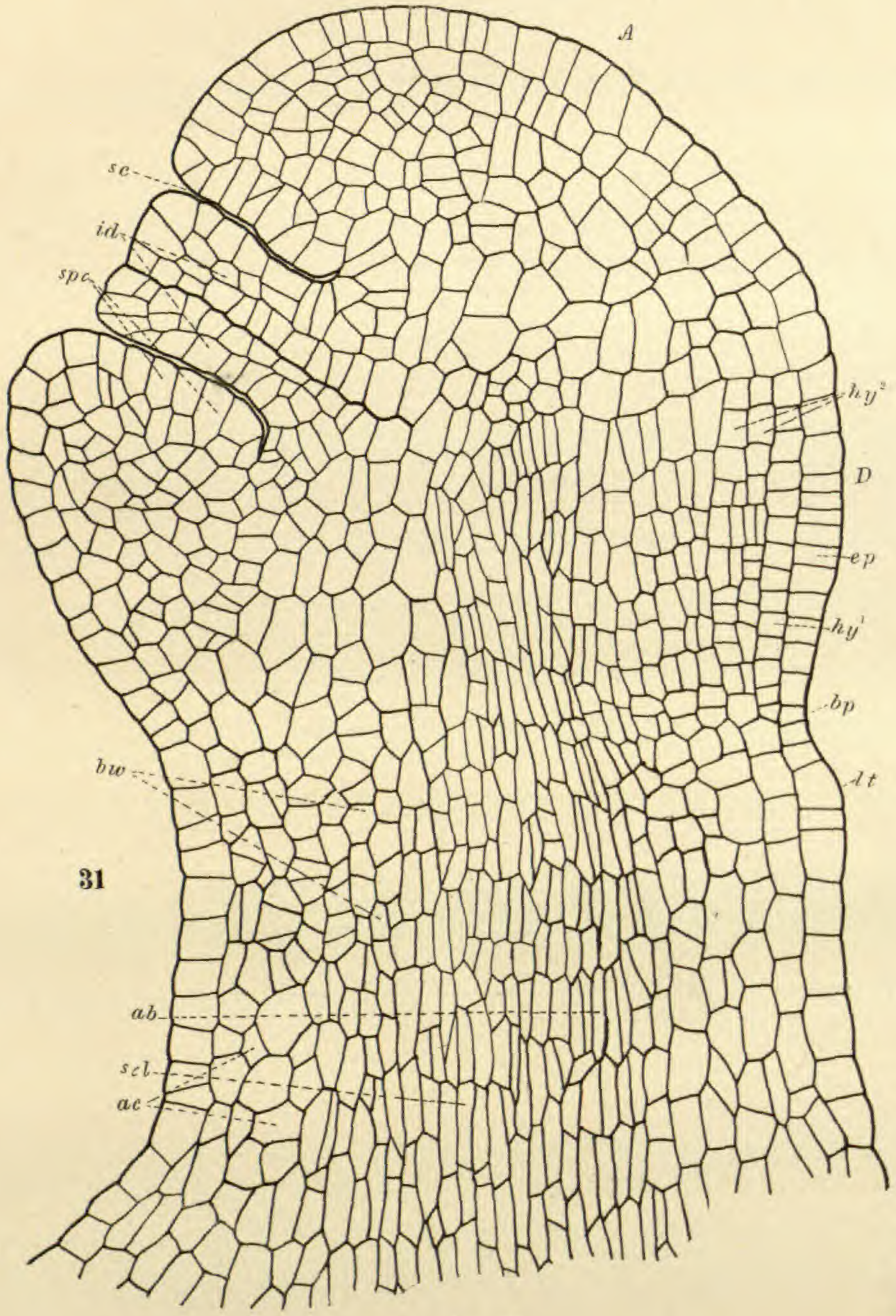

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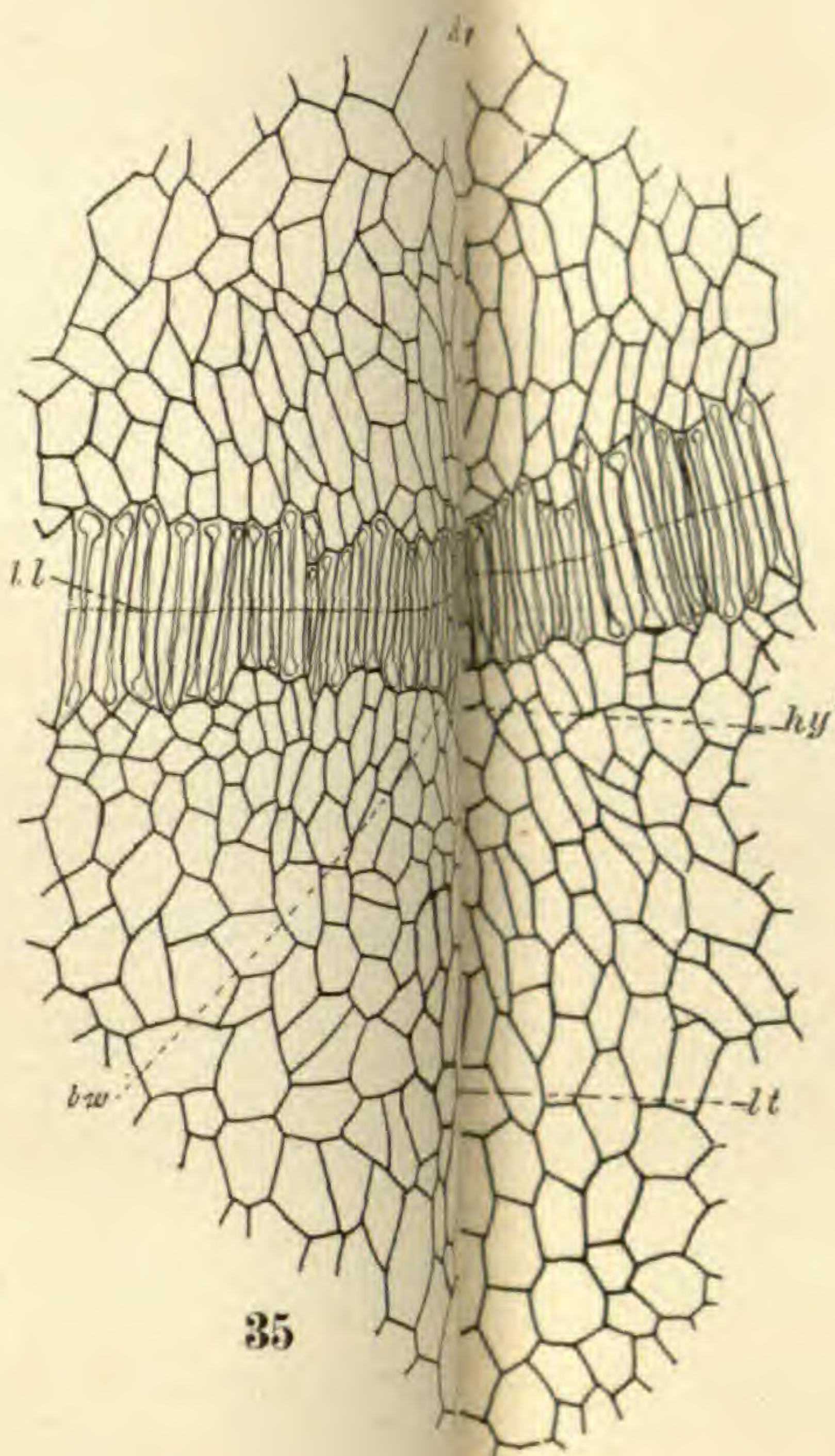

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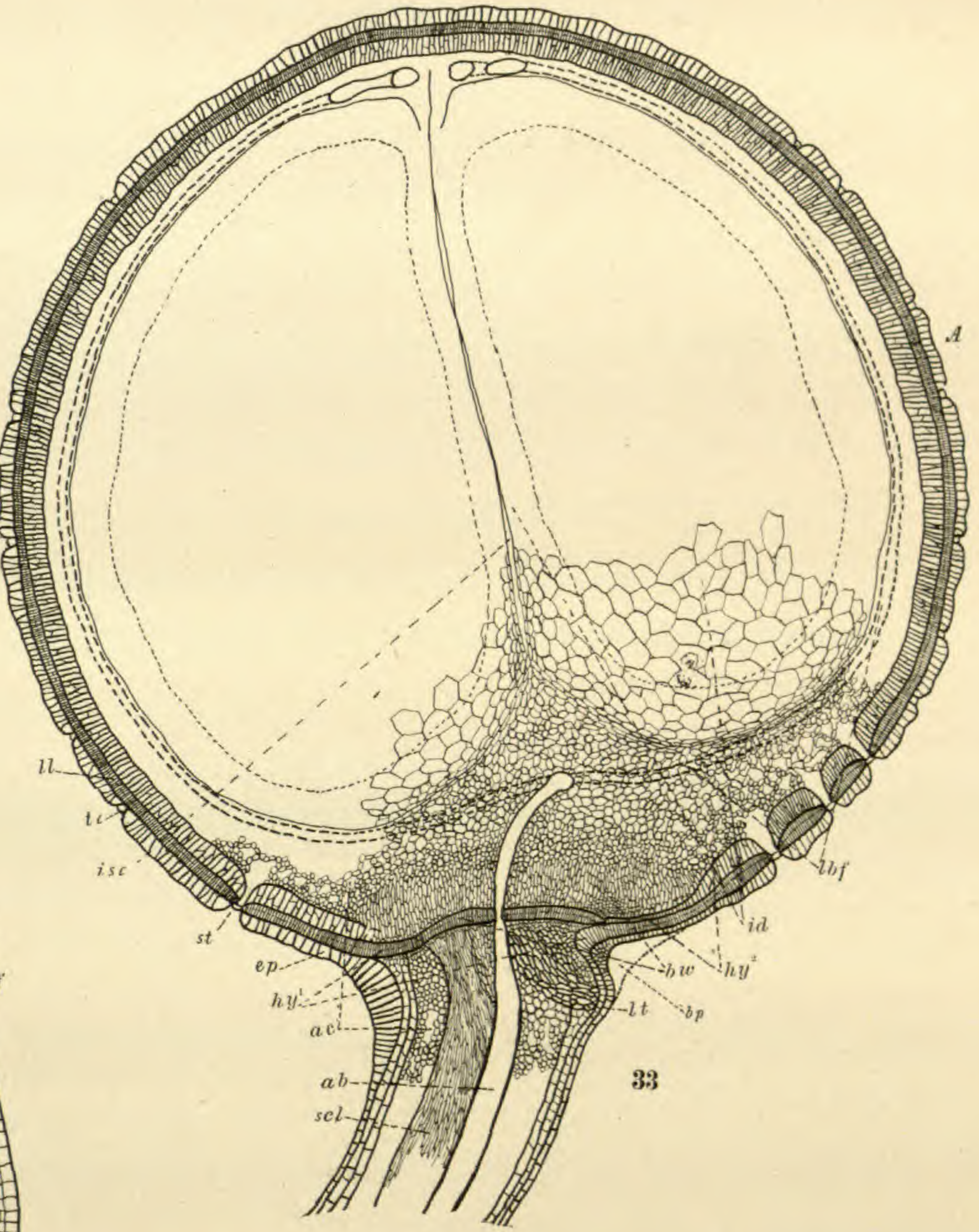

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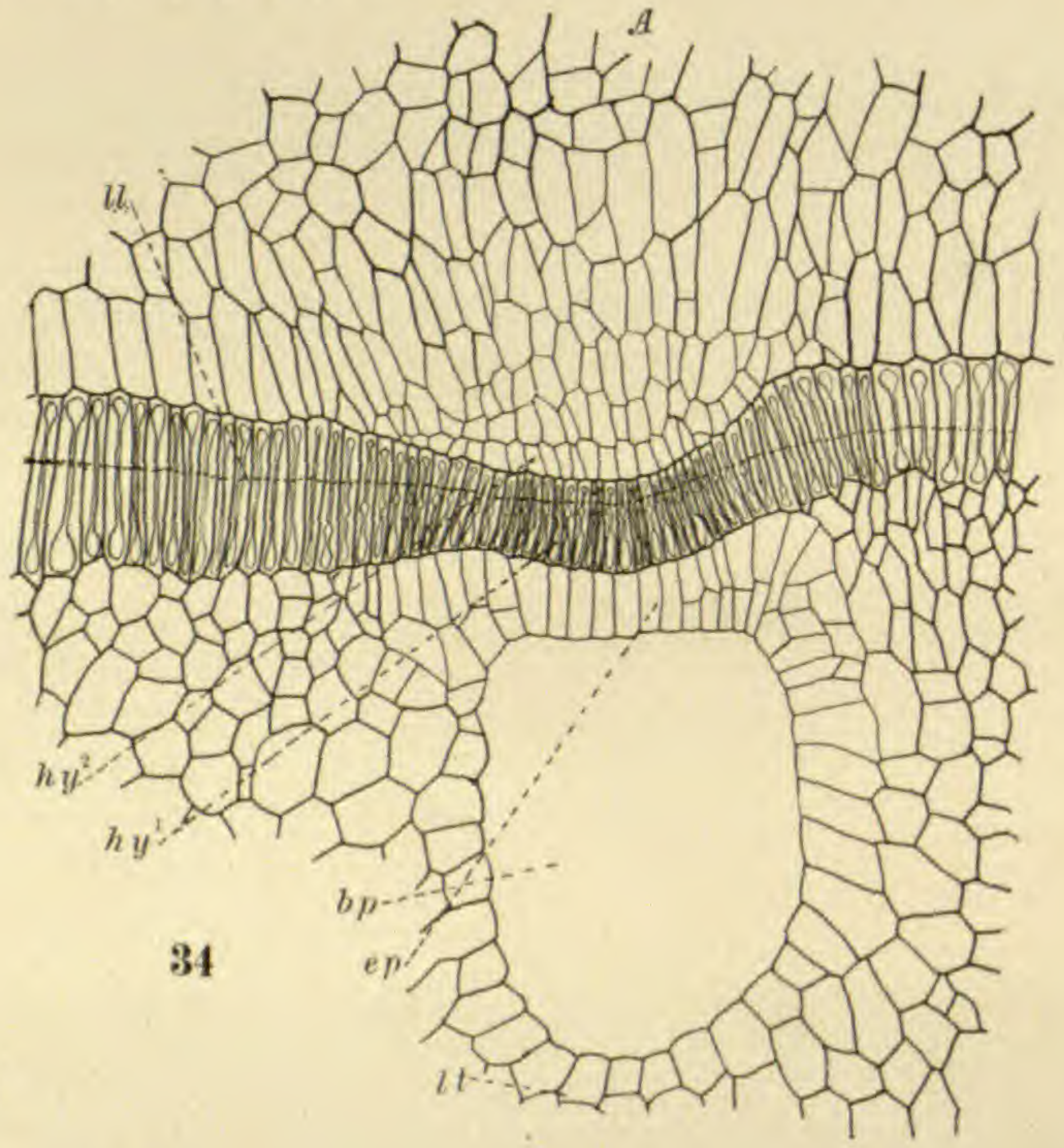

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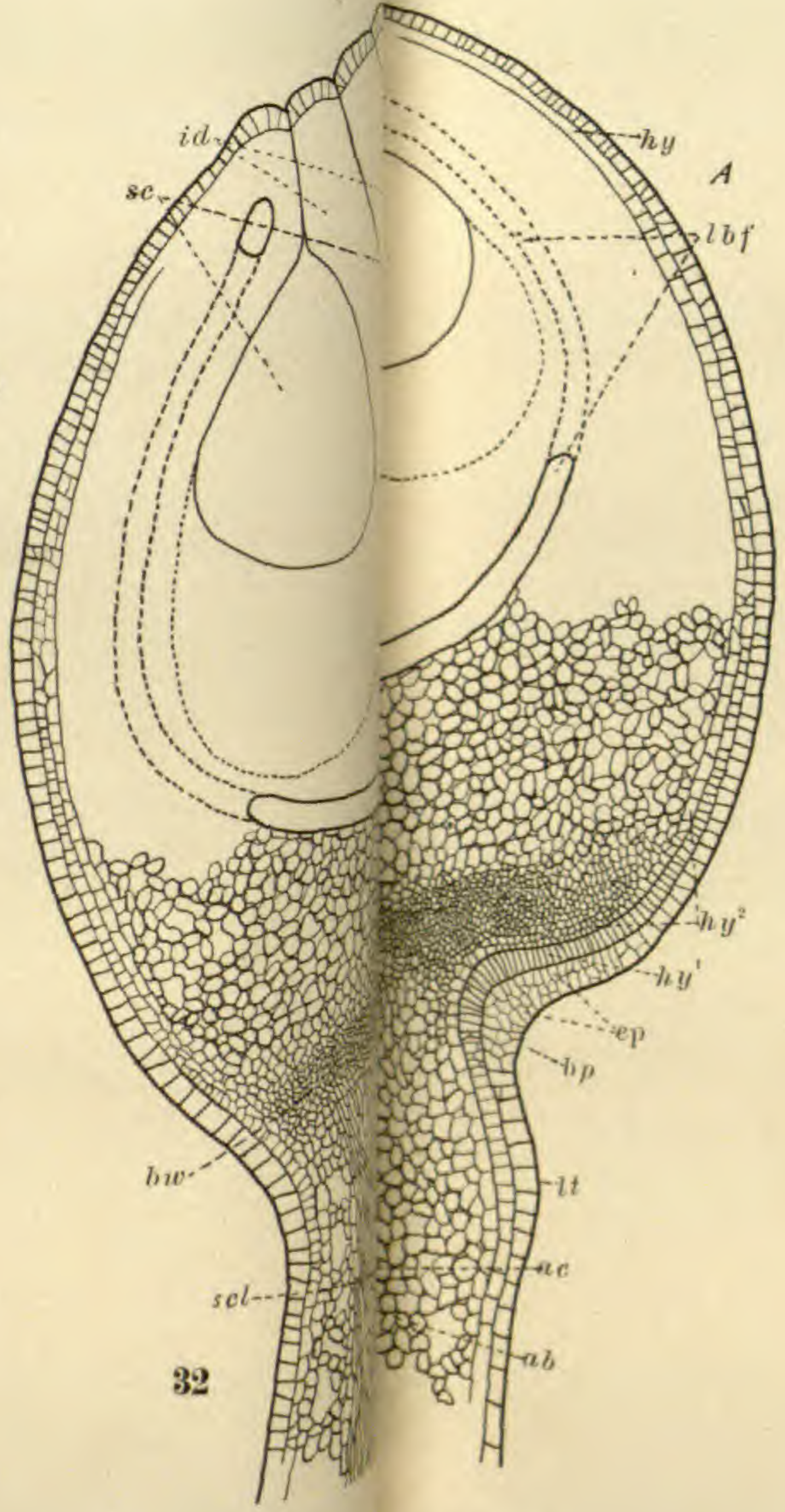

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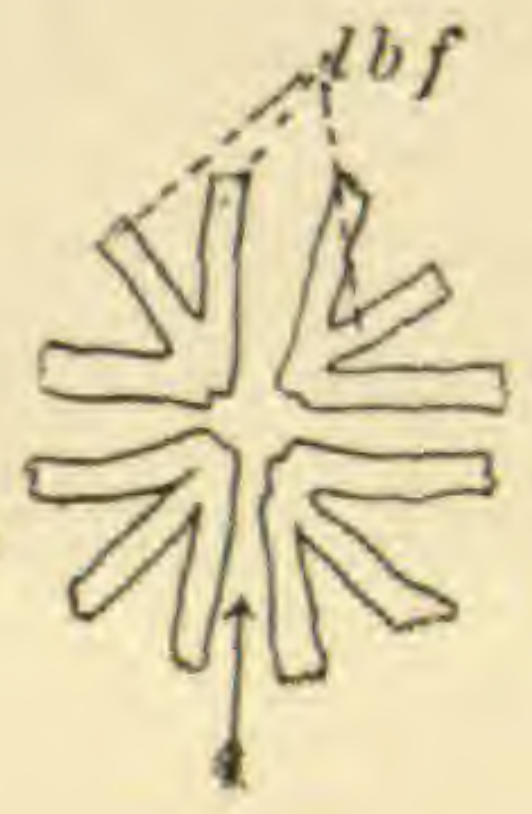

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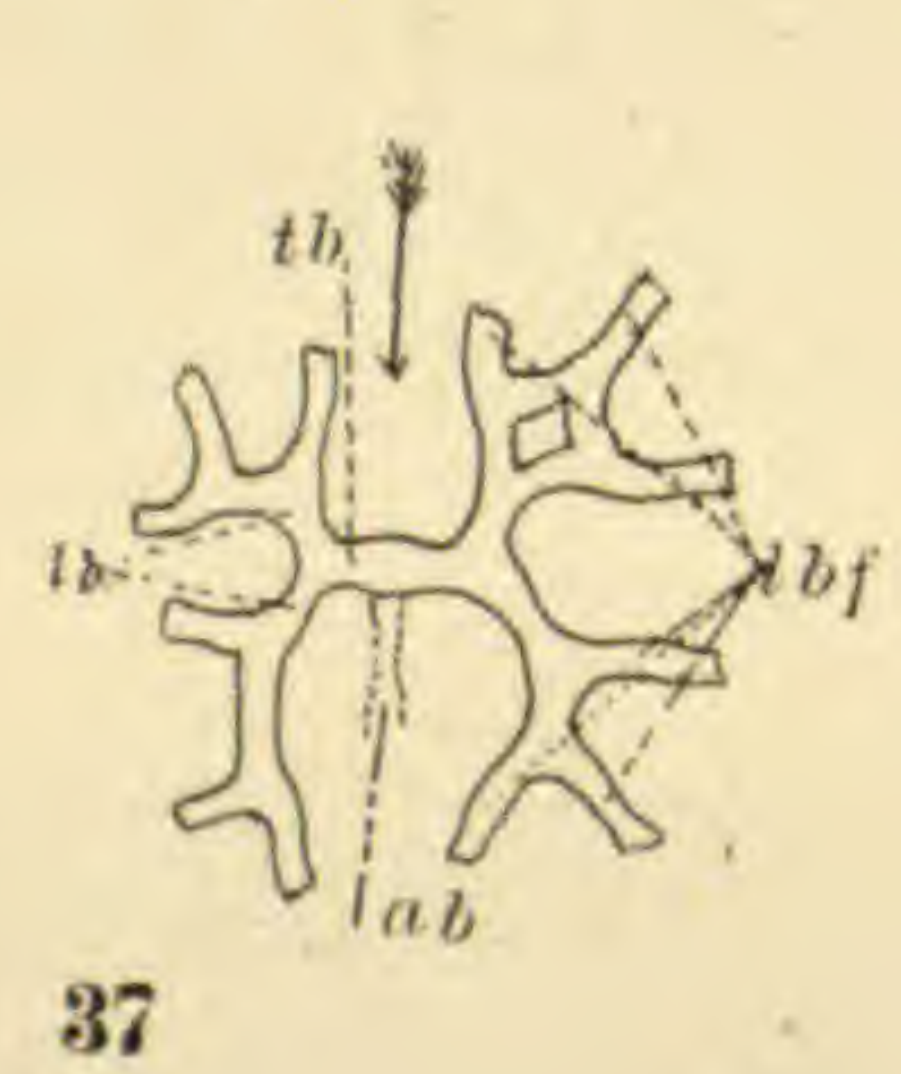

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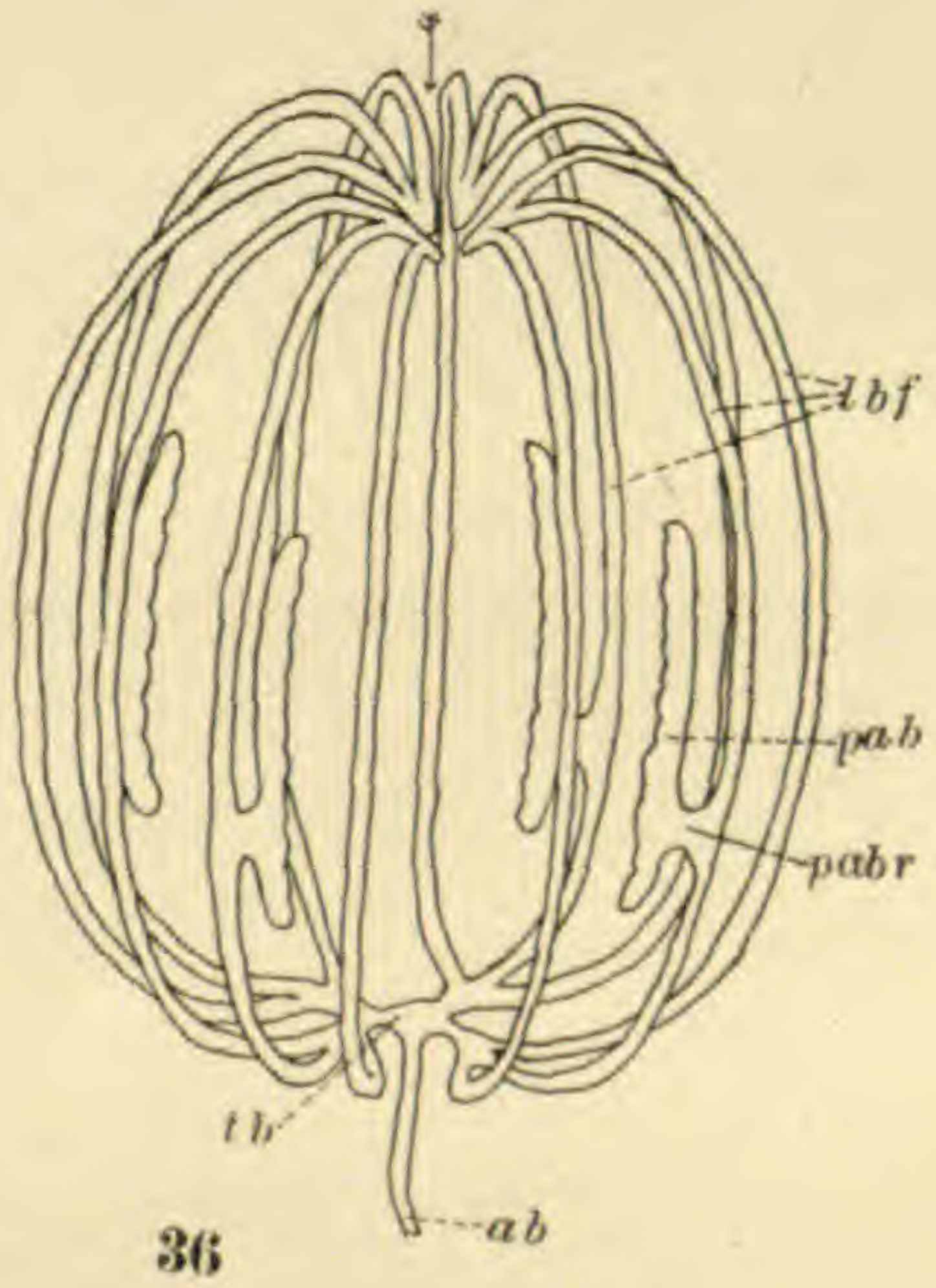

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CONDITIONS FOR THE GERMINATION OF THE SPORES OF BRYOPHYTES AND PTERIDOPHYTES.

FRED DE FOREST HEALD.

(WITH PLATE IV)

I. INTRODUCTION.

THE investigations upon the effect of light on the germination of fern and moss spores have led to opposite and contradictory results. According to Borodin, Schmidt and others, the failure of fern spores to germinate in the dark is experimentally demonstrated, while Göppert and Schelting arrived at exactly opposite conclusions. Leitgeb has shown the necessity of light for the germination of liverwort spores, and Milde succeeded in germinating Equisetum spores in the dark. Up to this time no systematic work on the germination of moss spores in light and darkness has been carried out. In order to clear up this existing confusion and extend our knowledge in regard to the conditions for the germination of moss spores, the present investigation was undertaken.

Before proceeding with the results of my own experiments however, I will treat a little more in detail the investigations bearing upon this subject, which have been hitherto published.

II. HISTORICAL.

The early botanists were in no sense of the word physiologists, and so from the time when the spores of mosses were first observed and compared to the seeds of flowering plants nearly to the present time, their germination has been treated almost exclusively from the morphological point of view. A historical summary of the works on the germination of the spores of Musci and Hepaticæ, up to 1884, is brought together by Lindberg.[1] The summary is not quite complete, as no mention is made of the result which Borodin[2] obtained with spores of *Polytrichum commune.* He found that they were unable to germinate in darkness. The work of Müller-Turgau[3] on the germination of spores and the production of secondary protonema is also omitted.

As regards the fern spores, the earlier investigators made the assertion that light prevents their germination, as is to be noted in the works of Senebier, Humboldt,[4] Ingenhouss,[5] and Treviranus.[6] More recent investigators, as Kaulfuss,[7] Leszczye-Suminski,[8] Merklin,[9] Wiegand[10] and Hofmeister,[11] intimate that light is one of the necessary conditions for germination, although no definite investigations in that line are mentioned.

The first investigations of importance from the physiological point of view are those of Borodin.[12] He experimented with eight different species of ferns and found that in all cases light was necessary for germination, and that in the dark no bursting of the exine occurred. His experiments are lacking in one datum, since he does not state at what temperature the cultures were kept. As shown by my own investigations this is one of the most important points. Two years later Göppert[13] succeeded in bringing the spores of Osmunda to germinate in the dark, but the temperature at which the cultures were grown is unknown to me. A year later, Schmidt,[14] with cultures of the spores of *Aspidium violaceus* and *filix-mas*, confirmed the results previously

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[1] Historiska Data rörande vår Kännedom om Moss-sporens Groning. Helsingfors, 1884. Rectorprogram.

[2] Bull. de l'acad. imp. de S. Petersbourg, **12** : 433–440. 1867.

[3] Arb. d. Bot. Inst. zu Würzburg **1** : 475–499.

[4] Aphorismen 90.

[5] Versuche mit Pflanzen II. 5. Abschnitt.

[6] Physiologie der Gewächse **2**^{2} : 584. 1838.

[7] Das Wesen der Farnkräuter 59. 1827.

[8] Zur Entwickelungsgeschichte der Farnkräuter 8. 1849. Berlin.

[9] Beobachtungen am Prothalium der Farnkräuter 5. 1850.

[10] Entwickelungsgeschichte der Farnkräuter. Bot. Zeitung **7** : 17. 1849.

[11] Vergleichende Untersuchungen 78. 1851. [12] *Ibid*, 529–541.

[13] Schmidt, Über einige Wirkungen des Lichtes auf Pflanzen 21. 1870. Breslau.

[14] *Ibid*, p. 20.

obtained by Borodin. In 1872 Kny[15] obtained results which contradicted those of Göppert for Osmunda spores. The next work of importance was that of Schelting[16] in 1875. He investigated the spores of four different species and found that in all cases germination occurred in the dark. One of the species which he used, *Aneimia Phyllitidis*, was also used by Borodin in the investigations above cited. I have not had access to the original paper, but the probability is, from the review, that the cultures were kept at a temperature higher than the normal room temperature.

Again later, G. Beck[17] has shown that the spores of *Scolopendrium vulgare* germinate only when exposed to light.

Milde[18] and Sadebeck[19] have shown that the spores of Equisetum germinate in the dark as well as in the light; while Leitgeb[20] in his excellent work on the liverworts has shown that darkness prevents the germination of the spores; also that faint illumination causes the development of protonemata which differ markedly in form from those grown under normal illumination. With this short historical summary as an introduction I proceed to the results of my own investigations.

III. EXPERIMENTAL.

The majority of the cultures were made either upon filter-paper, pieces of flower pots, or earth placed in Petri dishes and carefully sterilized. Any special methods will be described in connection with the experiments themselves.

I. MOSS SPORES.

First as to the experiments with moss spores. Cultures of *Funaria hygrometrica* spores were made, and in one case exposed to normal illumination, and in another placed in the dark cham-

[15] Jahrb. f. wiss. Bot. **8** : 4. 1872.

[16] Bot. Jahresber. 3 : 328. 1875.

[17] Bot. Zeitung **36** : 780. 1878.

[18] Nova Acta Acad. L. C. F. **23** : 2.

[19] Bot. Zeitung **35** : 44, 45. 1877.

[20] Sitzungsber. d Akad. d. Wiss. Wien. **74** : 1. 1876.

ber; both being kept at a temperature varying from 19–21° C. At the end of three days the spores exposed to light had germinated abundantly, while those in the dark chamber showed no signs of germination, not even a bursting of the exospore. The dark culture was kept for a month, and at the end of that time there was no indication of germination. That the spores had remained normal and had not lost their power of growth was shown by their speedy germination when exposed to ordinary illumination. This experiment was repeated several times with the same result. Similar experiments were carried out with spores of *Brachythecium rutabulum*, *Bryum pendulum*, and *Mnium cuspidatum*, and all revealed the same dependence of germination upon illumination.

In order to determine which part of the spectrum was effective in producing germination, cultures ot spores were placed under double-walled bell-glasses filled respectively with potassium bichromate and ammoniated copper oxide. The cultures included *Funaria hygrometrica*, *Bryum pendulum*, and *Brachythecium rutabulum*. At the end of three days the spores exposed to the less refrangible rays of the spectrum had germinated with as great readiness as under normal illumination, while the cultures in the blue light showed no signs of germination, thus acting the same as in darkness. The spores, although retained in the blue light for over a month, showed no germination whatever. The failure of the spores to germinate in the strongly refrangible rays would seem to throw some light upon the processes which occur in germination. Although the spores form some chlorophyll in the blue light, the photosyntactic processes are not active, and hence it might be thought that germination depended upon the elaboration of new material which can only occur to any extent in the less refrangible rays. That this view is highly improbable is shown by the experiments which follow.

Cultures of spores were made of the three species above mentioned and placed in the light in air free from CO_2, the apparatus being the same as that figured by Pfeffer.[21] The first

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[21] Pflanzenphysiologie 1: 191. 1881.

series of experiments in bright light showed that photosyntax was not necessary for germination, since the spores had germinated as readily in the air free from CO_2 as under ordinary conditions. The same result was obtained when the apparatus was exposed to less intense illumination by the interposition of an opaque screen. Under these conditions the photosyntax would be insignificant, and hence it appears evident that germination is independent of that process. The influence of light in germination must be sought, then, presumably in a transformation of food products already present in the spore; these chemical changes being initiated by light, and only by the less refrangible rays. More in regard to the nature of this transformation will be brought forward when later experiments are described.

The question which now presented itself was: Is continued exposure to light necessary to germination; in other words, is there a light induction? In order to determine this point, cultures of spores which had been in the dark for twelve hours were placed in the light and carefully watched for the first signs of germination. After about fourteen hours of illumination the spores showed the first signs of germination, in some cases the exine being burst; a slight protuberance, the beginning of the protonema, was also evident. Half of the cultures were allowed to remain in the light as control experiments, while the other half were removed to the dark chamber to undergo further development. Those spores which showed no beginning of germination before removed to the dark did not germinate in the dark, although they had formed an abundant chlorophyll content. Those spores which had begun to put out a protonemal filament continued their growth somewhat, but the filament was long and slender and did not attain any considerable size on account of lack of plastic material. These experiments were carried out with spores of *Funaria hygrometrica*, *Bryum pendulum*, and *Brachythecium rutabulum*, all with the same result. Essentially the same fact has been shown by Borodin[22] for fern spores.

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[22] *Ibid.*, 539.

Leitgeb[23] has shown that for the germination of liverwort spores a certain intensity of light is necessary, and my experiments with moss spores show that the same thing is true, only to a less marked extent. In experiments which I conducted with *Marchantia polymorpha* spores, parallel with the cultures of moss spores, where all were exposed to the light in the middle of the laboratory, the different behavior was very marked. The moss spores germinated in the usual length of time and without any apparent modification due to the weakness of the light. The Marchantia spores, on the other hand, showed a very remarkable retardation in germination, and when germination did occur only a long, narrow filament was produced, which gave no indication of the formation of the thallus according to the ordinary method of growth in sufficiently intense illumination. Other cultures were made and exposed to a much weaker light, a room in the Institute basement with only one window being used. First, cultures were placed on a shelf at a distance of about three meters from the window, then at two meters, and then in the window itself. The cultures at a distance of three and two meters from the window showed a complete failure of the spores to germinate, although they produced chlorophyll to some extent. Those which were grown in the window germinated after the ordinary length of time. That the spores remained capable of germination was shown by the fact that they began growth as soon as they were exposed to normal illumination. These experiments then show that under ordinary conditions of temperature and food supply, the moss spores require a certain intensity of light for germination, but that the required intensity is not as great as in the case of the liverwort spores. These facts were demonstrated for the three species of mosses mentioned above.

Reasoning from the results which I had already obtained with fern spores, a series of experiments was carried out in which cultures of spores were exposed to different temperatures. The failure of the spores to germinate in the dark is due, as has

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[23] *Loc. cit.*

already been stated, to the fact that the conditions of temperature, light, etc., were such that certain chemical processes necessary for germination could not be active. The results with fern spores show that heat is able to effect this change as well as light, so that germination may be called forth in complete darkness by subjecting the spores to a higher degree of temperature than the normal room temperature. That moss spores would be affected in the same way as fern spores would seem quite probable, but nevertheless my experiments in this direction have failed to find any temperature at which moss spores will germinate in complete darkness, when supplied with only inorganic material. The temperature to which the general cultures were exposed ranged from 19–21° C. Cultures were made for the following degrees of temperature: 23°, 24°, 27°, 29°, 32°, and 35° C., and in each case in complete darkness. The cultures at 35° C. were kept for four days. At the end of that time no signs of germination were visible, hence they were removed to the light and kept at the ordinary temperature. The failure of the spores to germinate under these conditions showed that they had been killed by the high temperature. The other cultures were allowed to remain in the dark for six days and then removed to the light. The spores subjected to 32° were not killed, but a very marked retardation of germination occurred, since the period required for germination was extended from three days to ten. The cultures that had been kept at 29° also showed a retardation of germination, five days being required after the exposure to light. In the other three series of cultures at 27°, 24°, and 23°, no apparent retardation of germination was noticed when the spores were exposed to light.

The above experiments have shown clearly that a continuous exposure to high temperatures is not sufficient to produce germination of the moss spores in the dark. As suggested by the results obtained by Liebenberg[24] for seeds of Poa, it was thought that perhaps a *change* of temperature might be effective in producing germination. To this end the following experi-

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[24] Bot. Centralblatt 14:21–26. 1884.

ments were carried out: Two cultures of *Funaria hygrometrica* spores were placed in the dark for twelve hours, then in the thermostat at 41° C. for four hours. The cultures were then removed and one placed in light, the other in the dark, both at a temperature of 19–21° C. After three days the spores in the light had germinated abundantly, but those in the dark showed no signs of growth, although they were kept for two weeks. Similar cultures were exposed to a temperature of 41° C. for three hours with the same result.

Cultures similar to the above were made for *Funaria hygrometrica*, *Bryum pendulum*, and *Brachythecium rutabulum* and exposed to a temperature of 32° C. for twenty-four hours. At the end of this time they were placed at the ordinary temperature, the control experiments in the light, the others in the dark. Those in the light germinated after the usual length of time, but in the dark no signs whatever of germination were noted. Thus, change of temperature is also shown to be insufficient in producing germination in complete darkness.

It is known that ether has a stimulating influence on the production of shoots from certain phanerogams, when under normal conditions none are produced. It might also be supposed that it would act as a stimulus to call forth the germination of spores in the dark. In order to determine this point, a series of cultures was made in which the spores were subjected for different lengths of time to a saturated or partially saturated atmosphere of ether. Cultures of Funaria spores were allowed to remain in the dark for twenty-four hours, in order that they might be in a moist condition, and then placed in an ether atmosphere. In the first case they were exposed to the ether atmosphere for one hour, in the next for two hours, and in the next for three hours. Two cultures were used in each case and as soon as they were removed from the ether atmosphere, one was placed in the light and the other in the dark chamber. The control experiments in the light showed, in the experiments to which a two and three hours' exposure to ether was given, that germination did not take place, and hence that the spores had been killed by the strong ether atmosphere. In the case of spores which had been in the ether for one hour, germination occurred in the light, but it was considerably retarded. In the dark no sign of germination was noted.

From the above experiments it was quite evident that too strong a dose of anæsthetic was administered. Another series of experiments was therefore conducted in which the spores were subjected to an atmosphere containing less ether. In order to supply the ether atmosphere, one part of ether was mixed with twenty of water. The cultures were then exposed to this atmosphere for one and three hours respectively. Those spores which had been in the ether atmosphere for one hour showed a very slight retardation of germination even in the light, but in the corresponding dark culture no germination whatever was noted. Those spores which had been in the ether atmosphere for three hours showed a very marked retardation, the period required for germination being extended from three to ten days. Those in the dark showed no germination. Another culture was treated in a slightly different way ; it was placed in the ether atmosphere for one hour, then in the dark for twenty-four hours, then in the ether atmosphere again for one hour, and from that time on in the dark under ordinary conditions. These cultures were kept in the dark for three weeks with the complete failure of the spores to germinate. In so far as the above experiments are concerned, ether retarded the germination of the spores even in the light, and had no effect upon their germination in the dark.

The non-nitrogenous food supply of spores is in the form of oils or fat. The first change of the fats in germination is apparently a decomposition into glycerin and fatty acid.[25] That the ultimate product from this food supply which is used in the first growth is a carbohydrate in the form of sugar may be surmised. At any rate the failure of the spores to germinate in the dark is due presumably to the fact that conditions are not afforded for the chemical changes which the reserve material

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[25] Vines, Physiology of plants 173. 1886.

must undergo before it can be used as plastic material for the growth of the cell. There is a possibility that the failure to germinate may be due to the proteid reserve material remaining in a form which cannot be used. This is, however, not as probable as the view just advanced for the non-nitrogenous reserve food. If the supposition is correct, spores when supplied with organic material in the form which the reserve assumes ultimately in germination might be expected to germinate in complete darkness.

As a nutritive solution the following preparation was made: To 100^{cc} of 0.25 pro mille normal inorganic nutritive solution, 2 per cent. of grape sugar and 1 per cent. of peptone was added, and the whole sterilized on the water bath for one hour. Cultures of Funaria spores were made for both light and dark and supplied with this nutritive solution, as great precautions as possible being taken to keep the cultures sterile. An examination of the cultures at the end of three days showed that the spores had germinated as well in the dark as in the light. The very noticeable feature of this experiment was that under these conditions the protonemata were four or five times as large as when supplied with only inorganic nourishment and grown in the light; also that the cells were crowded with large, irregular starch masses, as shown by the iodine test (see *fig. 2*). The question now was: Is this germination in the dark due to the sugar or the peptone or both? In order to determine this point, the following experiments were carried out:

A 2 per cent. grape sugar solution was made from the 0.25 pro mille normal nutritive solution, and cultures of the Funaria spores made for both light and dark. After three days an examination of the cultures showed that germination had occurred as well in the dark as in the light, thus demonstrating the power of grape sugar alone to call forth germinations in the dark. A 1 per cent. peptone solution was then prepared in the 0.25 pro mille normal nutritive solution, and cultures of Funaria spores made for both light and dark. After three days, these cultures also showed germination of the spores in both light and darkness, with the same increase in size of the protonema as in the case where sugar alone was used. In the cultures with sugar nearly every spore germinated, both in light and in darkness; in the peptone culture in the light also the same, but in the dark the number of spores which germinated was relatively small. The above results had already been obtained when Goebel's preliminary note[26] concerning the same phenomenon appeared.

Similar experiments to the above were carried out for *Bryum pendulum*, *Brachythecium rutabulum*, and *Mnium cuspidatum*. With these species essentially the same results were obtained as regards the germination in light and darkness, but the protonemata showed no increase in size, which was such a noticeable feature in the case of the Funaria spores. In the peptone cultures the number of spores germinating in the dark was rather smaller than for Funaria.

That the germination in the dark is due to the nutritive value of the sugar and peptone is highly probable, but still it might be claimed that osmotic pressure was the active agent. In order to throw some light upon this point, the following experiments were carried out: Spores of *Funaria hygrometrica*, *Bryum pendulum*, and *Brachythecium rutabulum* were placed in culture and supplied with a 0.5 per cent. solution of KNO_3. The cultures in the light showed germination after the usual length of time, but no sign of germination was observed in those which were deprived of light. Experiments with the same results were also carried out for the same species in a 1 per cent. solution of KNO_3. De Vries[27] has shown that the osmotic value of KNO_3 is about double that of grape sugar with equal parts of the gram-molecule, or more exactly, the isotonic coefficient of grape sugar is 1.88. The osmotic value of a 0.5 per cent. solution of KNO_3, or approximately a $\frac{1}{6}$ gram molecule solution, would be about the same as that of a 2 per cent. grape sugar solution, or a $\frac{1}{9}$ gram-molecule. The failure then of the spores to germinate under the above conditions would tend to show that the osmotic pres-

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[26] Flora **82**: 75. 1896.

[27] Jahrbücher für wiss. Bot. **14**: 454. 1884.

sure within the spore could not have been the operative force in bringing about germination

The absence of any effect from osmotic pressure was also rendered probable from the experiments in which the spores were supplied with either glycerin or potassium tartrate. Spores of the three species above mentioned germinated readily in 1 and 2 per cent. solutions of glycerin in the light, but in the dark they remained unchanged. Glycerin is a non-nutritive substance for the moss-spores, and at the strength used would be about osmotically equivalent to the sugar. In the 1 per cent. solution of potassium tartrate the spores germinated neither in the light nor dark, but in the 0.5 per cent. solution the growth was the same in the light as in the control experiment. In the dark cultures supplied with 0.5 per ccnt. potassium tartrate there was a complete failure to germinate. The isotonic coefficient of potassium tartrate is 399[28], and consequently the osmotic value of the last solution would not be far from that of 2 per cent. grape sugar. Cultures of spores which were supplied with a 2 per cent. solution of lactose, also non-nutritive for the moss spores, showed the same failure of germination in complete darkness. The spores which were exposed to light germinated however with as great readiness as in the control experiment, where they were exposed to ordinary conditions.

It is known that certain substances like iron chloride and cobalt salts, when used in a solution which is too dilute to be poisonous, exercise an accelerating influence upon the growth of fungi. The substances are non-nutritive, and the acceleration of growth is presumably due to a so-called catalytic action. This fact suggested the possibility of calling forth germination in the dark by means of such substances, and to this end the following experiments were performed: Spores of the species generally used were grown in different strengths of iron chloride: 0.25 per cent., 0.125 per cent. In no case was germination called forth in the dark. In the 0.25 per cent. solution the Bryum and Brachythecium spores germinated neither in light

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[28] DE VRIES, *Ibid.* 506.

nor darkness. In the 0.125 per cent. solution, however, the spores germinated abundantly in the light. A series of experiments was also carried out in which the spores of *Funaria hygrometrica* were supplied with a dilute solution of cobalt sulfate, $CoSO_4$. I have shown in my investigations with seedlings[29] that cobalt solutions are extremely poisonous; hence in order to obtain solutions which would not have a toxic action, a very great dilution of the stock solution was required. Sowings of the spores were made for both light and darkness and supplied with $\frac{1}{100000}$, $\frac{1}{200000}$, $\frac{1}{400000}$, and $\frac{1}{800000}$ gram-molecule solutions. In all of the cultures the spores germinated in the light without any marked retardation, but in the dark, the same as in previous experiments, no germination occurred. Thus all of the previous experiments point to the fact that germination in the dark was due to the nutritive value of the sugar and peptone, and not to any stimulating or catalytic action.

It is also interesting to know the minimum amount of sugar which will suffice to call forth germination in the dark. First, cultures of Funaria spores were supplied with $\frac{1}{900}$, $\frac{1}{225}$ and $\frac{1}{135}$ gram-molecule solution of grape sugar and placed in darkness. An examination after three days showed that in the first two dilutions, none of the spores had germinated, while in the $\frac{1}{135}$ gram-molecule solution they had germinated the same as in light under ordinary conditions; and also with the usual increase in size, and with the accumulation of starch. The spores of *Bryum pendulum* also germinated in a solution of the same dilution, but those of Brachythecium required a still stronger solution, only germinating in the dark when they were supplied with $\frac{1}{90}$ gram-molecule. The maximum concentration at which germination can occur is not so important, but results were obtained in this line for a single species. Cultures of Funaria spore were supplied with 5, 10 and 20 per cent. solutions of grape sugar. The first two concentrations allowed germination in both darkness and light, but in the 20 per cent. solution the spores germinated neither in light nor darkness. In the 5 and 10 per

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[29] BOT. GAZ. **22**: 143. 1896.

cent. solutions, the protonemata which were formed in the light were perfectly colorless and without chlorophyll.

The great difficulty of obtaining perfectly sterile cultures of moss protonemata upon an organic substratum will at once be evident to all who have ever worked in this line. Goebel[30] was unable to obtain perfectly sterile cultures in his investigations upon *Funaria hygrometrica*. If perfectly sterile cultures could be obtained, it would be possible then to determine whether moss protonemata are able to thrive in the dark, when supplied with organic material, as sugar and peptone. This was the problem which now presented itself for solution and to which my attention was next directed. A considerable number of attempts were made, and at last my efforts met with success. The details of the experiments I will describe in the order in which they were carried out.

The medium for the growth of the spores was made as follows: 200^{cc} of 0.23 pro mille normal nutritive solution; 2 gr. grape sugar; 1 gr. peptone; 1 gr. agar-agar. The mixture was boiled on a water bath for three hours and then filtered, and preparations made in small Petri dishes.

Capsules of Funaria were selected which had the opercula still intact and attempts were made to sterilize them. They were first soaked in water until the water had penetrated them thoroughly and then placed in 1 per cent. formol for different lengths of time. The preparation of the cultures was carried out under all possible precautions against infection, in a chamber which had been saturated with steam. So far as these experiments were concerned it was shown that an immersion in the 1 per cent. formol for a length of time sufficient to kill the adhering germs, also proved fatal to the spores.

In order to preserve the spores and at the same time have the capsules in a sterile condition, I was obliged to resort to another method. The capsules were first dipped in melted paraffin and perfectly coated over, and then placed in the formol. The coating of paraffin thus prevented all penetration of the

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[30] GOEBEL, Sitzber math.-phys. Classe k. Bayer. Akad. Wiss. **26**: 462. 1897.

formol into the interior of the capsules. Then, by operating in the chamber which had been saturated with steam, perfectly sterile cultures were obtained.

The Petri dish cultures offered subsequent opportunities for the penetration of molds, even when extreme care was taken, so that cultures which had been kept sterile for several weeks would often be spoiled by the inroads of fungi. The best results were obtained with cultures made in Erlenmeyer flasks.

Cultures of Funaria protonemata were kept in Erlenmeyer flasks from the first of January to the first of May, four months, in perfectly sterile conditions, and in both light and darkness. Parallel with these was a culture started at the same time upon sterilized earth. The mode of growth of the protonemata on the earth agreed with that already described by Schimper,[31] two protonemal axes generally being produced from each spore and growing in opposite directions. There was almost a complete absence of any rhizoid production. Müller-Turgau[32] claims a quite abundant production of rhizoids by Funaria protonemata. After growing for nine weeks the protonemata had produced an abundance of buds, and rhizoids were then produced from the basiscopic cell of the bud.

Mention has already been made[33] of the power of *Barbula muralis* protonema to separate into distinct cells, which are conidia-like and have the power of growing into new protonemata. Sachs[34] speaks of this capability in regard to Funaria protonemata, and Schröder[35] states it as a general principle, that moss protonemata, when cultivated on too dry soil, break up into the separate cells, which are more resistant, and grow into new protonemata under favorable conditions. In case of the leaf protonema of *Barbula muralis* I have shown that this manner of growth cannot be due to desiccation, since the culture was sup-

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[31] *Ibid., plate 1.*

[32] Arb. Bot. Inst. Würzburg **1**: 480. 1874.

[33] Gametophytic regeneration as exhibited by mosses 25. Oswald Schmidt, Leipzig. 1897.

[34] Lehrbuch der Bot. 366. 1874.

[35] Unt. Bot. Inst. Tübingen **2**: 15–21. 1886.

plied with abundant moisture. In my cultures of Funaria protonemata on earth this manner of growth was very marked. The cultures were supplied with a considerable amount of moisture, so that the separation into the individual cells could hardly have been called forth by an insufficient amount. In the original culture the spores were sowed in the center of the Petri dish, and after several weeks of growth only covered an area about 2^{cm} in diameter. After ten weeks nearly the whole Petri dish (6^{cm} in diameter) was filled with a luxuriant growth of protonemata, a large majority of which had grown from separate cells.

The cultures in the light on agar-agar produced no buds although they were exposed to sufficient illumination for four months. The control culture on earth had produced an abundance of buds after nine weeks. The growth of the whole protonema was not as vigorous as in the control experiment. *Fig. 4* shows where the original spore cell has started to form a bud by the insertion of an oblique cross wall; further than this, however, no indication of bud formation was noted. The cultures in the dark produced protonemata of considerable size and vigor, but the vigor of growth was markedly below the same cultures in the light. The protonemata were perfectly free from chlorophyll, and the considerable size attained shows that to a certain extent they are able to adapt themselves to a saprophytic mode of nourishment.

In the light the main protonemal axes were directed parallel to the incident rays of light, and grew either in or on the surface of the culture medium. The secondary branches grew erect from the prostrate axes, and directed themselves towards the light at an angle of about 45°, thus exhibiting a marked positive heliotropism. Sachs[36] has already referred to the so-called dorsiventrality of Funaria protonema. In the dark the main axes were without any definite direction, while the secondary branches grew more or less vertical, but irregularly in all directions. Whether this vertical growth of the secondary branches in the dark is due to negative geotropism, I am not able as yet

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[36] Vorlesungen über Pflanzenphysiologie 640. 1882.

to state with certainty. Some cultures which were grown in the dark in an inverted position showed that the protonemal branches grew downward, away from the culture medium. These experiments would tend to show that the vertical growth was not due to geotropic sensitiveness, but rather perhaps to negative hydrotropism, as in the case of fungi. More experiments in this line are necessary, however, to make these conclusions certain.

It was thought that by using the culture medium with less peptone the protonemata might be brought to a more vigorous development. A second series of experiments was carried out, in which the same culture medium as described above was used, except that only traces of peptone were added. Even in this medium the protonemata did not grow with their normal vigor, either in light or darkness. The growth was, however, more luxuriant than in the cultures which were supplied with more peptone.

2. MARCHANTIA SPORES.

The work of Leitgeb upon the effect of light on the germination of liverwort spores has already been mentioned. Since he found that the spores were unable to germinate in complete darkness, a confirmation of his results at this point cannot be without interest. A culture of Marchantia spores was kept in the dark for over two months without any signs of germination. At the end of this time they were placed in the light, and after a lapse of six days the majority of the spores had germinated. My experiments also confirmed his results in regard to the intensity of light necessary for germination. In weak light germination was retarded, and when growth did take place the spores produced only a narrow filament, with a small amount of chlorophyll. The filament did not attain any considerable size or form a germ disk.

As regards the part of the spectrum effective in producing germination, my experiments with Marchantia spores yielded the same results as for moss spores, and the same as has been found for fern spores by Borodin.[37] That is, the blue rays, the more strongly refrangible, have apparently the same effect as complete darkness. In the potassium bichromate light germination occurred after six or seven days, and with every evidence of as vigorous growth as under normal illumination.

The effect of temperature on the germination of Marchantia spores in the dark was also investigated. A series of cultures was made for 32°, 29°, 27°, 24°, and 23° C., and all placed in the dark. After two weeks' time they were observed, and none of the spores had germinated. They were then placed in the light to see if they had remained capable of germination. In the cultures which had been kept at 29° and 32° C. germination was retarded for a few days, but the spores from the remainder of the cultures grew after the usual length of time.

The length of time required for germination, and the condition of the material, rendered the preparation of sterile cultures impossible, so that the cultures with grape sugar were not very satisfactory. Although I did not succeed in bringing the spores to germinate under these conditions, they gave every indication of growth, and I attribute the failure to germinate only to the inroads of bacteria. In the dark in sugar solution the spores increased to three or four times their original diameter and formed large starch masses the same as in the moss protonemata.

Further than this they could not be brought, although repeated attempts were made, and when the cultures were placed in the light even then germination did not proceed, showing that the spores had not remained capable of germination. If, however, the cultures could have been kept sterile, there was every indication that the spores would have germinated.

3. FERN SPORES.

A culture of the spores of *Ceratopteris thalictroides* was kept in the dark for three months without any signs of germination, while a sowing of the same spores germinated in the light after

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[37] *Ibid.*, 536.

twelve days. Experiments with the spores of *Alsophila Loddigesii* led to the same results. Thus for the species investigated, it can be stated as certain, that under ordinary conditions of nourishment and at a temperature of 19–21° C. the spores are not capable of germinating. The effect of a higher temperature was then tried for the spores of *Ceratopteris*, a culture of the spores being kept at 32° C. in the dark. After a lapse of sixteen days the culture was examined, and it was found that the spores had germinated abundantly. The form of growth was that of a cell filament, seven or eight cells long, the whole being about 2^{mm} in length (see *fig. 5*). The basal cell always produced a rhizoid, and in some cases the end cells of the prothallium divided also longitudinally. The comparative size and form of a prothallium grown under these conditions and one grown in light at the normal temperature is shown in *figs. 5* and *7*. Experiments of a similar nature were also carried out for *Alsophila Loddigesii*. These experiments are interesting in that they show how Borodin and Schmidt, and Göppert and Schelting could have obtained such contradictory results.

4. EQUISETUM SPORES.

There are no contradictory views in regard to the germination of Equisetum spores, both investigations cited admitting and establishing the fact that germination occurred in perfect darkness. I have repeated these experiments for spores of *Equisetum arvense*, with the same result. It can then be stated with absolute certainty, that Equisetum spores are able to germinate under ordinary conditions of nourishment and at a temperature of 19–21° C., in darkness as well as in light. From the foregoing results it seems that light or organic nourishment is one of the necessary conditions for the germination of moss and liverwort spores, in order that chemical changes may take place which will bring the reserve food material into a condition in which it can be used in growth. For the ferns, these chemical processes may be initiated either by light or a sufficiently high temperature, while in the case of Equisetum these changes can occur at a much lower temperature in both light and darkness.

IV. SUMMARY.

The more important results of the foregoing investigations may be stated as follows:—

1. Under ordinary conditions of temperature and inorganic nourishment, moss and liverwort spores are unable to germinate in the dark. Spores when subjected to the more strongly refrangible rays of the spectrum only behave the same as in darkness.

2. Organic nourishment in the form of either peptone or grape sugar will call forth the germination of moss spores in complete darkness. Moss protonemata are able to attain a considerable size in the dark, by a saprophytic nourishment, although the vigor of growth is considerably below the normal.

3. Under ordinary conditions of temperature and inorganic nourishment, fern spores are unable to germinate in the dark. A higher temperature, however, will furnish conditions for the germination in complete darkness.

4. The spores of Equisetum germinate apparently as well in darkness as in light and at the ordinary room temperature of 19–21°C.

The experiments for this work were conducted during 1896–7 at the Botanical Institute, Leipzig, under the direction of Herr Geheimrat Professor Dr. Pfeffer, to whom thanks are due for many valuable suggestions.

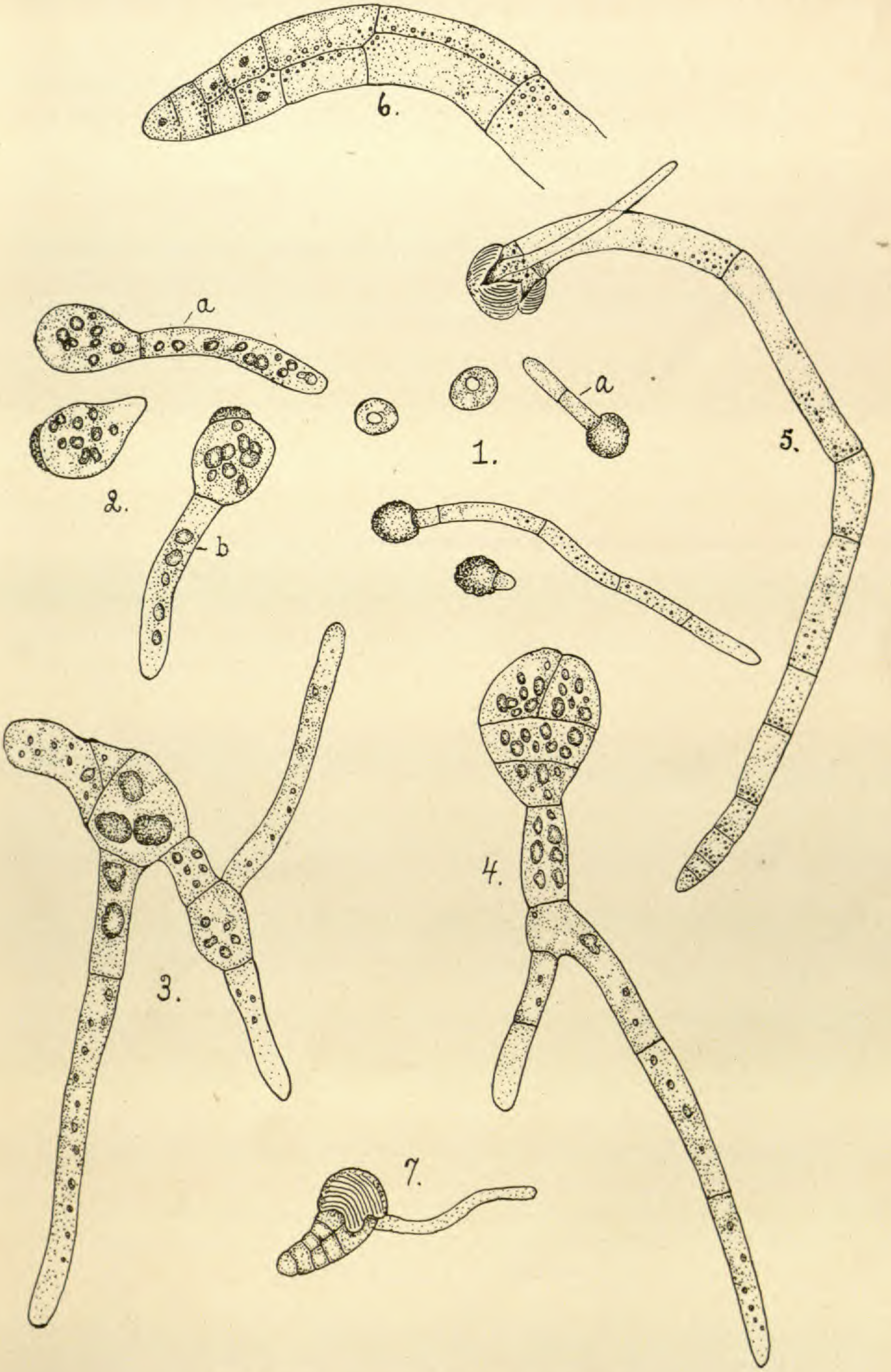
PARSONS COLLEGE,
Fairfield, Ia.

EXPLANATION OF PLATE IV.

FIG. 1. Various stages of Funaria spores, germinated in the light under normal conditions; *a*, after being in culture for three days. × 330.

FIG. 2. Spores of Funaria germinated in the dark in a sugar solution; *a* and *b*, after being in culture for three days. × 330.

PLATE IV



HEALD on GERMINATION of SPORES

FIGS. 3, 4. Protonemata of Funaria grown in the dark; eight days on peptone, sugar, and agar-agar. × 330.

FIGS. 2, 3, 4 show a large number of starch masses.

FIG. 5. Prothallium of *Ceratopteris thalictroides*, grown in darkness, at 32°C. In culture sixteen days. × 330.

FIG. 6. Apical portion of a prothallium of the same species, showing longitudinal as well as transverse divisions. × 330.

FIG. 7. Germinating spores of the same age as in *fig. 5*, but grown in light at a temperature of 19°–21°C. × 330.

BRIEFER ARTICLES.

NOTES ON THE GENUS *BARTONIA*.

In August 1894, while collecting near Holyrood, on Conception Bay, Newfoundland, Mr. H. von Schrenk and the writer secured some sixty or more individuals of a Bartonia. These inconspicuous plants were collected in a small sphagnum bog near South Arm river, and in the field were taken for *B. tenella* Willd; but, when later compared with copious herbarium material of this species, the Newfoundland plant was found to differ in several particulars. From its alternate leaf scales and relatively long corolla (twice the length of the calyx), it was then regarded as the *Centaurella Moseri*[1] of Steudel and Hochstetter, and was accordingly distributed as *Bartonia Moseri* Rob. & Schrenk. But before an account of the Newfoundland collecting expedition was published it became doubtful whether the Bartonia was after all identical with the plants of Moser and Drummond upon which *Centaurella Moseri* was founded. Therefore, to avoid making in print the new combination *Bartonia Moseri* based upon indefinite material, the plant was treated as follows:[2]

"Bartonia sp. (*Centaurella Moseri*, Steud. & Hochst., acc. to Griseb., in DC. Prodr. 9: 121). A plant which appears to represent, at least in part, this rare and poorly understood species, was discovered in a small bog near Holyrood (5). The species was first described from specimens collected by Moser at Saltsburg, Pa., and Drummond at Covington, La. In his treatment of the genus in DeCandolle's Prodromus, however, Grisebach includes in it, with the mark of affirmation, a specimen collected by La Pylaie in Newfoundland. As the present plant agrees with Grisebach's description as regards alternate leaf scales and in having the corolla twice as long as the calyx, there can be little doubt that it is the plant of La Pylaie. It is, however, of lower growth, less branched, and less numerously flowered than Drummond's specimen — differences perhaps wholly due to the

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[1] First published in Griseb. Gen. et Sp. Gentianearum, 308. 1839.

[2] Robinson & Schrenk: Notes on the Flora of Newfoundland, Canad. Rec. Sci. 1896, p. 20 of reprint.

climate. The flowers, also, are mostly larger and solitary, on peduncles which are often six or nine lines long. From *B. tenella* the Newfoundland plant differs in its alternate leaf scales, loose few-flowered raceme, and relatively larger corolla, which in the fresh state is pinkish; also in its purplish anthers. More perfect material of the United States form of *Centaurella Moseri* is much to be desired."

The combination, *Bartonia Moseri* Rob. & Schrenk, was later published in Britton & Brown's Ill. Fl. 2 : 621, where it is used to cover both the United States material and the Newfoundland plant. Having just received additional specimens of the latter, collected at Grand Lake, Newfoundland, by the Rev. A. C. Waghorne, and in all regards identical with those from Holyrood, the writer has made further study of the plants in question, and is now forced to the conclusion that the Newfoundland form is distinct from any species of the United States. It may be characterized as follows :

Bartonia iodandra, n. sp.—Delicate annual, 4 to 12^{cm} high ; root a fascicle of few slender fibers ; stem single, erect from a somewhat bent or decumbent base, either quite simple and terminated by a solitary flower, or alternately branched above the middle ; branches 0.5 to 3^{cm} long, erect or curved-ascending, being mostly simple leafless peduncles each bearing a solitary terminal flower, but the lowest rarely bearing 2 or 3 flowers ; leaf scales alternate, subulate, 2 to 3^{mm} long ; flowers at full maturity 6 or 7^{mm} long, distinctly purplish-tinged ; calyx turbinate below, its segments ovate-oblong to oblong-lanceolate acuminate ; corolla about twice the length of the calyx, when fresh of flesh color, in dried state becoming slightly yellowish but retaining even after several years a suggestion of its erubescent coloration, its segments rather broadly oblong, obtusish and mucronate ; anthers at maturity deep purple or dark maroon ; filaments broadened below; ovary ovoid, obtuse, surmounted by a thickish sessile short-columnar slightly bilobed stigma which is included within the corolla.—*Bartonia* sp. Rob. & Schrenk, Canad. Rec. Sci. 1896, p. 20 of reprint. *B. Moseri* Rob. & Schrenk in Britton & Brown, Ill. Fl. 2 :621, as to Newfoundland locality. *Centaurella Moseri* Griseb. in DC. Prodr. 9: 121, in part (as to pl. of La Pylaie), not Steud. & Hochst.— Collected by B. L. Robinson and H. von Schrenk in sphagnum near Holyrood, Newfoundland, August 23, 1894, no. 5 ; also by Rev. A. C. Waghorne in bogs near Grand Lake, Newfoundland, August 11, 1897 ; these stations being nearly 200 miles apart.

B. TENELLA Willd., which is rather widely distributed in the eastern United States, differs from the species just described in having more numerous slightly smaller flowers of a more yellow cast and in well grown individuals borne in many short opposite 1–several-flowered cymes. The corolla is one and a half times the length of the calyx; its segments are narrower and more acute than in *B. iodandra;* the anthers are yellow; the stigma is mostly exserted; and the leaf scales are usually opposite.

Centaurella Moseri Steud. & Hochst. was distinguished from *Bartonia verna* by its still smaller flowers (4^{mm} long) racemosely arranged upon alternate branches, also by its more acutely lobed corolla twice the length of the calyx. The species is represented in herb. Gray by a specimen with the Torrey & Gray label but without data, and by Drummond's specimen from Covington, La., cited in the original description. Both may be merely tall small-flowered specimens of *B. verna.* They differ from *B. iodandra* in stature, inflorescence, considerably smaller flowers, narrower much more acute corolla lobes, and yellow anthers. In formerly classing the two plants together the writer placed too great importance upon the alternation of the leaf scales and the relative length of calyx and corolla—points of resemblance which now seem of less weight than the differences above enumerated, which are probably of specific value.—B. L. ROBINSON, *Gray Herbarium, Harvard University.*

NOTES ON SUNDRY AMERICAN PLUMS.

THE plum section of the genus Prunus is of great interest to American botanists and of still greater consequence to American horticulturists. But even after much careful work by some of our best botanical and horticultural students there are still many difficulties in the delimitation and description of species. The horticulturists have sought to avail themselves of the botanists' classifications, but have found them in many respects inadequate and ill-fitting; and these horticultural difficulties have, to a considerable degree, reacted upon our ideas of the botanical classification of plums, bringing in doubts and complications which would not have occurred to the botanists working by themselves. At the present time the botany and the horticulture of this group are inseparably linked. The horticultural varieties cannot be classified without a knowledge of the botanical species; and these species cannot be fully understood without a wide study of the cultivated varieties. This is my excuse for calling attention here to some of the species, supposedly among the best known in American botany.

PRUNUS AMERICANA Marshall.—In the absence of Marshall's type specimens his original description makes it impossible to say whether he had in hand the western form which now passes generally under this name, or the northeastern *Prunus Americana nigra*. As long as the two are consolidated after the manner of Gray's *Manual* it makes little difference. If, however, the group is to be divided into two species, according to Sargent's *Sylva* and Britton and Brown's *Illustrated Flora*, it is an open question which part should bear Marshall's name.

PRUNUS AMERICANA NIGRA F. A. Waugh.—This question as to whether our common American plums should constitute one species or two has not yet been fully settled. On the one hand we have Sargent, Britton and Brown, Sudworth[1] and others leaning strongly toward the separation of the two groups; while the Gray publications and the numerous followers of Gray, including Bailey, one of our foremost plum students, hold out for consolidation. It seems to me that, were I unacquainted with the cultivated varieties, I would not hesitate to recognize two species; but the many surprising combinations of *Americana* and *nigra* characters seen in the garden, and the impossibility of disentangling all these varieties, make it more convenient to regard Aiton's group as a botanical variety of *Prunus Americana*. I set forth more fully my reasons for taking this view at the time when I proposed to call this group *P. Americana nigra*.[2]

PRUNUS AMERICANA MOLLIS Torrey & Gray.—Sudworth[3] proposes the name *Prunus Americana lanata* for this variety. No explanation is given for this change, and the variety name of Torrey and Gray seems likely to stand. This variety marks the southwestern evolution of the great *Americana* group, as *P. Americana nigra* is a northeastern modification. The extreme forms are quite as distinct, and by them-

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[1] Nomenclature of the arborescent flora of the U. S. Bull. 14, U. S. Dept. Agr., Div. Forestry.

[2] Bull. Vt. Exp. Sta. 53 : 60. 1896.

[3] Op. cit. 237. 1897.

selves might readily be described as a separate species. T. V. Munson, an experienced horticulturist and botanist in whose observations I have great faith, has taken this view, and has called the group *Prunus australis* (ined.). This variety is supposed to have a distinctively southern distribution, and it does in fact represent exclusively the species at the extreme south; but the woolly pubescent-leaved specimens are mixed with the smooth leaved plants through northern Texas, Oklahoma and southern Kansas, and probably over a much greater range. The horticultural variety Wolf, which belongs distinctively to this group, originated in Wapello county, Iowa,[4] and the variety Van Buren, also characteristically pubescent, originated in the same state. This matter of distribution is especially interesting in connection with the examination of Scheele's *Prunus rivularis* (see below).

THE HORTULANA GROUP.—The species *Prunus hortulana*[5] was proposed by a horticulturist chiefly to clear up a cloud of horticultural difficulties. Further study of wild and cultivated plums has convinced Bailey[6] that this is "a mongrel type of plums, no doubt hybrids" of *Prunus Americana* and *P. angustifolia.* This view appears to me to be much the best one to take of the *hortulana* plums, as I have taken occasion to explain a year ago.[7] The *hortulana* group is so large and contains so many distinct types that one does not get an intelligent idea of it when it is lumped off as a single species, coordinate with *Prunus Americana* and *P. angustifolia.* As soon as we view it as a group of hybrids we can account for the several more or less distinct subgroups. The best marked types in the *hortulana* group are the Wildgoose type, the Wayland type (see below), and the Miner type (*P. hortulana Mineri* Bailey). The relations of these groups I have already discussed in the article referred to above. One group, however, is of special interest. This is the one which I have characterized as the Wayland group.[8] Credit is due to T. V. Munson[9] for calling attention to the distinctness of this group, and for referring it to Scheele's *Prunus rivularis.* I have given in another article[10] my

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[4] L. H. BAILEY, Bull. Cornell Exp. Sta. 38: 14.

[5] L. H. BAILEY, Garden and Forest 5: 90. 1892.

[6] Cornell Exp. Sta. Bull. 131: 170. 1897.

[7] Garden and Forest 10: 340. 1897.

[8] Ann. Rep. Vt. Exp. Sta. 10: 103. 1897.

[9] Catalogue, 1896.

[10] Garden and Forest 10: 350. 1897; see also Ann. Rep. Vt. Exp. Sta. *loc. cit.*

reasons for including the varieties of this group with the great company of *hortulana* hybrids and for rejecting the supposition of a *Prunus rivularis* derivation. Further investigation confirms me in my earlier view, but leads me at the same time to the belief that Munson was correct in identifying the Wayland varieties with Scheele's *P. rivularis.* In other words, I am convinced that *P. rivularis* Scheele is nothing more than one of the more distinct subdivisions of the multiform *hortulana* group. A part of the argument for this conclusion is already set forth in the article referred to, giving the geographical origin of the varieties of the Wayland subgroup. That is, such varieties as Golden Beauty, coming from the range of the supposed *P. rivularis*, and almost certainly identical with that supposed species, are conspicuously like such other varieties as Cumberland, Garfield, Kanawha, Leptune, Missouri Apricot, Moreman, Sucker State, and Wayland, which have originated respectively in the states of Tennessee, Ohio, Kentucky, Arkansas, Missouri, Kentucky, Illinois, and Kentucky. All these varieties agree fairly well with Scheele's description of *P. rivularis.* If there were such a species it would be almost impossible to exclude all these varieties, and quite impossible to include them all, because we cannot suppose a distribution of *P. rivularis* through the states named.

Moreover, an examination of the material in herbaria passing as *Prunus rivularis* seems to support this conclusion. Scheele founded his *P. rivularis* upon Lindheimer's 389 in *Exsiccata Flora Texana.* Through the kindness of the curator I have been enabled recently to examine the material in the National Herbarium, including a specimen of Lindheimer's 389. This specimen is not an extra good one, but shows flowers, fruit, leaves, and some small twigs, giving most of the characters fairly well. It is a trifle Chicasaw-like in general appearance, but answers nicely in every particular to Bailey's description of *P. hortulana.* It also looks most like Golden Beauty and some other varieties belonging distinctly to the Wayland group. This specimen was collected in 1846, and it seems strange that a greater number of specimens have not been collected since then.

Another specimen in the National Herbarium is 187 of Elihu Hall, and was collected at Dallas in 1872. This one is still more easily referred to the *hortulana* group. In fact it conforms much more readily to our ideas of *P. hortulana* as represented in literature and in herbarium material than do many of the cultivated varieties which have gone unquestioned into this group. Wright's 181 in *Plantæ Wrightianæ Texano-Neo-Mexicanæ* is referred to *P. rivularis* by Gray,[11] who says, however, "verging to *P. Americana;*" and this specimen in the National Herbarium is transferred to *P. Americana* "fide Sargent, 1892," which shows how equivocal are the current notions of *P. rivularis.* This is, however, a very interesting and puzzling specimen having broad oval leaves, with irregular shallow obtuse obscurely glandular crenulations. Still another specimen which has sometimes been referred to *P. rivularis* is one collected by J. Wolf in Illinois in 1875. This is quite doubtful. In the National Herbarium it is marked "*P. hortulana,* fide Sargent, 1892." The leaves of this are small and shining, with a fine downy pubescence on the young twigs and petioles. But this pubescent character, which is important in the Wayland group, is not at all so marked as among the Wayland varieties proper. Another specimen, sometimes named *P. rivularis,* is that of Thos. Bassler from Manhattan, Kan., 1883. This is a poor specimen, with only flowers and twigs, but is unquestionably *P. Americana.*

The characters of the Wayland varieties, as well as of the *Prunus rivularis* material, are such as would suggest hybridity between *P. angustifolia* and *P. Americana mollis.* Especially the pubescent nature of the petioles and of the veins on the backs of the leaves indicates the parentage of *P. Americana mollis.* The general shape of the leaves and the character of the serratures also point in the same direction. As already pointed out, the distribution of the Wayland varieties almost exactly corresponds to the joint distribution of *P. angustifolia* and *P. Americana mollis.* T. V. Munson, in private correspondence assures me that, in extensive travels through western Texas, he has quite uniformly found an abundance of Scheele's *P. rivularis, i. e.,* plums of the Wayland class, and, distributed everywhere with these, *P. australis* (*P. Americana mollis*) and *P. angustifolia.* He writes me also that he has grown hundreds of seedlings from this wild stock along with the cultivated varieties and their seedlings, and that the group is quite homogeneous and distinct.

Thus it seems probable that Scheele, who, perhaps, had no personal acquaintance with plums in America, and who had a comparatively small amount of material in Lindheimer's 389, gave specific rank to a group which American botanists would not have mentioned separately, and which American horticulturists would have classified immediately

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[11] Pl. Wright. Tex.-Neo-Mex. 67. 1850.

by reference to recognized pomological groups. If, however, *P. rivularis* is to stand, the date of its publication would give it precedence over *P. hortulana* for that part of the *hortulana* plums represented; but in view of the tendency to abandon *P. hortulana,* this does not appear to be of very much consequence.

It is interesting to note in this connection that *Prunus Texana,*[12] which Scheele erected at the same time as *P. rivularis* from some more Texas material, has not been heard from since, except to be consolidated with the latter by Sereno Watson.[13]

PRUNUS WATSONI Sargent.—Quite a number of cultivated forms of this species, some of them named and catalogued by nurserymen, have recently come under my observation.[14] I have also examined a quantity of herbarium material. It appears to me that it will be very difficult to draw the line between this species and *P. angustifolia.* Even when Sargent's unabridged descriptions of the two species are placed in parallel columns and diligently scrutinized they will be found to yield but a single character of distinction. The calyx lobes of *P. angustifolia* are said to be glandular-ciliate; while of *P. Watsoni* they are said to be eglandular-ciliate; but this distinction cannot be safely applied to the cultivated varieties, as I have had sufficient opportunity to observe. *P. Watsoni* is usually dwarfer, with more zigzag ashy-gray twigs, and with more appearance of thorniness, and usually has smaller leaves with more finely crenulate margins; but none of these characters will serve for critical discrimination. It may even be found necessary in the future to abandon *P. Watsoni* or to reduce it to a variety of *P. angustifolia;* but for the present this species, name, and description seem to be useful in calling attention to a neglected and very interesting group of native plums.—F. A. WAUGH, *Experiment Station, University of Vermont.*

TWO NOTEWORTHY OAKS.

(WITH PLATES V AND VI)

I. A NEW HYBRID.

FOR three seasons I have been observing an oak which grows in the damp sandy woods near the village of Thornton, Ill., six miles

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[12] Beiträge zur Flora von Texas. Linn. **21**: 593. 1848.

[13] Bibl. Index. N. A. Bot. 307.

[14] "The Sand Plums," Country Gentleman **63**: 68. 1898.

south of the southern limits of Chicago. The difficulty experienced in bringing this type of oak under any described species early led to a suspicion of hybridity, and further observations have confirmed this view. The fact that oaks hybridize somewhat readily is strongly in favor of such a solution, when one or two isolated trees are found in the midst of well-marked species of the ordinary kinds. I find no record of a cross between *Quercus palustris* Du Roi and *Q. coccinea* Wang., which evidently takes places here. Dr. Engelmann [1] reported a hybrid of *Q. palustris* and *Q. imbricaria* found near St. Louis about 1870, an account of which was also given by Alexander Braun.[2] This appears to be the only case hitherto noted of any hybrid of *Q. palustris*. It is so much more nearly allied in the character of its leaves to *Q. coccinea* than to *Q. imbricaria* as to add to the difficulty of distinguishing a cross between the two if the leaves only are taken into account, and reliance must therefore be placed principally upon other distinctions, though the color of the autumn leaves is a clear gain. This is the only section near Chicago where I find *Q. palustris*, and it appears to reach its northern limit near the southern end of Lake Michigan here, extending eastward into Indiana and southward in Cook and Will counties, Ill., along Thorn creek and it branches. *Q. coccinea* is more abundant than usual in the woods where the hybrid is found and more sharply defined from *Q. velutina* than customary here. Although there are some features that might be better defined by an assumption of a cross of *Q. palustris* with the latter, the acorns and the autumn leaves are much better explained by a cross with the former. In habit and appearance of the trunk the hybrid is so nearly like *Q. palustris* as at first to have been taken for it. It is a tree of recent growth, 4^{dm} in diameter and about 13^{m} high. The characters are as follows :

Top oblong, the limbs spreading, the lower drooping. Bark of trunk dark gray-brown, tinged with green, close and rather smooth, divided into narrow longitudinal plates, 5–15^{cm} long by 2–3^{cm} wide. Inner bark coarsely cellular, reddish, colored about like that of *Q. palustris*. Young shoots pubescent, becoming smooth or nearly so in autumn. Branches of the first year brown, tinged with yellow, with small, scattered, slightly raised lenticels. Older branches gray, tinged with red. Winter buds ovate-conical, obtusish, slightly angled, 4–6^{mm} long, pubescent with pale or white hairs. Bud scales oval, obtuse,

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[1] Botanical Works 405.

[2] Bot. Zeit. 29 : 202. 1871.

brown or with brown margins. Leaves, when bursting from the bud, densely whitish pubescent. As they expand they spread on rather long petioles like those of *Q. coccinea,* and are thin, light green, and soon smooth above, densely white puberulent beneath, retaining the pubescence longer than on the upper surface. Mature leaves in outline broadly oval or some slightly obovate, $9–12^{cm}$ long and nearly as wide. They are a light glossy green above, lighter and slightly yellow tinged beneath; smooth except tufts of webby hairs in the axils of the principal veins below, mostly confined to the axils of branches of the midvein. They are divided by two deep rounded sinuses on each side, which extend one-half to two-thirds of the way to the midrib. The lobes, except the basal, are somewhat broader above. The lobes are trilobed with shallow rounded sinuses, the terminal lobules three-toothed, the lateral one to three-toothed. The divisions all end in a bristle $4–7^{mm}$ long. The base of the leaves is truncate or slightly cuneate. Petioles slender, $3–4^{cm}$ long. Autumn leaves purplish, or spotted with purple, red, or yellow, or many of the leaves scarlet. Male catkins $5–8^{cm}$ long, hairy; stamens 4 or 5, anthers oblong-oval, retuse or blunt; calyx hairy, 2–4 parted or lobed, frequently 3-parted; segments oval to broad oval or often roundish; they are usually tinged with purple or red. Calyx of the female flower tubular, hairy, tinged with red, six-lobed or cleft. Styles three-parted; stigmas thick, dark and two-lobed. Scales at base of the flower membranaceous. Acorns single or in pairs on peduncles $5–10^{mm}$ long. The cup is cup-shaped, covering about half the nut, rather thick, contracted at the edge into a thin border, and is yellowish within. Cup scales ovate-oblong, rounded at the apex, slightly pubescent, pale umber colored, with thin margins. When dry they are sometimes loosened near the margin of the cup. Nut globular-ovate, $17–20^{mm}$ long, $15–17^{mm}$ wide, pale cinnamon-brown to chestnut color, slightly pubescent, sometimes striped with darker lines.

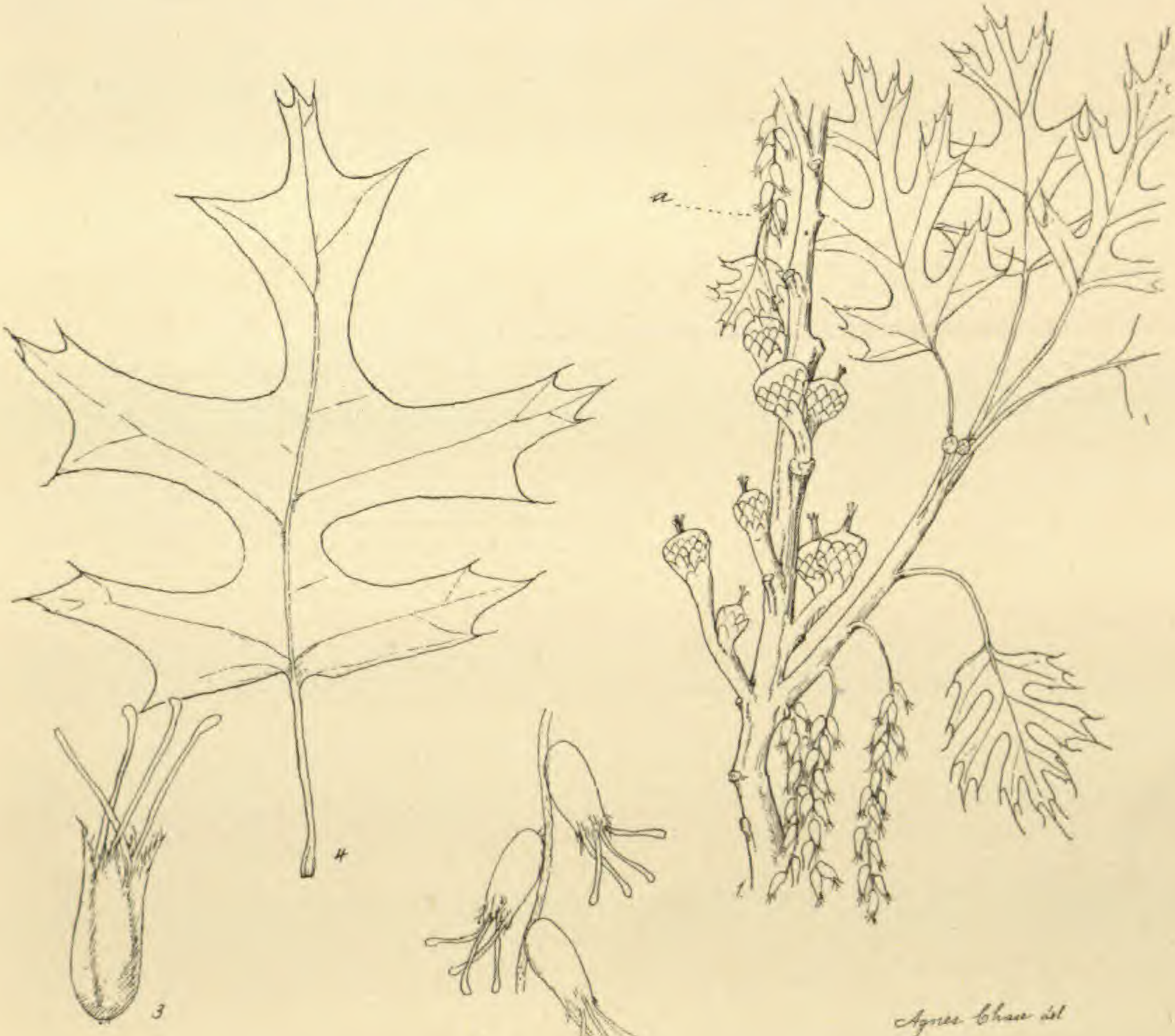
II. A TERATOLOGICAL SPECIMEN.

Farther south in the vicinity of Glenwood is a group of three oaks near the bank of Thorn creek. These have proved of special interest on account of their teratological features. They are evidently developed from the stool shoots of an older tree and of an age that would permit such a tree to have been cut down since the settlement of the region, being $2–3^{dm}$ in diameter. There were originally five, one having been cut down and one is dead though still standing. Since they are so close as now to be uniting at the base and have the habit of those springing from a stump, this seems the true explanation of the group. This is important for it suggests if it does not imply the same habit in the tree from which they have sprung. The three trees agree in having the stamens, or perhaps more properly, the filaments of the aments transformed into styles. Numerous flowers have been examined without finding any ordinary stamens. Such may be produced as the aments are borne in profusion. Sometimes the styles or transformed filaments are a little enlarged at the base, but no ovules or traces of them have been found. A minute embryological investigation has not been undertaken. Another teratological feature is the branching or forking of the rachis, or the production of leaves at its end. In this is seen a tendency of the ament to change its function from the reproductive to the vegetative. Since the styles are transformed filaments or substitutes for them, it may be asked, in the case of a monœcious plant at least, whether the male or female element is at the farthest remove from the vegetative. These aments are short lived, lasting about as long as ordinary male aments. The normal pistillate flowers are also regularly produced, and since the trees ripen an abundance of acorns the change in no way seems to interfere with their reproductive power. Cross fertilization becomes a necessity in this case, the trees being functionally diœcious. Since this habit of the trees has been verified three springs in succession, it may be looked upon as fixed. In character they accord best with *Q. coccinea*, but are not typical, being one of the forms which closely approach *Q. velutina.* A detailed description of its peculiarities is subjoined.

Aments producing styles or pistils in place of stamens. They are from 1–3^{cm} long including the peduncle, which is usually short, in some cases 1^{cm} long. Styles four or five, mostly four, flattened, about 2^{mm} long, projecting considerably beyond the rim of the calyx. The base is hairy, dark colored, and when enlarged oblong. They are paler above, slightly curved outward, with the tip usually enlarged like a stigma, but smaller than the stigmas of the normal flower. The enlargement is commonly confined to three as if representing the three styles of the fertile flower. The calyx is hairy, narrowly urceolate, the four or five segments united two-thirds or three-fourths of the way to the top. Its shape is more like that of the pistillate flower than the more open and campanulate calyx of the staminate flower. In

Agnes Chase del.

HILL on QUERCUS COCCINEA × PALUSTRIS.



HILL on an ABNORMAL OAK.

some aments the rachis ends in a leafy shoot. One examined had three leaves, one of them small and rudimentary, two being lobed and toothed, the blade 8^{mm} long by 2 or 3^{mm} wide, on petioles 3 or 4^{mm} long (*fig. 1, a*). Another ament was found 15^{mm} long, branched near the top, one branch bearing transformed stamens, the other with a leaf similar to the above but slightly larger.—E. J. HILL, *Chicago.*

EXPLANATION OF PLATES V, VI.

PLATE V. Quercus coccinea × palustris.

FIG. 1. Flowering branch, natural size.

FIG. 2. Pistillate flower. × 6.

FIG. 3. Staminate flower. × 6.

FIG. 4. Leaf, natural size.

FIG. 5. Acorns, natural size.

PLATE VI. Teratological form.

FIG. 1. Flowering branch, natural size.

FIG. 2. Portion of ament. × 6.

FIG. 3. Flower. × 12.

FIG. 4. Leaf, reduced one-half.

CURRENT LITERATURE.

BOOK REVIEWS.

The pruning-book.[1]

THIS book, the latest of the "Gardencraft Series," like all of Professor Bailey's works, deals with the subject in hand from a scientific standpoint, is systematic in arrangement, and so practical in all its suggestions that the average fruit-grower cannot fail to derive much valuable information from a perusal of its pages.

The book is divided into two parts. Part I treats of the "Fundamentals," and Part II the "Incidentals."

In the first part the philosophy and principles of pruning are discussed at length, and in the arguments brought forth it is made very evident to the most casual observer that the author is a firm believer in the theory of evolution as affecting plants, as well as animals. Consequently many of the reasons advanced for certain statements are comparatively new to us, because no American writer has ever taken so advanced a position on this subject as Professor Bailey has done; not so marked perhaps in this as in *The Survival of the Unlike*, which makes a good companion to the present volume.

A very common opinion held by practical horticulturists of the present day is that pruning exhausts the vitality of plants to a greater or less degree, according to the severity of the operation. In discussing this question the author maintains that no injury is done to the plant when the pruning is properly performed, and in support of this statement he presents arguments from three sources, viz., philosophy, plant physiology, and common experience. A tree, he says, is essentially a collection or colony of individual parts. Every branch is endeavoring to do what every other branch does — bear leaves, flowers, and seeds. Every branch competes with every other branch, and there are more rudiments of branches — that is, more buds — than there can be branches upon any tree. The limbs and organs of an animal are not competitors but copartners, each performing some function or office which another does not, and they all obtain at maturity a definite size and shape. But a branch never obtains its full size until it ceases to grow and thereby begins to die. Branches are competing individuals; hence there is a struggle

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[1] BAILEY, L. H.: The pruning-book. A monograph of the pruning and training of plants as applied to American conditions. 12mo. pp. xii + 537. New York: The Macmillan Co. $1.50.

for existence among the branches of a tree, and some of them must perish; the destruction of these branches, therefore, must conduce to the betterment of those that remain.

Most fruit-growers advise early and continuous pruning as a means of saving time, and also to direct the energy of the tree which is put forth to produce these superfluous branches into those which are to remain. Professor Bailey believes that annual pruning is desirable, but he is equally convinced that it does not pay, either in cost of pruning or in good to the tree, to cut out all superfluous branches at each pruning. These twigs can often be left till three or four years old with advantage. Pruning in itself cannot be injurious so long as it does not interfere with the nutrition of the plant. Eight reasons are given why pruning should be done.

Part II treats more of the details of everyday practice in starting and shaping the heads of plants; and here the reader is urged to bear in mind the distinction between training or trimming the plant into some desired form, and pruning for definite results in the welfare of the plant and in fruit-bearing.

In discussing the subject of root-pruning the so-called Stringfellow system of stub-root pruning is compared with the ordinary method. Results obtained by the author at the Cornell Experiment Station proved that trees moderately root-pruned were clearly the best. Others, however, have had good results from the Stringfellow method, all of which shows that this method is to be considered a matter of local practice and not a matter of general principle.

The closing chapters of the book treat of training American grapes. The various methods are fully discussed and illustrated, thereby making this one of the most valuable features of the book, especially to the American grape-grower.—J. TROOP.

Fossil botany.

BOTANISTS and geologists both are bound to welcome Professor Seward's work on fossil plants, the first volume of which has recently appeared.[2] This book forms one of the familiar Cambridge "Natural Science Manuals," and is rather more extensive than the others. It is surely safe to say that no general work on paleobotany had yet appeared in English that is satisfactory to both botanists and geologists, and very few that are satisfactory to either. Thus it is a pleasure to read in the preface that this book is intended for both botanists and geologists, and hence has to be adapted to both non-geologists and non-botanists, since it is unfortunately true that neither class as a

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[2] SEWARD, A. C.: Fossil plants for students of botany and geology. Vol. I. pp. 450, with illustrations. Cambridge: University Press. 1898.

rule appreciates the standpoint of the other. The first chapter contains a brief historical sketch of paleobotany, in which the author gives special credit to Brongniart and Williamson. Chapter two gives the relation of the subject to botany and geology. Professor Seward tells how paleobotany has been buffeted about by the geologist and the botanist, the one culling out facts relating to the correlation of strata, the other caring only for facts which give hints as to phylogeny and evolution. He pleads for the recognition of paleobotany as a science of and for itself, with its own peculiar problems, viz., the determination of the historical succession of plants in geological time; the delineation of the actual evolution of the plant kingdom, giving light on phylogenetic mysteries; the presentation of the various floral areas of the past, leading up to an explanation of the distribution of plants in the present day; conclusions as to climatic and other conditions in geological time, as revealed by the occurrence of certain peculiar plant types and by anatomical adaptations to environment.

The third chapter gives the leading facts of geological history and is designed for botanical readers.

The next chapter discusses the various methods for the preservation of plants as fossils; structure unmodified, as in fossil soils and forests; carbonization; incrustation, as travertine; casts; petrifactions. The relative rarity of plant fossils is due to their soft structure and land habitats. Chapter five is exceedingly interesting and valuable, as it demonstrates the enormous difficulties and sources of error, such as (1) the danger of depending too much on external resemblances, since many forms from algæ up to seed plants may look alike, even in modern forms, much more in fossils; (2) fragmental preservation (this is much more common than in animal fossils, and also leads to much more error, since a plant often can be identified only in fruit); (3) the decorticated trunks and pith cylinders; (4) resemblance to animals or animal tracks and mineral deposits.

After a chapter on nomenclature, the author takes up the plants by groups. In this first volume he treats only of the thallophytes, bryophytes, and some pteridophytes. Among the algæ there is an abundance of undoubted fossil blue-green algæ, forming deposits of travertine and possibly oolite; Professor Seward thinks that similar forms probably represented the first life of the Algonkian. Because of their siliceous tests there are vast deposits of diatoms, mainly from the Cretaceous on. Of the larger marine algæ those forms are especially preserved which are covered during life by calcareous incrustations, especially the corallines. Many plants of all kinds and many mineral deposits, rill marks, and animal tracks have been referred to the algæ, and especially to the fucoids. Among the fungi there are abundant evidences of fossil bacteria, but the higher forms are rare, though found in the Carboniferous and Tertiary. The liverworts and mosses are poorly preserved and difficult to identify. Of the pteridophytes, the author considers in this volume only the Equisetales and Sphenophyllales. Both of these groups are abundantly preserved and well known. At the close of the volume is an excellent bibliography.

This work has at least three features to commend it that are by no means common to all books on paleobotany. It is extremely cautious in its statements; many forms commonly described are either classified tentatively or omitted altogether; there are not so many startling allusions to high grade plants in the early ages, but there are more real facts on which to base safe conclusions. Another valuable feature of the book is that important facts have been culled out from a mass of unimportant material, and by no means least in its commendable qualities is that it is actually readable; even the botanical or geological layman may enjoy it, if he cares for such things at all. Everyone who reads the first volume will anxiously await the appearance of the second.— HENRY C. COWLES.

MINOR NOTICES.

DR. L. M. UNDERWOOD read a wise and vigorous paper on the study of botany in high schools before the New York Science Teachers' Association last December. Copies from the *Journal of Pedagogy* for April have been distributed.

DR. W. F. GANONG published in this journal seven years ago (May 1891) a brief account of the raised peat bogs of New Brunswick. During the summers of 1895 and 1896 he was able to give these additional study, and has now published a much more complete and detailed description of the ecological and physical features of these interesting areas.[3]—C. R. B.

TWO BULLETINS of the U. S. Forestry Division have recently been issued.

Bulletin no. 15 is by F. V. Coville, on "Forest growth and sheep grazing in the Cascade mountains of Oregon." It furnishes an account of the methods of sheep grazing on the government reservations in the region named, and their relation to forest preservation both from overgrazing and from fires. Under recent legislation the Interior Department is empowered to make regulations governing grazing on public lands. This report suggests an equitable and apparently feasible system.

Bulletin no. 16 discusses the "Forestry conditions and interests of Wisconsin." It presents the information acquired by Mr. Filibert Roth, a special agent of the department, who made a forest census under the auspices of the state forestry commission and the natural history survey. Botanists will be glad to know that Wisconsin is awakening to an interest in rational forest management. The recommendations of Dr. Fernow, based upon the infor-

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[3] Transactions of the Royal Society of Canada II. **2**: 131–163. *figs. 11.* 1897.

mation gathered by Mr. Roth, are as follows: (1) the appointment of a permanent forest commissioner or commission and a fire warden with suitable powers; (2) state control of the manner of exploiting the forest resources; (3) the acquisition of forest lands by the state at their market value, to be paid for in non-taxable scrip bearing 3 per cent. interest, payable after thirty years in yearly payments equaling 10 per cent. of the principal and accumulated interest; and (4) the good management of these lands by the employment of technical skill. To the latter end it is recommended that instruction in forestry be provided at the state university.— C. R. B.

DR. J. C. ARTHUR describes in *Proceedings* of the Indiana Academy of Science for 1897 a simple arrangement for securing uniform water power for use with physiological apparatus. He uses a tank, set in the upper story of the building, and kept filled from the city water supply by an automatic float valve, such as is used for water closet tanks. A small lead pipe, which can be put in place without skilled labor, siphons the water over the top of the tank — he uses a barrel — and is closed by a piece of rubber tubing and a pinch-cock below. A head of fifteen feet is sufficient to run a water motor which will drive a centrifuge. The uniform pressure is useful for many other purposes.— C. R. B.

DR. A. J. GROUT has prepared a list of the mosses of Vermont represented in the collections of Messrs. C. C. Frost, C. G. Blanchard, C. E. and E. Faxon, G. G. Kennedy, Mrs. E. G. Britton, and the author.[4] Dichotomous keys to both genera and species are provided, so that determinations are much facilitated. A number of species, reported but not known to be represented by specimens, are enumerated in a separate list. The arrangement of families and the nomenclature are modernized.—C. R. B.

THE NUMBER of species and varieties, not to mention the forms and subforms, of Sphagnum has grown so great and the synonymy is so intricate and confused that it is almost impossible for even a bryologist who is not a sphagnologist to find his way through the maze. M. Jules Cardot, an able student of this genus, has rendered his fellow bryologists a most acceptable service by publishing a catalogue of all the species and varieties, giving the synonymy, bibliography, and geographical distribution.[5] It is based upon the most recent work, especially upon Warnstorf's comprehensive studies.

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[4] GROUT, A. J.—A list of the mosses of Vermont with analytical keys to the genera and species. 8vo. pp. 40. Published by the Botanical Department of the University of Vermont. 15 Mr. 1898.

[5] CARDOT, JULES.— Répertoire sphagnologique: catalogue alphabétique de toutes les espèces et variétés du genre Sphagnum, avec la synonymie, la bibliographie et la distribution géographique, d'après les travaux le plus récents. 8vo. pp. 200. Autun: De Jussieu Père et Fils. 1897.

Though obliged on account of their number to omit the forms and subforms, the catalogue contains 215 species, almost 600 varieties, and about 2000 bibliographical citations. The names are all alphabetically arranged, so that reference is easy. Synonyms appear in their proper place alphabetically and are also grouped chronologically under the species to which they are referred. Such work as this is too little appreciated, but deserves the fullest recognition because it saves others hours of time and does a great deal to facilitate study.

The paper is reprinted (and repaged) from the tenth volume of the *Bulletin de la Société d'Histoire Naturelle d'Autun* (for 1897), the first page of text (p. 3) corresponding to p. 235 of that volume.—C. R. B.

NOTES FOR STUDENTS.

IT IS CURIOUS to find M. Henri Coupin, in experiments to determine the toxic dose of various substances for plants, using *percentage* solutions. If the new knowledge of solutions has taught physiologists anything, it is that percentage solutions of different substances are absolutely incomparable, and to base a comparative research on them now is absurd. The first paper of a promised series is on the toxicity of sodium chloride and sea water.[6] The seedlings of peas and wheat were supported at the surface of the solutions by pins, whose corrosion no doubt adds considerably to the toxicity of the fluids. With such sources of error, the series of experiments does not promise to be valuable.—C. R. B.

MOST INVESTIGATIONS as to the effect of the X-rays seem to be yielding negative results. Schober and Müller find no heliotropic action; Beauregard and Guichard, and Atkinson find that they do not affect the vitality of bacteria; the latter also observed no effect on oscillarias or the sensitive plant. MM. Maldiney and Thouvenin now report[7] that the X-rays have no effect in the formation of chlorophyll. These investigators, however, show that the germination of certain seeds is hastened by exposure for an hour or more to X-rays.

THE LLOYD LIBRARY is coming to be known throughout this country and Europe as one of the most important botanical libraries. Two years ago we asked Mr. C. G. Lloyd to prepare for the GAZETTE a brief account of this library. He acceded to this request, but his absorption in other work and his frequent prolonged absences from this country have interfered with the plan. Now a description of the library has been published by Dr. E. Kremers, editor of the *Pharmaceutical Review*, in that journal (**16**: 85–94.

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[6] Revue général de Botanique **10**: 177. May 1898.

[7] Revue général de Botanique **10**: 81. 1898.

1898). To that description we refer our readers. A few of its salient facts we reproduce here.

The founders of the library are John Uri Lloyd and Curtis Gates Lloyd, brothers, who constitute the firm of Lloyd Brothers, extensive manufacturing pharmacists of Cincinnati. The small collection of text-books purchased by the two brothers while serving their apprenticeship in drug stores, constitutes the nucleus of the present handsome library. It has been found advisable to divide it into two departments, one embracing pure botany, in charge of C. G. Lloyd; the other, embracing medical botany, pharmacognosy, pharmacy, and related branches, in charge of J. U. Lloyd, and since 1894 in custody of his assistant, Dr. S. Waldbott. The library is being constantly enlarged by the liberal acquisition of new books and serials. It now comprises approximately 4000 volumes and 1000 pamphlets in the pharmaceutical department, and about 5500 volumes and 3000 pamphlets in the botanical division. There is also in the same building a large herbarium and about 1500 jars of fleshy fungi preserved in alcohol. A building at 224 Court street was purchased in 1891 to house these collections, and though it was then considered ample for some years to come, it had to be enlarged in area and a third story added in 1895 to accommodate the increase. Persons who desire to utilize the exceptional facilities of the library are accorded every possible privilege at Cincinnati, and books are even generously loaned to those at a distance. Professor Flückiger was struck by the remarkable resources of this library when on a visit to this country some years ago, and endeavored to persuade Mr. Lloyd to donate it to some German University. But its founders have determined to donate or bequeath it intact to some educational institution in this country where it can accomplish the most good.—C. R. B.

FOR MORE THAN forty years, notwithstanding close search and careful experimentation, no one was able to add much of importance to the descriptions given by Hofmeister and Mettenius of the gametophytes of Botrychium and Ophioglossum. Hence, when Mr. E. C. Jeffrey published a preliminary statement in the *Annals of Botany* announcing his discovery of more than six hundred prothallia of *Botrychium Virginianum*, botanists awaited the full results of his studies with considerable interest. These have now been published,[8] and, as was expected, prove to be a most valuable contribution to morphology, and by far the most complete investigation of the gametophyte of any of the Ophioglossaceæ that has yet been made. Only one gap in the life history now remains to be filled, viz., that between the chlorophyll-bearing three-celled prothallia obtained from the spores by Professor Campbell, and the tuberous saprophytic form of the mature prothallia.

The prothallia of *Botrychium Virginianum* are oval in shape, destitute of

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[8] The gametophyte of *Botrychium Virginianum*. Edward C. Jeffrey. Trans. Canadian Institute —: 265–294. 1896–7.

chlorophyll, and entirely subterranean, ranging in size from 2 to 20^{mm} in length, and from 1.5 to 15^{mm} in breadth. Growth is carried on by means of an apical meristem of probably a single cell situated on the upper anterior side. All the prothallia found were infected with an intracellular endophytic fungus which occupies the lower portion of the gametophyte body, with the exception of two or three outer layers of cells. This fungus Mr. Jeffrey regards as intermediate between a Completoria and a Pythium, since it agrees with the former in its mode of penetration into the host and its possession of large vesicles, and with the latter in the formation of its conidia and the structure of the filamentous part.

The reproductive organs are confined to a median ridge on the upper surface of the prothallium. The antheridia, in mode of origin and development, agree pretty closely with those of other eusporangiate pteridophytes, but the antheridial wall becomes two-layered. The spermatozoids are of the usual filicineous type, large and multiciliate. In the developing spermatozoids no structure was observed comparable to the blepharoplast of Zamia described by Webber, or the "Nebenkern" seen by Belajeff in Filicineæ and Equisetineæ. The archegonium also originates in a superficial cell. It does not differ strikingly from other fern archegonia, but conforms more closely to those of the higher Leptosporangiatæ than to those of Marattia and Ophioglossum, having a protruding neck, small evanescent ventral canal cell, and non-septate binucleate neck canal cell.

Still more interesting is the growth of the embryo. The first or basal wall is transverse, as in all eusporangiate pteridophytes, and median and octant walls follow. But then regularity ceases, and owing to the late appearance of the embryonic organs it was impossible to assign them to definite quadrants of the segmented oospore. The half-grown embryo presents some resemblance to that of Isoetes, since the lower half forms the foot, and the upper half gives rise to stem, cotyledon, and root. Unlike Isoetes, however, but like Equisetum, it has the stem apex differentiated before the first appearance of the cotyledon. The older embryonic organs, except the foot, grow from well-defined apical cells. The gametophyte is remarkably persistent, having been found in one instance attached to a sporophyte eight years old.

Mr. Jeffrey's paper deals also with the stem anatomy of the young sporophyte.

Undoubtedly these results will strengthen the view that the eusporangiate type of pteridophyte is the more primitive. Just which genus is most like the primitive stock it might not be wise at present to conjecture, but it is interesting to note that Botrychium presents points of contact with each of the very divergent lines, Marattiaceæ, Leptosporangiatæ, Isoetaceæ, Equisetineæ, and Lycopodiaceæ.—WILSON R. SMITH.

We call attention to a series of papers which may be overlooked by plant physiologists who fail to keep an eye on the general literature of physiology. These papers record some of the researches of Professor Jacques Loeb and his students in the Hull Physiological Laboratory of the University of Chicago. Several have appeared recently in Pflüger's *Archiv.*[9]

The interest of these papers to botanists lies, of course, in the unity of the facts which they present with those observable in plants, and in the theoretical discussions which must necessarily be applicable to both. Some of these we here summarize.

It is interesting to find that the development of polyps in colonies of *Eudendrium racemosum* is dependent upon light, and that only the more refrangible part of the spectrum is efficient in calling out this reaction; a relation which at once recalls the phenomena of heliotropism, both in plants and animals. Professor Loeb explains this reaction in accordance with Sachs' theory; that under the influence of light certain substances are produced which further the formation of polyps, while in darkness these substances are not produced at all or only in small quantities. On this we remark that these substances are not necessarily the plastic products themselves, but, as Beyerinck suggested, may be substances which act after the fashion of an enzyme to hasten the necessary chemical processes. Indeed, this seems *a priori* more probable.

The peculiar dissolution of the protoplasm of many protozoa on the anodal side when traversed by a constant galvanic current, and the activity of the skin glands of Amblystoma on the anodal side under the same conditions are the reverse of the reaction of the common nerve-muscle preparation, in which, on the closure of the circuit, stimulation begins at the cathode. To explain this discrepancy, Loeb and Budgett seek to establish the theory that the action of a galvanic current on irritable structures is only indirect, the current producing electrolysis. In the nerve-muscle preparation, they would say, there was electrolysis of the internal fluids of these structures. In the exceptional cases above noted, they show that the current produces electrolysis of the surrounding fluid, and that what is called the electrical

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[9] Loeb, J.—Ueber den Einfluss des Lichtes auf die Organbildung bei Thieren. Archiv f. die ges. Phys. **63**: 273–292. 1896.

Loeb, J. and Budgett, S. P.—Ueber die Ausscheidung electropositiver Ionen an der äusseren Anodenfläche protoplasmatischer Gebilde als Ursache der Abweichungen vom Pflüger'schen Erregungsgesetz. *Ibid.* **65**: 518–534. *pl. 1.* 1897.

Loeb, J.—Zur Theorie der physiologischen Licht- und Schwerkraftwirkungen. *Ibid.* **66**: 439–466. *f. 2.* 1897.

Loeb, J.—Physiologische Untersuchungen über Ionenwirkungen. I Mittheilung. Versuche am Muskel. *Ibid.* **69**: 1–27. 1897.

Loeb, J.—Ueber die physiologische Wirkung elektrischer Wellen. *Ibid.* **69**: 99–114. *f. 9.* 1897.

action of the current is really chemical and molecular (poisoning) action of the electropositive ions set free at the anode, which leads to the formation of alkalies in that region. In support of this they point out that a certain duration of the current is necessary for the production of any reaction, and show that the effect of dilute alkalies is precisely the same as the effect of the current at the anode. The authors think it probable that all galvanic action is indirect in the same sense.

In the paper on the theory of the physiological action of light and gravity, Professor Loeb expresses confidence in the complete analogy between electric and photic stimuli; theorizes on the source of energy for geotropic phenomena; demonstrates clearly (in certain cases at least) the mechanics of stimulation curves; and discusses the so-called "light sense" of eyeless animals. The energy for geotropic curvatures he ascribes to such change of position of substances in the cell as increases or decreases the surface for chemical reactions. This change is conceived as due to the unequal specific gravity of the different substances which become spatially rearranged when the organ is displaced. Such rearrangement leads, directly or indirectly, to the increase of the chemical reaction surfaces of the materials in the cells on the under side of the stem, and their decrease in those on the upper. This theory reminds us strongly, *mutatis mutandis*, of the oldest explanation of geotropism.

As to the mechanics of curvatures, Loeb holds that in all organisms, animal or plant, whether growing, locomotive, or attached, there is the same variable, viz., contractile protoplasm, whose contraction is brought about by stimuli, and that this contraction is the efficient cause of the curvatures. This agrees well with observations on the shortening of the cells on the concave side of plant organs, and the accumulation of osmotically active substances in the cells of that side. Loeb adds a beautiful demonstration from Campanularia, a hydroid polyp.

In the first of a series of papers on the physiological action of ions, Loeb calls attention to the fact that Kahlenberg and True, who were the first to study this general subject, used as a test organism one which did not permit sufficiently accurate discriminations. Loeb has used muscle, and determined the effect of H and HO ions in equivalent solutions upon the increase of the muscle in weight when immersed in a physiological salt solution. In general it was found that the physiological action of dilute inorganic acids and bases was equal when the number of H or HO ions per unit-volume was equal. For organic acids this was not true, on account of the anions and undissociated molecules. The relative poisonousness of ions of the groups Li, Na, K, Rb, Cs, and Be, Mg, Ca, Sr, Ba depends on the rate of migration of the ions and not on the atomic weight of the elements.—C. R. B.

NEWS.

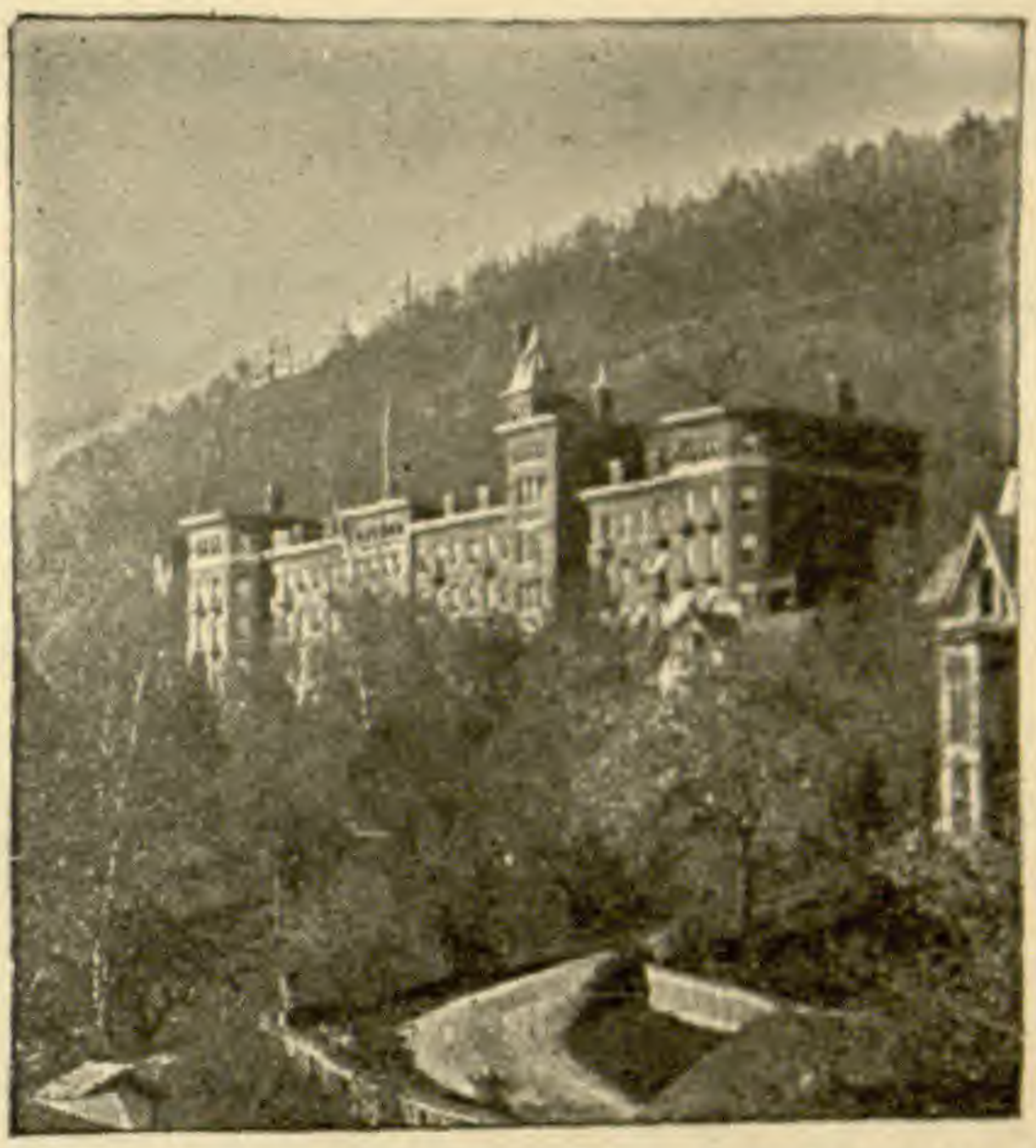
SOME OF THE treasures of the library of the Missouri Botanical Garden are described by Miss Eva M. Reed in the April number of the *St. Louis Public Library Magazine*. A list of the best botanical books for amateurs, beginners, and young people is appended.

DR. B. E. FERNOW, for many years chief of the U. S. Division of Forestry, has been appointed director of the new College of Forestry of Cornell University. The curriculum of the college will be announced this summer. It will include mathematics, civil engineering, botany (especially dendrology), entomology, physics, chemistry, geology, and meteorology. Mr. Gifford Pinchot has been appointed to succeed Dr. Fernow.

PARIS'S *Index Bryologicus* has now progressed as far as *Thuidium* and will be completed in one more, the fifth, part. One comment on the multiplication of forms and subforms in the genus Sphagnum is too good to allow it to remain buried in this reference work. In a footnote to Röll's Systematik the author remarks: "Spezielle Systematik der Torfmoose. Versuch einer Gruppirung der (Nord-Amerikanischen) Torfmoose nach natürlichen Formenreihen, 36 Formenreihen, 373 Varietäten, 325 Formen und zahlreichen Unter- und Nebenformen enthaltend." Röll in *Flora* 1886. Sit brevius dictum: "Tot specimina, quot nomina." O Lindbergii Schimperique manes!

DR. A. MÖLLER of Eberswalde has undertaken the preparation of a memoir of Fritz Müller, the distinguished naturalist of Brazil. He would be greatly obliged for the assistance of friends and any who were brought into scientific relations with Müller. Letters, especially those with scientifically valuable contents, separates of his earlier publications, information as to distinctions conferred upon him and his connection with scientific societies, notices in newspapers and periodicals—in fact all contributions which will facilitate the preparation of a suitable memoir—are solicited. All materials will be carefully used and returned to the owner.

THE DANISH botanist Johan Lange died at his home in Copenhagen on the third day of April, this year, at the age of eighty. Although Professor Lange devoted most of his time to the study and description of the flora of Denmark, he also published several voluminous works upon the flora of Greenland and Spain; besides a number of articles upon systematic botany, with descriptions of new species from various parts of the world. His principal work, however, was a *Manual of the Danish flora*, and the last ten volumes of *Flora Danica*. He was for twenty years director of the botanical garden at Copenhagen, and presided over the Danish botanical society for twenty-seven years; besides being professor of botany at the Agricultural College at Copenhagen. During this long career Professor Lange gained a world-wide reputation as a botanist, and was elected a member of numerous scientific societies.—THEO. HOLM.

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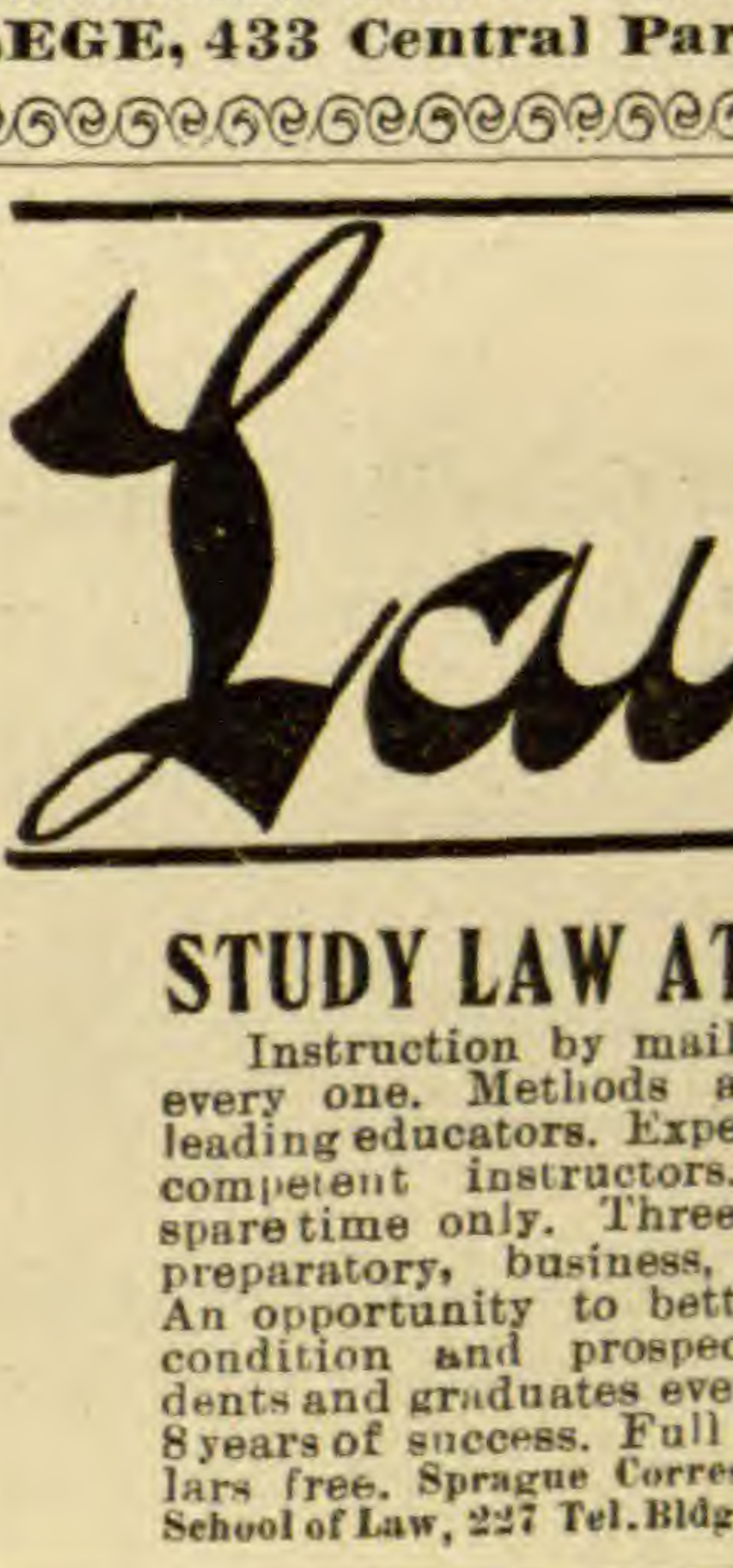
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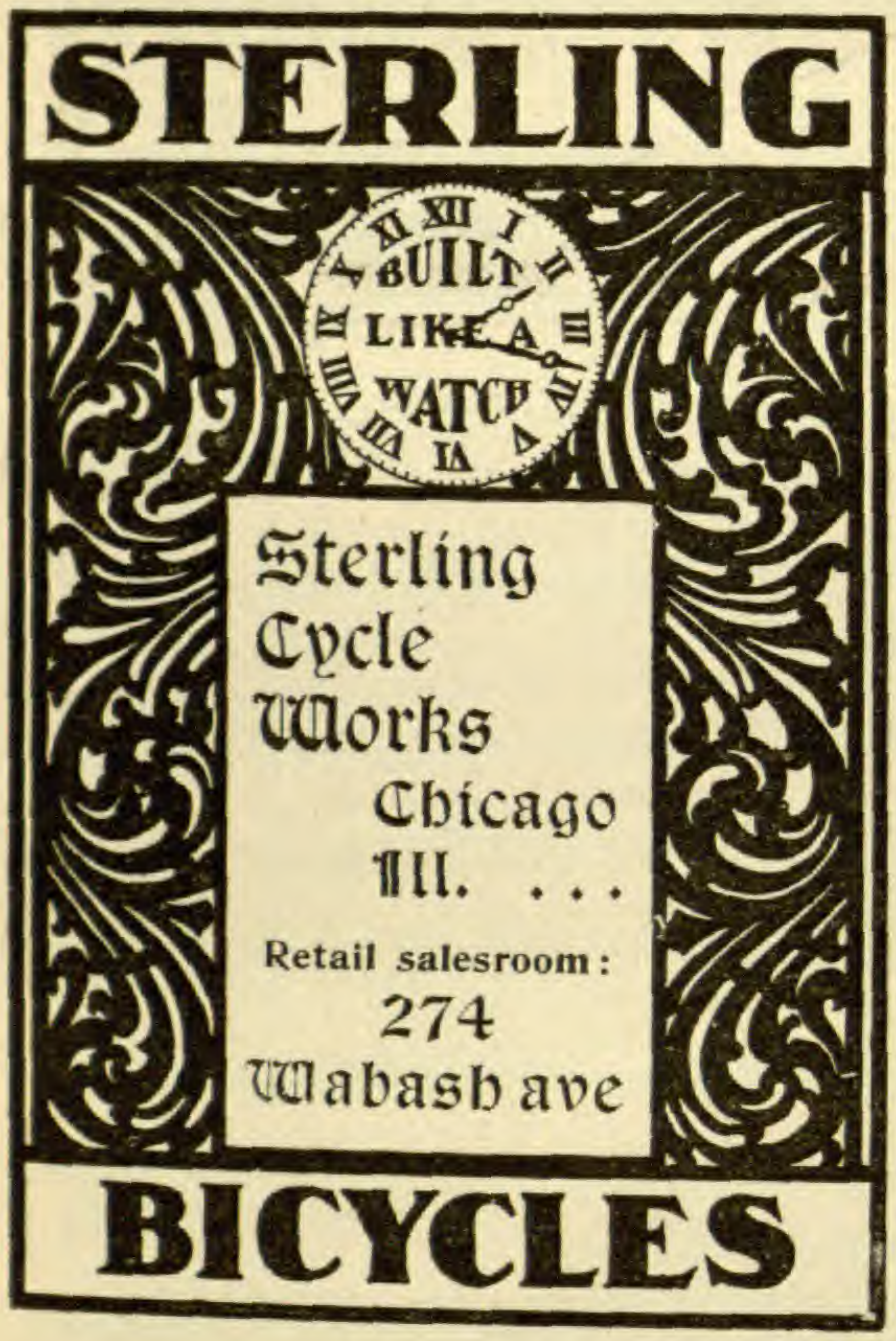

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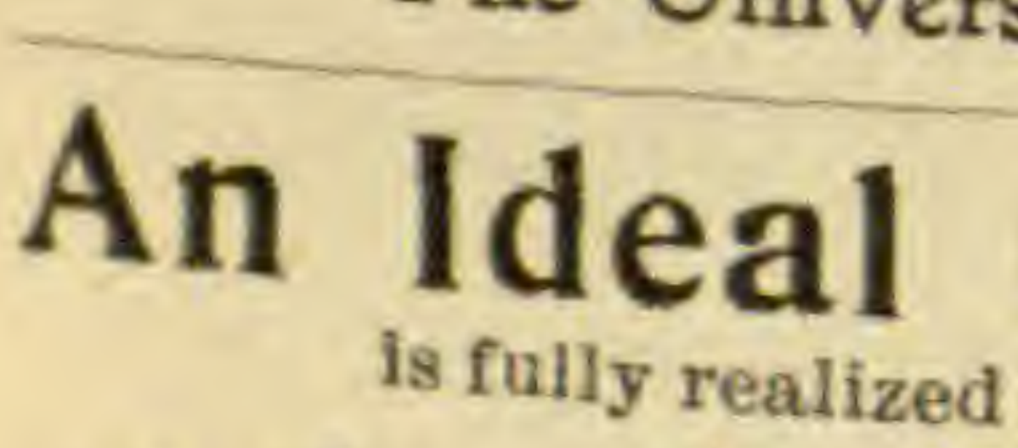

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VOLUME XXVI NUMBER 2

BOTANICAL GAZETTE

AUGUST 1898

A COMPARATIVE STUDY OF THE DEVELOPMENT OF SOME ANTHRACNOSES.

BERTHA STONEMAN.

(WITH PLATES VII–XVIII)

INTRODUCTION.

THE investigations recorded in the following paper were undertaken (1) for the purpose of ascertaining by the growth characters developed in artificial cultures, the relationship of certain fungous diseases grouped under the common name of anthracnose, and (2) to determine, if possible, by a study of their life histories, the connection of these so-called imperfect fungi with perfect or ascigerous stages.

Following the established precedent I have included under this general term certain conidial forms belonging to the family Melanconiaceæ; and a few species of the closely related sphæropsidaceous genus Vermicularia, and Volutella belonging to the Tuberculariaceæ, which so closely approach the genus Colletotrichum in their structural characters and in the effect upon the host plant that diseases belonging to these genera have been referred to the anthracnoses,[1] have also been studied.

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[1] The popular term anthracnose has no systematic value. The name first applied to the "bird's eye" fungus of the grape (*Sphaceloma ampelinum* De Bary, Bot. Zeit. 32: 451. 1874) has since been applied to diseases having a similar external appearance and agreeing in general in microbotanical characters.

The greater number of diseases described as anthracnoses have fallen under the genera Glœosporium and Colletotrichum. These are characterized as fungi appearing at the time of fruiting in subcutaneous or subepidermal acervuli, which at maturity become partly erumpent. The conidia are borne upon basidia arising from a more or less definite basal stroma. At maturity the conidia issue upon the surface of the host in a conglutinated mass, usually of a roseate hue. The acervuli frequently occur upon the host in quite regular concentric circles. The characters of the genus Colletotrichum agree in the main with those of Glœosporium, with the exception of the presence of setæ in the former genus, which is not an absolute line of distinction, however, since Glœosporium develops occasional setæ, and the setæ in Colletotrichum sometimes become so reduced in number that the pustules cannot be distinguished from those of Glœosporium.

The large number of species of these genera, which closely resemble each other in structural characters, and the fact that the anthracnose of one host will adapt itself to others, indicate their close relationship, and suggest that many more species have been established than should be maintained. Moreover, species are often established, especially among the imperfect fungi, from characters which vary with the conditions of growth.

It is well known that these fungi, though parasitic, adapt themselves quite readily to saprophytic conditions, and may be grown in various nutrient media. In artificial cultures, distinct species present more or less marked growth characters, and it is with the aid of these characters that I have attempted to relate, or distinguish, the species of some of this group of fungi, since the characters peculiar to each are sufficiently constant and well marked to be of taxonomic value.

In studying the characters, the ordinary dilution culture method has been employed, and the colonies photographed from Petri dishes. The fungus is then transferred to tubes of sterilized nutrient media. Various media have been employed, but sterilized bean stems have proven the most satisfactory for general purposes, as they are rich in nitrogenous matter and the fungus has a vigorous healthy growth upon a substratum of a consistency near that upon which they are accustomed to grow.

Of nearly all the species studied, the structural characters and relation to the host have received previous study from an economic standpoint; in such cases these points have been briefly mentioned. While germination of conidia has been observed in all species, a detailed account of those which agree quite closely would be tedious; it has, therefore, been usually omitted except in cases where some differences from the normal type have been observed.

Herbarium specimens, tube cultures, and microscopic mounts have been placed in the Botanical Department of Cornell University where the work has been conducted.

My acknowledgments are due to Professor George F. Atkinson at whose suggestion the work was undertaken and to whose ready advice and assistance I have been greatly indebted, and to Messrs. J. B. Ellis, S. M. Tracy, Byron D. Halsted, and others for their cheerful compliance to requests for fungi from their herbaria.

GLŒOSPORIUM FRUCTIGENUM Berk. (*figs. 1–4, 33–38, 83*).

This species, which has been so fully and carefully described by Miss Southworth,[2] and to which Mr. Alwood[3] has recently devoted considerable attention, is comparatively rare in the northern states. The material from which the disease was studied was obtained from apples in the northern markets and from quinces in an orchard at Ithaca. The presence of the fungus was indicated by the characteristic dark brown spots which spread rapidly in size and become somewhat sunken. The center of the spot becomes quite dark in color from the numerous black pustules which rupture the epidermis a few days after the spot has made its appearance. From some of the pustules the abundance of conidia presents a pale rose

[2] Jour. Myc. **6**: 164–173. 1891.

[3] Ag. Exp. Sta. Virginia, Bull. no. 40, May 1894.

color; at the margin of the spot the pustules are frequently arranged in concentric circles.

Sections of the fruiting bodies show the extreme variation marked by Miss Southworth. The developing stroma at the base of the pustule causes in some a depression in the tissue of the host, which is shrunken and brown for some distance down in the fruit. In others there is scarcely any depression; the base of the pustule is very narrow, and the basidia, which become septate with age and quite dark in color, spread gradually and extend a considerable distance above the host, giving the pustule in cross section a flabellate appearance. In the older pustules the disappearance of the basidia at the center was observed, and in addition to the ordinary conidia, on some of the elongated basidia were borne large oval or club-shaped bodies which become fuliginous, and are single-celled or once septate. They resemble the so-called secondary spores so frequently observed in artificial cultures. The conidia are hyaline, single-celled, elliptical, ovate or sometimes curved, varying considerably in size and shape.

In a dilution culture of meat-, or potato-agar, the conidia germinate readily within three or four hours. A germ tube is developed usually near the end of the conidium, which becomes coarsely granular and the contents begin slowly to pass into the tube. Two or three germ tubes frequently arise from the conidium. Sometimes the conidium upon germination becomes septate, but this is the exception under favorable conditions of growth. The fusion of the conidia mentioned by Mr. Alwood[4] is not peculiar to the species, but is frequently seen in other species, and is apparently due to a lack of nutrition, as it is most noticeable in water cultures or in agar-agar cultures when the growth is crowded, or when the nutritive material is exhausted.

Within two or three days after sowing is made, the small stellate colonies may be seen in the agar with the unaided eye. They are subcircular or elliptical, the center being marked by a slightly elevated, more compact growth of mycelium, elongated

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[4] Loc. cit., 67.

and radiating in two to five directions. Upon this growth the first and most abundant development of conidia takes place, which gives it a flesh color ; beyond this the growth is nearly uniform. The colony is almost colorless at first, later assuming a delicate flesh color with the pigment developed in connection with production of conidia. The conidia are formed acrogenously on the branches of the mycelium ; as the successive ones are formed they push the older ones aside, where they may be seen lying in evenly arranged rows or piled up in little heaps. Becoming more numerously developed in some places, they form light pink acervuli quite evenly distributed over the colony.

On bean stems the fungus develops a dense white or grayish mycelium, which extends over the stems and the surface of the infusion in a flocculent weft. About three days after transferring, blackened fruiting sori make their appearance upon the stems ; from these issue the pink masses of conidia, varying in color under different conditions ; in parallel cultures the pigment had a deeper tint on infusion of apple than on bean stems. With age there is developed an abundant stroma, spreading over the stems and underlying the younger flocculent mycelium. The mycelium forming the stroma becomes coarse, irregular, and dark colored.

In old plate cultures the protoplasm of the mycelium has been seen to break up into elliptical spore-like bodies arranged somewhat diagonally in the cells or placed end to end. The dark, club-shaped bodies may be lacking in the entire life cycle of this species, but conidia sown in a hanging-drop of water frequently send out a short promycelium upon which these bodies are borne the second or third day after germination.

It has been observed that in old cultures on bean stems, especially in those that have been repeatedly transferred, the acervuli become less prominent, in fact scarcely make their appearance at all ; but an abundant stroma is developed. This peculiarity corresponds apparently to the habit of the fungus on its natural host, for in the older pustules, in which the ends of the basidia have grown out in long, dark colored filaments, the production of conidia seems to have ceased, and the ends of the hyphæ terminate in the enlarged bodies.

The Glœosporium found on the quince produces also a dark brown depressed spot which increases by well-marked concentric rings. The tissue remains quite firm, becoming more or less hardened, and frequently cracks. In the growth characters of the colonies, and in the habit on bean stems, the resemblance to the species found on the apple is so close as to leave no doubt that the two fruits are infested by the same species ; the slightly different effect produced on the host being doubtless accounted for by the firmer tissue of the quince. Professor Halsted[5] further confirmed the identity by inoculating the quince with "virus" obtained from the apple. The writer has also successfully transferred the Glœosporium from the quince to the apple. However, since these forms easily adapt themselves to artificial cultures and are in a measure saprophytic, too much importance should not be attached to the results of laboratory inoculations, where the conditions are more or less artificial.

No indication of a yeast form has been found in connection with the development of the species.

GLŒOSPORIUM PHOMOIDES Sacc. (*figs. 5–7, 39–41*); on tomato (*Lycopersicum esculentum*).

An anthracnose causing a ripe rot of the tomato is manifested at first by a small circular depressed area. Older spots show a lighter central portion surrounded by a dark marginal band 2–3^{cm} in diameter. Upon the central portion, the dark-colored fruiting pustules first appear, producing irregular fissures in the epidermis, which often turns a bright yellow on the margins. From the pustules the conidia ooze out in light pink masses. With age the diseased portions become quite black.

The spore measurements vary considerably from those given in Saccardo (**3** : 618), some of them measuring 18.5 × 5–6μ. In shape they may be oblong, elliptical, fusoid or reniform, and sometimes curved.

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[5] N. J. Ag. Exp. Rept. 316–317.

The acervuli in section bear little resemblance to those of the ripe rot of apple. From a well developed cup-shaped stroma, lying some distance beneath the epidermis, the short continuous basidia arise. They do not project beyond the host, but the conidia are delimited beneath the epidermis. Although the acervuli may be closely adjacent, they seldom become confluent, and the structural characters maintain a greater uniformity than is seen in *G. fructigenum.*

In dilution cultures with meat- or potato-agar, however, the two species resemble each other in the early appearance of the colony. The conidia of *G. phomoides* germinate readily, frequently becoming once septate. The colonies show the dense, elongated, Y-shaped, or stellate center ; the marginal growth does not present the regular, more or less parallel arrangement of hyphæ seen in *G. fructigenum,* although this character depends somewhat on external conditions. With age, however, the roseate tinge of the colony is less marked. The mycelium is nearly or quite white until a stroma begins to develop. This usually makes its first appearance in a circle about midway between the center and the margin, when the colony is from six to nine days old. This extends gradually both toward the center and the margin of the entire colony, frequently becoming in time a dark reddish-brown. In parallel cultures of the two species this difference is more marked in potato- than in meat-agar. In meat-agar the mycelium approaches the buff-pink tinge seen in *G. fructigenum,* but here also a stroma is conspicuously developed. So uniform is this feature that it seems a valuable specific character. On bean stems the mycelium is a grayish-white at first, rather long and spreading ; an abundant stroma is developed subsequently, which discolors the stems with thin, spreading, elliptical patches ; upon these the dark fruiting pustules are situated. While the appearance on the stems is suggestive of the Glœosporium of the apple and quince, in parallel observations of the two, the Glœosporium of the tomato was distinguished by the darker fruiting pustules, and the duller tint of the conidium mass. At different times, however, and under slightly varying conditions of the infusion of bean stems, these characters were found to vary and were not regarded as of so much importance as the characters developed in Petri dishes. Notwithstanding the fact that this fungus has been found to grow on the apple and quince in laboratory inoculations, the characters manifested in artificial cultures are sufficiently distinct, so that it seems to merit a distinct specific name.

Another disease appearing on maturing tomatoes causes the fruit to crack. These fissures are filled with an abundant white mycelial growth. The conidia are elliptical, oval, or fusoid, and resemble those of *G. phomoides*. On making a dilution culture it was found that the conidia were borne in chains, and proved to be the *Oidium lactis*.

GLŒOSPORIUM VENETUM Speg. (*figs. 8, 42–46*); on *Rubus* sp.

The raspberry is a most generous host for the anthracnoses, and the different genera and species parasitic upon it have formed an interesting group for study.

The most destructive of these, *G. venetum* Speg., has already received considerable attention from economic mycologists, and a brief description of the external characters of this species will suffice. The disease is said to attack all parts of the plant, even the fruit, although so far as the observations of the writer extend, it has been confined to the stems and petioles of both feral and cultivated plants.

It appears first in small purple spots, the oldest ones being found near the base of the plant. As the spots increase in size they become grayish-white at the center, where the tissue of the host frequently becomes ruptured. Encircling the spot may usually be seen an elevated purple border. The disease seldom permeates deeply into the tissue of the plant, but is located chiefly in the cambium layer, where the cells become shrunken and brown.

The conidia form amber colored masses on these spots, and upon examination may be distinguished easily from the other species on the raspberry by their small size. They are oblong-elliptical, measuring 5–7 × 2.5–3μ. The short basidia, which soon become erumpent, spread over the spot and are not confined to a definite pustule.

The fungus does not adapt itself readily to artificial culture, and considerable difficulty was experienced before obtaining a pure culture. The conidia are not easily distinguished from isolated yeast cells, and a fungus forming light colored masses on the anthracnosed spots, and producing conidia closely resembling the conidia of *G. venetum*, proved to be a yeast form.

The conidia germinate readily in water or agar, but after the germ tube has attained a length of three or four times the length of the conidium, further development is very slow. In agar, numerous short branches are sent out from the primary germ tubes, which become closely septate; the cells, including the conidium, become somewhat swollen, so that the conidium itself can be distinguished with difficulty from the cells of the mycelium. Separation is more or less difficult, since growth in acidified agar is even less favorable than in a neutral medium, and bacterial and other foreign growth is liable to contaminate the cultures before the colonies can be seen in order to be separated.

Many unsuccessful attempts were made to obtain a pure culture of the anthracnose of the raspberry.

As late as November 29 fresh conidia were again obtained. With some of these a culture was made in a hanging-drop of water; dilution cultures were also made in acidified and neutral agar. On the following day the cultures were examined and many conidia were found to be sending out slender germ tubes by which, in the crowded condition in the hanging-drop, the conidia were frequently fused; the tubes attaining three or four times the length of the conidium. Four days after sowing, the germ tubes in the Petri dish cultures had attained a length of 24–60μ. They were divided into cells but slightly longer than broad, which were swollen so that the mycelium presented a moniliform appearance. On December 2 transfers of blocks of agar containing germinating conidia were made to tubes of bean stems. The growth at first seemed very unpromising. Small tufts of white mycelium appeared on some of the stems. By December 22 the growth had spread so as to form colonies about 2–3^{mm} in diameter. Very little mycelium could be seen, but one pink mass of conidia was borne on the upper portion of one of the stems. On examination the mass was found to be composed of closely packed basidia, bearing at the end elliptical or oval conidia 6–7μ in length, although occasionally one was found measuring 12 or 14μ. These were sometimes united by short germ tubes. Dilution cultures were made in potato-agar from this colony. Growth took place very slowly; some of the conidia gave rise to two or three germ tubes, these branched frequently and became closely septate. The resulting colonies did not advance beyond a diameter of 3–4^{mm}. At first they presented a stellate, or snowflake appearance, but later became quite dense and compact, with a close even marginal growth. The mycelium assumed a deep red color, darker at the center and shaded to a light pink toward the margin, and presented a glazed, shining appearance. The production of conidia was not observed. Subsequent transfers to tube cultures on bean stems, as well as on sterilized raspberry stems, resulted in a very slight mycelial growth in scattered tufts. Some of these tufts floated freely on the surface of the infusion, in small stellate colonies, and often became attached to the sides of the tubes. In connection with the mycelial growth were small, pink, elevated masses.

So peculiar was the growth and unlike that of any other species of anthracnose studied, that in order to satisfy myself that the growth was that of the anthracnose, fresh material was again obtained the following July. The growth in agar and on bean stems manifested the same peculiarities as before, but upon closer examination of the newly formed patches on the stems the conidia were found. These quickly fall away and form the small colonies which were before mentioned floating freely on the infusion. The colonies in agar did not attain a diameter of more than 3–4^{mm} when six or nine days old. They presented the same dark red or copper colored center with a compact chocolate colored or dull pink margin. Upon teasing out the colonies and examining them under the microscope, the conidia were found in all stages of germination. Some of them presented a dumb-bell appearance, while in others the germ tube about equaled the conidium in diameter, so that it could scarcely be distinguished from the vegetating mycelium. This crowded growth, and the rapid germination of the conidia in the colony, probably accounts for the small size attained by the colonies and their dense, hard, interwoven character.

On sectioning portions of the bean stems upon which the fungus was growing, within the tufts of mycelium were found perithecia-like bodies with delicate walls of closely interwoven mycelium. These were quite small, measuring from 60 to 70μ in diameter, ovate or pyriform. The peripheral cells were light brown, the interior was filled with light colored cells rich in protoplasm. While this condition suggests an ascigerous stage in connection with the fungus, it has not yet matured.

On the hyphæ surrounding these bodies were developed buds or gemmae; these were smaller than those found in other species but were of the same general shape, and of a dark brown color.

SYNONYMY.—*Glœosporium venetum* Speg. is commonly regarded as a synonym of *G. necator* E. & E., the original distinction being that the former one affected the leaves while the latter was confined to the stems. This distinction is now seldom regarded, the description of the two as found in a natural state agreeing so closely that there is little doubt as to their identity. Not having obtained cultures from the fungus on the leaves, the writer is unable to discuss their growth characters in nutrient media.

Glœosporium naviculisporum, n. sp. (*figs. 11, 58–61*).

While attempting to obtain a culture of *G. venetum*, a species of Glœosporium was found on twigs obtained from Mr. Pearson, of Vineland, N. J. This proved to be quite a different species, although the conidia were obtained from canes quite badly affected with the characteristic spots caused by *G. venetum*.

The conidia of this new species are larger than those of *G. venetum*, measuring $12–15 \times 4–6\mu$, in shape fusoid or navicular and sometimes curved.

Unlike *G. venetum* the fungus is a rapid grower, the colonies attaining, under favorable conditions, a diameter of 1^{mm} in three or four days. The colonies have a uniform growth of pure white, erect mycelium, resembling at first those of *G. fructigenum*. It is separated from this species, as well as from *G. phomoides*, by the navicular character of the conidia and by later growth characters. In addition to the characteristic development of mycelium, there are developed abundant bright pink acervuli, formed in concentric rings. It is also distinguished in its development on bean stems by the entire absence of stroma; this character was noted throughout many generations of cultures. The abundant mycelial growth noted in the agar-agar cultures was not so marked on bean stems, but large pink acervuli are freely developed and the conidia frequently sink to the bottom of the tube, where they form a thick, pink sediment.

The colored, club-shaped bodies have been noted in hanging-drop water cultures. Growth on bean stems was at first less vigorous than on sterilized raspberry stems, but in laboratory culture it gradually adapted itself to the former. Inoculations were made on cuttings of raspberry stems transplanted in the greenhouse from the garden, in order to ascertain whether the fungus would adapt itself to growth on living stems. Eighteen days after the inoculations were made the fungus reappeared on the stems, the withered petioles, and along the veins of the leaves. As it has since been found on stems obtained from the university gardens in connection with *G. venetum*, it would be unsafe to say that the appearance was due to the inoculation, since the mycelium might have been lurking in the tissue before the transplantings were made, although the canes were in an apparently healthy condition.

The fungus seems to be a different species from those that have been described, and presents also growth characters distinct from the species studied in artificial cultures derived from different hosts. Unlike *G. venetum* the acervuli are not confined to spots on the host, but spread indefinitely over the stem or leaves. From the form of the conidia I propose the name *Glœosporium naviculisporum*, with the following diagnosis:

Acervuli erumpent-superficial, 60–240μ in diameter, not confined to definite areas on the host. Basidia elevated, hyaline, 30–35μ in length. Conidia fusoid-elliptical, straight or slightly curved; ends acute, hyaline, continuous, measuring 12–15×6μ; oozing out in deep pink masses on stems and leaves of Rubus.

HAINESIA RUBI (West) Sacc.[6] (*figs. 10, 51, 52*); on *Rubus.*

Another fungus of the raspberry is described by Saccardo under the name *Hainesia rubi* (West) Sacc. (Syll. 3:699). This species has been collected in various localities about Cornell University. It is found abundantly on the leaves of Rubus, and is associated with *Cæoma nitens* (æcidial stage of *Puccinia Peckiana*), although this fungus does not seem essential to its existence, since it will grow on artificial media in pure culture. The acervuli are subcuticular, soon subsuperficial, on both upper and lower sides of the leaf. At maturity the conidia ooze out in pale pink heaps.

In section the pustule has much the same appearance as that of *G. naviculisporum*, but the conidia have not the pronounced navicular form found in that species. The colonies have a growth strikingly similar however to that species. There is the same abundant growth of white mycelium which gives the colonies a uniform undifferentiated appearance. The species is fur-

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[6] The species which Miss Stoneman has studied here is identical with that described by Ellis and Everhart as *Glœosporium rubi* (Jour. Mycol. 4:52. 1888) associated with *Cæoma nitens* on Rubus from Mississippi. There has been no opportunity to compare this material with the European specimens, but since their habitat is identical (association with Uredineæ on Rubus), the difference in measurement of the spores, which is not very great, would not seem a sufficient ground for the separation of the species, if they are generically the same. The genus Hainesia has forked and branched basidia. This character is certainly not common in the American specimens which I have examined. While there is a strong probability that the American and European specimens are the same species, it is not possible at present to speak with certainty.—G. F. A.

ther distinguished from *G. naviculisporum* by the development of a stroma in old cultures on sterilized bean stems.

Glœosporium cactorum, n. sp. (*fig. 14*); on *Cactus* sp.

There is a member of the genus Glœosporium which infests the cactus in greenhouse cultivation. The acervuli are erumpent-superficial, pale pink, becoming dark colored, situated on dark brown, decayed spots. On the margin of the spots the acervuli become confluent, often forming a close ring surrounding the less gregarious acervuli of the central portion. The conidia are elliptical, with rounded ends, and measure 12–17 ×4–6μ.

The conidia germinate readily in nutrient agar, and growth takes place rapidly. The colony has a white, snowflake appearance, belonging to a group showing a loose, open growth at the center, with the slender radiating strands of mycelium growing from the central point. The growth of the mycelium above the surface of the agar gives the colony a downy or flocculent appearance. . The marginal mycelium presents a less regular growth than is seen in the open centered colony of *Colletotrichum glœosporoides*, and the open center is usually less distinct. By comparing the colonies with those of *G. cingulatum* Atk. (see *fig. 26*) a close resemblance will be observed. The latter, however, differs in the looser, irregular marginal growth, as well as in morphological characters, which will be discussed more at length in connection with that species.

On bean stems a dense growth of white mycelium is produced, which shows later a slight development of stroma appearing along the edges of the stems. A well developed stroma is formed at the base of the acervulum. The conidia ooze out in light pink masses. Associated with the acervuli are compact stromata, forming dark spherical elevations on the stems. Their appearance suggests perithecia, but no indication of asci has been found in connection with the species. *Fig. 17* represents colonies of the same species collected from a different variety of cactus a year later.

GLŒOSPORIUM MUSARUM Cke. & Mass. (*fig. 11*), on banana (*Musa paradisiaca*).

The anthracnose of bananas is quite commonly found on ripe bunches of the fruit in warm weather. The fungus appears in roseate, innate, erumpent, gregarious acervuli on blackened spots of the fruit. These spots spread over the entire fruit, and the underlying tissue becomes disorganized. The conidia are elongate, ellipsoidal, rounded at each end, usually with a single vacuole, and measure 16–18×4 μ.[7]

The material from which the first cultures were made was obtained from Ellis & Everhart's N. A. F. no. 3178. Conidia from the material collected in July 1894 germinated readily when sown in November of the same year. Germination takes place in the ordinary manner, one or two germ tubes originating at or near the end of the conidium. The conidia remain single-celled upon germination. Growth is rapid and the first crop of conidia in potato-agar appears the second day after sowing. The colonies have at first a stellate appearance, which becomes more or less obscured with further growth. Hyphal growth is sparse at the center, and the mycelium radiates in more or less straight lines. The flocculent or feathery radiations extending from the center to the margin give the colony a characteristic appearance. It is at first grayish in color, and assumes a buff tinge when the acervuli appear, which are scattered irregularly over the surface. Very little mycelium is developed on bean stems, but a compact grayish mat spreads over the surface of the infusion. Over this mat, as well as on the bean stems, the acervuli are produced in great abundance. They are comparatively large and attended with the development of a stroma, which does not spread thickly over the stems as in *G. cactorum, fructigenum*, and *phomoides*. Its entire growth marks it as a species distinct from the others that have been studied. The fungus readily adapts itself to various nutrient media. Although growing upon soft tissue on its natural host it shows a vigorous growth

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[7] The original description in Grevillea (**16**: 3), gives the spore measurements 12×4μ.

of mycelium and an abundance of acervuli when transferred to sterilized oak and grape stems. The development of the so-called secondary spores has not been observed in cultures of this species.

Glœosporium fœtidophilum, n. sp.[8] (*fig. 12*); on skunk cabbage (*Spathyema fœtida*).

The Glœosporium which was found to infest this host causes black depressed, elliptical spots on the spathes. In a microscopic section, the cell walls are found to be very much collapsed; with the exception of those cells just above the acervuli, which frequently retain their normal shape and color though elevated by the underlying mycelium, and causing pale elevated spots on the surrounding blackened portion. The acervuli remain covered for some time, and the customary basal stroma is lacking; the mycelium forms an irregular, loosely interwoven mass at the fruiting points, the conidia being borne some distance beneath the surface, frequently filling the large intercellular spaces. They are slender, elliptical, and slightly inequilateral, varying in size from $7–12–15 \times 2–3\mu$.

Conidia sown in a hanging-drop of water become closely granular or vacuolate, usually once septate and frequently swollen at the ends, previous to germination. They send out two or three germ tubes which produce conidia quite close to the mother conidium. In potato-agar the growth is much more vigorous, as many as five germ tubes having been observed to originate from a single conidium. These branch frequently in a monopodial fashion and the conidia are abjointed so abundantly as to give the colony a yeast-like appearance. The colony is characterized by the pronounced stellate radiations which remain quite distinct from each other in the earlier growth, but the outspreading mycelium becomes more or less intermingled, rendering the radiations less pronounced. About 2^{mm} from the center these radiations branch profusely, giving to the colony a more or less uniform margin. The colony which is at first quite white assumes with age a pale yellow tinge.

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[8] Collected by Professor G. F. Atkinson, Ithaca Flats, April 10, 1896.

On bean stems there is scarcely any development of mycelium. The conidia do not remain collected in heaps, but spread over the stems or collect in a dense layer on the surface of the infusion. The cultures in the tubes are also characterized by the uniform yellow tinge. No stroma develops in the cultures, and the colored club-shaped bodies are not formed either in agar, in bean stems, or in a hanging-drop.

The characters are as follows: acervuli for a long time covered, finally erumpent, situated on black depressed spots. Basidia short; conidia sometimes borne on intercellular hyphæ, hyaline, elliptical, ends acute, 7–12–15×2–3μ. On spathes of *Spathyema fœtida*.

GLŒOSPORIUM NERVISEQUUM (Fckl.) Sacc. (*figs. 13, 53–61*); on oak (*Quercus*), sycamore (*Platanus*).

This species may be easily recognized on the host by the shrunken withered veins of the leaves bordered by arid brown patches. The fungus causes the leaves to curl and become much distorted in appearance. The conidia, which may be found from early in June until November, are distinguished from the usual type of Glœosporium by their ovate pyriform contour, some being so constricted at one end as to appear almost stipitate. Others are more regular in shape, ovate-oblong or oblong, measuring 10–12×4.5–5μ.

Owing to the slow growth after germination has taken place, considerable difficulty was experienced in obtaining a separation culture, as it was closely associated upon the leaves with cladosporium, a pycnidial form, and other rapidly growing fungi.

In several unsuccessful attempts to obtain a culture from affected oak leaves, a peculiarity in germination was observed; the germ tube, which had a bulbous swelling at the base, made a short curve near its origin, sometimes encircling the conidium in a close coil. After germination had been observed the pieces of agar containing the germinating conidia were transferred to infusions of oak leaves. No satisfactory growth, however, resulted from these cultures, which were made early in October, and they were discarded. On October 28 a Glœosporium was found on the leaves of a sycamore on Ithaca Flats. The veins of the leaves had the withered appearance and were bordered by the irregular patches which characterized the disease on the oak. Upon the under side of the leaf brown acervuli were produced, on which an abundance of conidia were found. The acervuli were not confined so closely to the region bordering the veins as was the case on oak leaves, and the withered portions were more expanded, but the color of the pustules, and the spore measurements were the same, and the same peculiarity in germination was noted, the germ tube frequently coiling once and a half or twice around the conidium. The fungus was less contaminated on the sycamore, and the growth could be more satisfactorily observed. On the day following the sowing of the conidia many were found to be germinating, sending out one or two germ tubes. On the third day after germination from three to five tubes could be seen to issue from a conidium which had in some cases become once septate, and the cells were slightly swollen.

The colonies in nutrient agar produce a rather scant mycelial growth, the clusters of conidia forming grayish masses for the most part submerged in the agar, are borne quite uniformly over nearly the entire colony. The colony has a loose, feathery, almost uniform growth, there being no marked radiations or abundant central growth. In both meat- and potato-agar the growth is slow. On bean stems, also, there is a very slight, inconspicuous growth of mycelium, and the tube cultures are marked by the pale brown acervuli which are produced quite freely on the stems.

In the following June (1896), material was again studied from diseased oak leaves; the appearance on the leaf and in section, as well as the peculiarity of germination and the growth developments in Petri dishes and test tubes, are sufficient evidence that the same species of Glœosporium infests both sycamore and oak.

COLLETOTRICHUM GLŒOSPORIOIDES Penz. (*figs. 15, 84*); on orange (*Citrus aurantium* L).

This disease, which was found on an orange tree in the conservatories, is also said to infest plants in outdoor cultivation. It causes, at first, light green spots on the leaves, which become collapsed and brown. Upon them are situated the black fruiting pustules which occur on both the upper and under surfaces of the leaf. Some spots show the acervuli arranged in quite regular circles around the margin, surrounding more indefinitely located acervuli at the center. The acervuli increase rapidly when the leaves are placed in a moist chamber, and the conidia ooze out in bright pink masses. They are rather broadly oval, 12–16 × 5–6μ, with one or two large oil drops. In section the acervuli, from 120–270μ in diameter, are seen to be erumpent, superficial, possessing a well-developed basal stroma, which gives rise to short basidia. The setæ, when present, are marginal, flexuous, once or twice septate, attaining a length of 130μ.

On bean stems the fungus develops an abundant loose, white, flocculent mycelium. The conidia ooze out in large masses, of a deep pink or orange color; a blackened stroma is developed quite abundantly, and the growth resembled that of *G. fructigenum*, of which parallel cultures were studied. Subsequent cultures, however, developed quite different characters in the colony than those of that species. The compact center developed in *G. fructigenum* is not seen in *Col. glœosporioides.* From the small central point of the colony of the latter species the mycelium radiates in from two to five directions. The branching of the mycelium is more or less suppressed at the center until the mycelium attains a growth some distance from the center. It there branches abundantly, the branches spreading out in a fan-shaped growth. These marginal tufts for a time remain quite distinct, but in older colonies well supplied with nutriment they mingle more or less, forming a continuous circular margin. The clear spaces at the center usually remain. The fruiting clusters appear in a circle some distance from the center. More or less of a stroma is developed in connection with the acervuli, so that they appear as black points in the white mycelium. At times there is a pink pigment developed, which gives color to the acervuli. In subsequent transfers to bean stems, in which the mycelium was less abundantly developed, the pustules showed a considerable formation of stroma, and setæ were distinctly seen, although their presence is quite variable.

COLLETOTRICHUM LAGENARIUM (Pass.). Sacc. and Roumg. (*figs. 17, 18, 62–69, 75–79*); on watermelon (*Citrullus vulgaris*).

In Farlow's host index this species is recorded for the following cucurbits; watermelon (*Citrullus vulgaris*), muskmelon (*Cucumis melo*), cucumber (*Cucumis sativus*), pumpkin (*Cucurbita pepo*), and squash (*Cucurbita* sp.).

Its presence is indicated by subcircular brown spots on the rind of the watermelon; on some spots the tissue at the margin may become black, or the order may be reversed and a dark center may be surrounded by a lighter brown portion. Dull roseate acervuli rupture the epidermis, and are arranged more or less concentrically. The presence of setæ is a variable character; in some pustules which were quite mature none could be detected even in carefully prepared microscopic sections. This has led to some confusion in the history of the fungus as to its generic position. The conidia are rather long, narrowly elliptical, 16–20 × 4–5μ, sometimes ovate-oblong or inequilateral.

A section through the pustule shows but a slight development of basal stroma; the basidia are rather long, immersed, but extending partially above the surface of the host.

The fungus does not adapt itself readily to artificial cultures, and several unsuccessful attempts were made before satisfactory results were obtained. Conidia sown in meat-agar were seen to germinate, but subsequent growth took place slowly, and the contents showed disintegration. The mycelium became coarsely granular, and the contents showed disintegration. More satisfactory results were obtained in potato-agar, but here, also, the growth, as well as on bean stems, made but little progress at first. With successive generations, obtained by making transfers of cultures, the fungus became gradually adapted to artificial conditions, and vigorous growth was obtained in potato-agar.

A normal type of germination takes place; one or two germ tubes arise from near the ends of the conidium, making their first appearance within six or twelve hours after the sowing is made. Twenty-four hours after sowing the conidia have usually all germinated.

The contents of the conidium become coarsely granular, and a clear space at the point of origin of the germ tube is seen as its contents pass into the tubes. The mycelium becomes coarsely granular or vacuolate, and branches in an irregular monopodial fashion. As the colonies exhaust the nutrient medium large hyaline vesicles appear as offshoots of the mycelium, or short branches of the mycelium become very much enlarged at the tips. The colonies make their first macroscopic appearance as small, irregularly stellate bodies; as they become older, the mycelial growth is nearly uniform, radiating from a small, dense central point. The conidia are first formed most abundantly at the center of the colony, where a pink acervulus appears. When the colony attains the age of five or seven days, the acervuli are formed irregularly over the central portion of the colony, the marginal mycelium keeping some distance in advance of the fruiting portion. The setæ are produced quite abundantly on the acervuli; in fact, the characters of Colletotrichum are often more distinctly manifested in artificial cultures than in a natural state. At the center of the colony a compact, reddish-brown stroma is formed, which does not spread far over the colony; beyond this stroma the colony acquires uniformly a buff or salmon tint. Faint concentric markings are sometimes seen in the colony.

Transfers to bean stems give rise at the point of inoculation to a spreading, grayish mycelium which covers the stems and the infusion. About three days after sowing the pustules appear in circular, elevated masses of a dull pink hue. As the culture becomes older they become surrounded by a stroma which gives them a blackened appearance at the margin, and long setæ project some distance above the mass of conidia ; these are dark brown except at the base, which is nearly hyaline, and they are frequently once or twice septate. The stems become blackened with a coarse, dark stroma, of irregular, more or less swollen cells, often terminating in club-shaped bodies. The mycelium does not develop below the surface of the infusion, but forms a compact coating over the surface which becomes glazed and shining, and of an intensely dark, reddish-brown color, becoming almost black, retaining, however, a reddish, iridescent hue.

The Colletotrichum on cucumber agrees so closely in all the growth characters that parallel cultures of the two in agar or on bean stems cannot be distinguished from each other. The similarity of growth leaves no doubt as to the identity of the species found on the two hosts, although the illustration of the two in section, and the appearance which the fungus gives to the host, might lead one to suppose them distinct species.

COLLETOTRICHUM LINDEMUTHIANUM (Sacc. & Magn.) Scribner, 1887 (*figs. 19–20, 70–74*); on bean (*Phaseolus vulgaris*).

The history of the anthracnose of the bean has been an interesting one, and much discussion has arisen in regard to its position and nomenclature.

We have an account of its first observation by Lindemuth at Popplesdorf, 1875. It was described and named in his honor by Saccardo and Magnus in *Michelia* 1 : 129, under the name *Glœosporium lindemuthianum*. Owing to its economic importance it subsequently received considerable attention, and has been figured and described in various journals.

Professor Scribner (Rept. Veg. Path. 1887), records the presence of setæ in the acervuli, and suggests that the species be placed in the genus Colletotrichum. In the report of the United States Department of Agriculture, 1887, Mr. Galloway describes the fungus and mentions that the presence of setæ was constant, though very scarce in some cases, in all the material. He also suggests that the species be transferred to the genus Colletotrichum or Vermicularia.

Under the title "Identity of anthracnose of the bean and watermelon,"[9] Dr. Halsted describes some interesting experiments in inoculation of anthracnoses. The anthracnose of the watermelon was easily transferred to the bean, and a third fruit, the citron, was made to receive the anthracnose of both bean and watermelon; and he therefore regards the anthracnose of bean and watermelon, as well as that of the cucumber and muskmelon, as identical. So different was the development of the watermelon anthracnose from that described by Professor Atkinson[10] for the anthracnose of the bean (*Colletotrichum lindemuthianum*), that the latter was compared in artificial cultures with *G. lagenarium*.

Some rusted beans of the Wardwell kidney wax variety were obtained and placed in a moist chamber to germinate. After the first pair of leaves had appeared on the stems of some of the seedlings, the anthracnose was manifested in the characteristic depressed patches. The center of the spots was of a light brown color, bordered by a reddish-brown margin. Scattered over the depressed portions were the small leather-colored pustules. The appearance on the host marked a difference in the species, the watermelon showing a more indefinitely spreading discolored portion of the host which is not depressed. The character of the pustules in section would give less evidence as to their identity; in fact, there is a similarity both in shape and position of the acervulus, as well as in the length of the basidia and character of the conidia.

Dilution cultures were made in acidified and unacidified agar. The former medium was unfavorable to growth, as none of the conidia germinated. Those in the neutral medium two days later showed signs of germination, while four days after sowing several were found in different stages of germination. The first evidence of activity was seen in the swollen condition of the

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[9] N. J. Agr. Exp. Sta. Rep., pp. 347, 352. 1893.

[10] Bot. Gaz. **20**: 305–311. 1895.

conidium at either end, which gives it the appearance of being constricted at the center. This agreed with the peculiarity observed by Professor Atkinson, as did the further development of the colony and the appearance on bean stems.

In order to compare the development of the anthracnose of the watermelon and the bean, parallel dilution cultures were made of the two on March 15, in order that uniform conditions of growth might be obtained. The material from which the cultures were made was obtained from separation cultures of the two previously made on bean stems. On March 16 the conidia of *Col. lagenarium* had sent out germ tubes about ten times their length, while others were not so far advanced, being shorter than the conidium itself. Some of the conidia were provided with septa, one usually at the middle. A few of the conidia of *Col. lindemuthianum* showed short germ tubes, but many had only increased in size. Four days later the conidia, which had just begun to germinate, showed the characteristic dumb-bell swelling, and many of those which had germinated earlier were also seen to be considerably swollen, and many were once septate. From some of the conidia as many as four germ tubes had formed. A few which had produced germ tubes of considerable size showed no appreciable difference in size or shape ; whether a change would come later could not be determined as they were obscured by the mycelial growth. While the spores of *Col. lagenarium* occasionally become distended, the pronounced dumb-bell appearance is not a feature of germination. The germination of *Col. lindemuthianum* resembles that frequently observed in spores of Marsonia, which are originally septate. As the colonies had exhausted the nutrient medium, the enlarged vescicles observed in the mycelium of *G. lagenarium* were seen in *G. lindemuthianum*. These were larger than those previously mentioned; they were frequently once septate, and sometimes sent out one or several short tubes.

Not only do these two species show distinct differences in early growth, but the mature colonies present a very different aspect. Instead of the salmon cast of the colony, it is at first a pure white, with a later development of sepia colored stroma over the central portion, where the fruiting pustules are most abundantly developed. This portion of the colony is not confined to such a limited area as it is in colonies of *Col. lagenarium ;* nor does the outer portion of the colony become tinged, but remains a distinct white.

On bean stems the stroma is also soon developed, causing a blackened appearance of the stems, upon which there is but slight mycelial development, but it forms a white mat over the surface, which for some time forms a marked contrast to the blackened stems. In cultures a month old this also develops a stroma.

Since making the original parallel cultures the two species have been subsequently studied in connection with others; and, from material collected at different times and localities, with uniform results. The colonies of the bean anthracnose leave the impression of a study in black and white, while that of the watermelon, one in pink or salmon and a dark reddish-brown. A comparison of the two is well shown in *figs. 17, 18, 19, 20.*

These various differences which are so marked, and which are quite constant under varying conditions of temperature, seem to show conclusively, notwithstanding previous results in inoculation, that the two are distinct species.

From experiments made by the writer, it would seem that very little dependence can be placed upon the results obtained from cross inoculations made in the laboratory. The host to be inoculated is placed in a moist chamber or under a bell jar, where the moisture of the fruit is conserved, and the conditions are then favorable for any fungus which is already lurking in the tissue to develop. On the other hand, it has been shown that the fungi of this group easily adapt themselves as saprophytes, and a watery fruit like the watermelon or citron, which has been separated from the plant, has lost to a degree the power of resistance, and becomes more or less of the nature of a culture medium.

Volutella citrulli, n. sp. (*figs. 24–25, 80–82*) ; an anthracnose of the citron.

From the Ithaca markets an anthracnosed citron was obtained. It was marked by light brown, subcircular, confluent patches thickly covered with black acervuli, from which the conidia oozed forth in light pink masses. In some of the sporodochia setæ were present, while in others they were wanting. The conidia are hyaline, single-celled, elliptical or clavate, sometimes slightly curved, 15–20×3–4μ. From the general macroscopic characters, and the shape and size of the conidia, as well as from the nature of the host, the fungus was at first referred to *Colletotrichum lagenarium* (Pass.) E. & H. Further study, however, revealed quite a marked difference in the two species.

The pustule of the citron anthracnose has its inception in a dense stroma just beneath the epidermis, but it extends some distance above the surface of the host. In some cases the stroma extends up around the basidia, almost forming a covering as is found in the genus Vermicularia. Long basidia arise above the stroma ; the elevated basidia and the marginal setæ, when setæ are present, would show a close relationship to the genus Volutella. The setæ are colored, two to three times septate, with a swollen base.

This species develops quite differently from that of the bean, or watermelon anthracnose in artificial cultures. In colonies the salmon colored pigment of *Col. lagenarium* is wanting, and the fruiting pustules are not so centrally located, but appear as light colored pustules more or less separated from each other and somewhat concentrically disposed. A stroma, instead of being centrally located as in the two previously under consideration, appears in clusters of peculiarly contorted sclerotoid bodies terminating in club-shaped cells. These masses are formed in concentric rings, intermingled with the fruiting portions. The mycelial growth radiates in quite straight rays from the center to the margin. The growth on bean stems also presents a different aspect from *Col. lagenarium*, just mentioned.

On the stems the mycelium is scarcely apparent, but with a hand lens it may be seen to form a very sparse growth of short threads spreading out on the inner surface of the tube. The stems bear blackened elevations which resemble perithecia in shape, but which have never been found to be associated with conidia. The conidia do not form large pustules on the stem, but can barely be distinguished as small light colored elevations. The surface of the infusion becomes coated with a light colored scanty growth of mycelium. Within this growth appear light colored elevations composed of aggregations of swollen cells which develop dark membranous enveloping walls, similar in appearance to the dark elevations on the stems.

While it is possible that the species *Colletotrichum lagenarium* infests the citron, the species in question is distinct from the one studied on the watermelon. There seems to be no species described in the genus Volutella which agrees with the one under discussion, and the name *Volutella citrulli* is proposed with the following description:

Acervuli elevated; basidia elongated, seated upon an abundant stroma rising above the tissue of the host. Conidia hyaline, single-celled, elliptical or clavate, sometimes slightly curved, $15–20 \times 3–4\mu$. Setæ, when present, marginal, septate, with a swollen base. Forming light brown, subcircular, confluent patches on the rinds of citron (*Citrullus vulgaris*, var.).

COLLETOTRICHUM LYCOPERSICI Chester (*fig. 21*).

Another anthracnose of the tomato is described by Chester[11] as follows: "Spots depressed, circular, slightly discolored, center black, $5–10^{mm}$ in diameter, becoming confluent. Acervuli abundant, densely gregarious, rusty brown or black, applanate, $95–150\mu$ in diameter. Setæ abundant, fuliginous, generally curved, rarely undulate or straight, gradually tapering, septate, $65–110\mu$, about 5μ at the base. Conidia oblong $16–22 \times 4\mu$, averaging $18–20 \times 4\mu$, hyaline, 2–3 guttulate. Basidia short, slender, $30–40\mu$, arising from a well developed basal stroma."

[11] Del. Agr. Exp. Sta. Rep. 4: 60–62. 1891.

Material was obtained from tomatoes of the yellow variety growing in the Cornell University gardens, answering in general to Chester's description, with the exception that the setæ are sometimes absent, and the basidia are rather longer than the measurements given in the original description. The colonies are quite different from those of the Glœosporium on tomato, as well as from those of *Col. lagenarium*. There is a scant development of decumbent, spreading mycelium, with a strong tendency to concentric markings in the growth, where the mycelium is more erect and in tufts, surrounding black, spherical perithecia-like bodies which produce long setæ. These, so far as has yet been determined, are sterile. The conidia formed freely on the mycelium do not mass up in large heaps. Toward the margin clusters are formed of knotted and swollen mycelium bearing quantities of dark colored buds or gemmæ. These lie quite close together, but are more or less distinct. They resemble the colonies of the Volutella on citron in this respect. On bean stems very little mycelium is developed, but the stems are plentifully covered with black spherical or hemispherical pustules, which bear long setæ. In some of these bodies setæ are absent. These bodies seem to be sterile, like those described in the colonies on nutrient agar. On the surface of the infusion a light colored mycelium forms a thick compact mat which does not have a flocculent appearance. but which is rather smooth and shining, and shows white compact aggregations of threads which with age turn black as those on the stems.

Another Colletotrichum was found on muskmelon, which from the similarity in artificial growth developments was referred to this species.

Volutella violæ, n. sp. (*figs. 22–23, 85–89*); on violet (*Viola cucullata*).

The Volutella on the violet is manifested on the leaves of the host by pale brown patches surrounded by a dark brown margin. In the center of the spots the black pustules of the fungus are formed, usually on the upper surface of the leaf, though they also occur on the lower side.

It is distinguished as a Volutella by the marginal setæ, and by the elevated character of the sporodochia, although in some cases the basidia are scarcely more elevated above the host than is found to be the case in some species of Colletotrichum. The conidia are continuous, hyaline, curved, acute at each end, measuring $15–21 \times 3–4\mu$.

Upon germination the conidium contents become coarsely granular, and a germ tube pushes out at or near the end on the concave side. Sometimes a second and a third germ tube succeeds the first. These soon become irregularly septate. With the growth of the fungus the mycelium becomes short celled and closely intermingled, forming at irregular intervals patches of stroma. The mycelium at these places, which is at first colorless, becomes irregularly swollen and colored; from the center of this mass the conidium bearing basidia are formed. Certain cells of the stroma give rise to the setæ, which are enlarged at the base, usually twice or three times septate. Large colored club-shaped bodies are formed at the ends of certain threads of the mycelium, which frequently form grotesque masses by elongation and budding.

The colony of the fungus is one of the most beautiful ones studied. Three or four days after germination the small colonies present a stellate appearance; this character is gradually effaced and the mycelium forms a uniform colony of compact radiating threads. The acervuli are confined to a central region in the colony, in irregular arrangement, where a pink pigment is developed. This gradually extends over the colony, changing to violet, and producing a beautifully iridescent play of colors.

In tube culture a sparse grayish mycelium spreads over the stems, and forms a compact shining mass over the surface of the infusion which displays the iridescence seen in the colonies. With age this coloring disappears in the tubes but is quite lasting in Petri dishes. This delicacy of coloring is less marked in colonies produced from conidia, which have for some time become adapted to artificial culture.

On sterilized stems the fruiting stools are formed similar to those found on the leaves but of a more vigorous habit. The setæ attain a length of 320μ. From the acervuli the conidia exude in dull pink masses.

The early growth characters and the development of the pigment show a close relationship with that of the Volutella of carnations described by Professor Atkinson. The colonies, however, of the latter show in photograph more decidedly stellate characters in the mature colonies, while in the former the stroma and setæ are black, instead of hyaline as in that species.

VERMICULARIA CIRCINANS Berk. (*fig. 16*).

The anthracnose of onions, which occurs quite frequently on the white varieties, was first described by Mr. M. J. Berkeley.[12] An account was subsequently given of the same disease by Dr. Thaxter.[13] The disease first appears as a small black dot, usually on the outer scales, which becomes encircled by rings. These concentric markings are caused by the acervuli, which as the disease spreads are scattered with less regularity over the scale. The pustules are plentifully supplied with setæ, and the conidia ooze out in dull flesh colored masses. They are elliptical, slightly curved, or inequilateral, measuring 20–22×3μ.

A section reveals a remarkable development of a stroma extending down into the tissue to a distance of 250–300μ. This development extends above the tissue to some extent. There is not, however, a perithecium developed, and although the fungus has been placed among the Sphæropsideæ, the character of the pustule shows a close resemblance to those species of Colletotrichum in which an abundant basal stroma is developed, while the marginal setæ and the elevated basidia, as well as the characters in artificial cultures, intimately associate the fungus with the genus Volutella.

[12] Gardener's Chronicle 11 : 595. 1851.

[13] Conn. Agr. Exp. Sta. Rep. 13: 163. 1889.

In germination the protoplasm pushes out through one or more germ tubes usually near the end of the spore, in the usual manner. The colony, as it first appears to the unaided eye, presents a somewhat stellate appearance, but later from the point of inoculation a nearly uniform appearance is presented over a larger part of the colony, with a delicately fringed margin of spreading mycelium. The mycelium which grows both above and below the surface of the agar is at first nearly colorless; with age it becomes a dark smoky color. The discoloration usually appearing some distance from the point of inoculation, extends outward in irregular radiations. The ends of the threads become enlarged, colored, and delimited by a septum. These enlargements are also intercalary and at times peculiarly lobed and branched. At the center of the colony are grouped the dark colored fruiting bodies. At these points a stroma is formed and from some cells of the stroma setæ are borne as in nature. On bean stems the fungus produces a grayish mycelium which spreads over the surface of the infusion, becoming in time of a dark smoky color. A thin stroma spreads over the stems, and acervuli are produced abundantly, and are at times confluent. The setæ, which are quite conspicuous, are borne usually on the margin, sometimes at the center of the pustule.

ASCIGEROUS FORMS.

The course of development of many of the Ascomycetes, especially the Pyrenomycetes, is pleomorphic, and various conidial forms have been definitely interpolated with ascigerous stages. The structure and habits of the species of Glœosporium and Colletotrichum suggest that they too are form genera, having biological relations with perfect forms, although little has been definitely proven in this group to establish the connection.

Since the mycelial growth takes place largely near the surface of the host, and the conidia, provided with delicate walls, require no resting period previous to germination, evidence is strong that in the course of their life history, or at least in some stage of their phylogenetic development, this group has, or once had, a complemental perithecial or pycnidial stage.

In 1886 Von Tafel[14] carried on some investigations with *Glœosporium nervisequum* (Fckl.) Sacc., which he suspected from morphological evidence to possess an organic relationship with a pycnidial form, *Discula platani* (Pk.) Sacc. Owing to the fact that the pycnidial form was always associated with the Glœosporium form on the leaves, he was led to suppose that the mycelium passed through the petioles to the branches and there formed the pycnidia whose conidia developed in turn the Glœosporium. He was unable, however, to establish the connection by cultures, and the question still remained an open one. In continuing the investigations there was a suggested connection of the Discula with an ascigerous form of the genus Fenestella. The apparent connection of this form with a second pycnidial form as well as with a form resembling Acrostalegma, tended to disprove rather than to establish the connection with the Glœosporium.

In connection with the study of *Glœosporium fructigenum* Berk., Miss Southworth[15] notes the finding of a perithecium containing two asci on the apple from which the Glœosporium was obtained, but the material, owing to contamination, could not be further examined. While the association of the two forms on the same host is interesting, very little value can be given to the incident in establishing a connection between them, for, as she says, the apple became contaminated and it is quite possible to account for the presence of the ascigerous form in that way.

Suggested connections are found in Saccardo's *Sylloge* of species of Glœosporium with ascigerous stages. *Gnomoniella? circinata*[16] on the leaves of Ribes is noted in connection with *Glœosporium ribis* and *Gnomoniella fimbriata* has been found associated with *Glœosporium carpini* on the leaves of Hedera.

In a large number of artificial cultures of *Glœosporium fructi-*

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[14] Bot. Zeit. 44: 284. 1886.

[15] Dept. Ag. Rept. Washington 348. 1887.

[16] Sacc. Syll. Fung. 1: 416–419.

genum no perithecial form was found in connection with it by the writer. In the study of *G. nervisequum* (Fckl.) Sacc., both pycnidial and perithecial forms were found associated with it in the first dilution cultures, but when pure cultures were obtained by subsequent dilutions only the conidial form was found in the cultures.

It is an interesting and significant fact that two species of Glœosporium should be found associated with the same ascigerous genus Gnomoniella. The writer made several attempts to obtain a culture of *G. ribis*, all of which failed and its culture was abandoned.

Gnomoniopsis cingulata Stoneman (*figs. 27, 28, 90–97*); *Glœosporium cingulatum* Atk. on *Ligustrum vulgare.*

In 1892 Professor Atkinson[17] described a new species of anthracnose of the privet (*Ligustrum vulgare*). The growth characters of the fungus in artificial cultures suggested the probable cycle of development of this Glœosporium. On cultures of sterilized bean stems the threads were associated into strands of compact tufts, several layers deep. Within these wefts were numerous black rotund perithecia-like bodies, white within and filled with rich protoplasmic contents, presaging, as the author suggested, a probable ascigerous stage. Subsequent to the publication of this study, mature perithecia were obtained in pure cultures of this Glœosporium, sections of which were mounted and preserved. The material studied was obtained from Penn Yan, N. Y. The discovery of the perfect stage in pure cultures rendered the investigations of Professor Atkinson of more value than any results which had been previously brought to bear on the subject.

In February 1895, material was received from Manhattan, Kansas, through Professor Hitchcock, of the State Agricultural College. The affected stems showed the elongated depressed areas of a light brown color corresponding to the affected twigs originally described. No spores could be obtained owing to the

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[17] Cornell University Exp. Sta. Bull. 49: 310. 1892.

age of the fruiting pustules, but with a flamed scalpel, after cutting away the surface tissues, portions of the affected areas were removed and transferred to tubes of sterilized bean stems on February 18. A grayish mycelium soon began to spread over the stems, and black perithecia-like bodies made their appearance in connection with the acervuli producing the masses of conidia. On March 18 an examination of the cultures was made, and the black elevated wefts of mycelium were found to be perithecia containing mature asci, agreeing in every respect with those previously mounted by Professor Atkinson.

The perithecia were cespitose, seated upon a subiculum or stroma of loosely interwoven mycelium, dark brown, flask-shaped, membranaceous, measuring from 250–320μ in length and about 150μ in diameter, gradually constricted toward the apex into a short rostrum. The perithecia were more or less hairy with a conspicuous tuft of coarse brown mycelium about the ostiolum. The asci were aparaphysate, clavate, sessile, measuring about 64 × 14μ. Spores eight, hyaline, elliptical, slightly curved, subdistichous, 20–28 × 5–7μ, usually with a clear spot at the center.

As it was impossible to say from what growth this result was obtained, it now remained to establish definitely the connection of the ascigerous stage and the conidial form. A dilution culture was therefore made in nutrient agar, and spores were marked which by their size and shape could be distinctly recognized as ascospores. These spores germinated in the same manner as do the conidia, by sending out a germ tube usually near the end, a little in advance of one originating near the opposite end. *Fig. 97* shows germinating ascospores eight hours after sowing; twenty-four hours later under favorable conditions they may attain a length of 500 or 600μ, showing indefinite septation and irregular branching. The germination of some spores may be retarded and the germ tube delayed until the day following the sowing, although the spores do not become altered in size or shape. On the second day after germination as many as four or five germ tubes may be seen to proceed from a single spore. These usually become branched quite near their origin, but the center of the colony remains open and the radiating mycelial strands remain distinct from each other for about 2^{mm} from the center. Beyond this the mycelium branches in a brush-like manner, mingling toward the margin in a loosely spreading uneven fringe. The colonies produced from the ascospore had the same characteristic snowflake appearance described by Professor Atkinson for the colonies resulting from the conidia. From the tips of the mycelium the elliptical or clavate conidia are delimited as early as the second day after germination; the time, however, varies, depending upon the separation of the colonies and the amount of nutriment. When the colonies are well separated and growing in an abundance of nutriment, the formation of conidia is delayed. In artificial cultures the acervuli are sometimes attended with setæ, although they are not sufficiently abundant to characterize the genus as a Colletotrichum, and none have thus far been found in sections of the acervuli made from the host plant. Very little pigment is developed in the agar in connection with the formation of conidia, but ten or fourteen days after sowing the colony begins to show a development of stromata in small circular masses scattered indefinitely over the colony, which become elevated above the agar and overspread it with a grayish mycelium. These are filled with coarse granular protoplasm, and represent the early stage of the perithecia; the agar, however, usually dries away before they become mature, although asci have occasionally been found in them. These are formed in connection with conidia, alike on the colonies developed from either ascospores or conidia. Portions of the mycelium produced from marked spores were removed to cultures of bean stems, the colonies being sufficiently separated so as to insure pure cultures. These separation cultures produced the grayish mycelium, bearing conidia abundantly, which collect in pink masses. The mycelium after about ten days becomes a dark brown; numerous dark buds or gemmae (?) are formed, and the association of the perithecia-producing stroma becomes manifest within a week or ten days after inoculation. The perithecia become mature when the cultures have attained an age of three or four weeks.

Again in November 1895 both stems and leaves were received from Kansas affected with *G. cingulatum* Atk. On the leaves the fungus appears in light brown arid spots, oval or fusoid, bordering the midribs. Fruiting pustules are formed on both surfaces of the leaf, though more abundantly on the upper surface. From cultures obtained from these conidia, ascospores were again obtained. The two forms have been obtained repeatedly in subsequent transfers made to preserve the species in artificial cultures, and definite connection of the two stages cannot be doubted. While the pleomorphic course of development can readily be traced, it cannot be said that one stage is necessarily intercalated between successive crops of the other.

Gnomoniopsis piperata Stoneman (*figs. 98–104*); *Glœosporium piperatum* E. & E.; on pepper (*Capsicum annuum* L.).

In October 1896, peppers affected with *Glœosporium* were received from Professor S. M. Tracy of the Mississippi Agricultural Experiment Station. The affected areas appeared as circular or oval spots in which pale yellowish fruiting pustules had ruptured the epidermis in elongated, irregular fissures, which were closely associated so as to be confluent at the older affected portions; around the margin they were arranged concentrically The conidia were elliptical to oval, measuring 12–23×5–6µ. A dilution culture of the conidia was made October 10. The conidia germinated in the ordinary manner within twelve hours; subsequent growth was slow and lest the colonies should become contaminated transfers were made to bean stems on October 23, although at this late date no conidia could be found in the cultures. The colonies showed few positive characters, the mycelium growing almost uniformly from a small light colored central point, with the exception of a less abundant growth surrounding the center about 4–5^{mm} in diameter. On bean stems the fungus developed quite an abundant grayish mycelium, standing out in a flocculent mass. On the surface of the infusion it is of a lighter color, and is usually more compact than on the stems, although this condition varies in different cultures; in tubes containing richer nutrient material there is a more abundant and more compact development of mycelium. This difference is quite marked in parallel cultures on bean stems and young bean pods. In the latter case the mycelium is very abundantly developed, quite or nearly concealing the fruiting pustules. In tube cultures made on October 23 pink masses of conidia made their appearance five days later. In connection with the pink acervuli many perithecia-like bodies were observed. From this series of separation cultures a second dilution culture was made. The colonies again showed the nearly undifferentiated mycelial growth with the exception of a less abundant growth about the center. This portion, which is nearly free from mycelium at first, becomes overrun as the colony advances in growth, but the colony always remains more open at this portion. The production of conidia was not delayed so late in the second series of dilution cultures, and a few were formed eight days after sowing. Whether their earlier appearance was due to the condition of the nutrient agar, or to the fact that the fungus was becoming adapted to artificial growth conditions was not ascertained. The aggregated conidia form pale acervuli scattered quite thickly over the colony with the exception of the lighter portion near the center. In cultures ten or twelve days old the conidia become much longer than normal, and once or twice septate. From these cultures in which the colonies were so separated that pure separation cultures could be with certainty obtained, transfers were made on November 18 to an infusion of bean stems. On December 15 an examination of the tube revealed fully developed perithecia in connection with conidial clusters and the colored club-shaped bodies. The perithecia were so covered by the mycelium that their presence was not detected until a portion of the growth was removed with a needle and examined with the microscope. In order to check the experiment a second sowing was made of conidia which had undergone desiccation in the laboratory for five months. These germinated and conidia and perithecia were obtained as before.

The perithecial form closely resembles that of *G. cingulatum* Atk. On first examination it was thought that, though of the same genus, a specific distinction existed in the more slender perithecia of the former and the smaller spore measurements. These characters vary, however, in different cultures, and the larger measurements of the perithecial stage of *G. piperatum.* E. & E. are common to the smaller perithecia and spores of the privet anthracnose.

Ascospores sown in nutrient agar produced the conidia, and later on perithecia, which matured in thirteen days in the agar cultures, the colonies from ascospores having the same appearance as those from conidia. These colonies differ from those of *G. cingulatum* Atk. in the more uniform growth and the compact interweaving of mycelium at the outer portion of the colony. A description of the perithecial stage is as follows :

Perithecia cespitose, thinly membranaceous, dark brown, of a lighter color toward the ostiolum, at least in younger forms, pear-shaped, hairy, situated upon or partly immersed in a light-colored stroma of loosely interwoven threads. Asci aparaphysate, clavate, sessile ; sporidia eight, hyaline, single-celled, slightly curved, elliptical, subdistichous, 12–18 × 4–6μ.

Gnomoniopsis cincta Stoneman (*figs. 31, 110–114*); *Colletotrichum cinctum* (Berk. & Curtiss) ; on orchid (*Maxillaria picta, Oncidium* sp.).

In connection with a study of the leaf spot of the conservatory orchid by Mr. Paddock, a student in the laboratory, one of the affected leaves, when placed in a moist chamber, developed an anthracnose. The anthracnose had apparently no connection with the so-called "leaf spot" of the orchid, which is probably of non-parasitic origin.[18] Later other anthracnosed orchids were found in cold house cultivation on species of the genera Maxillaria and Oncidium, having a similar appearance on the

[18] The disease has been found by Mr. Massee (*Annals of Bot.* 9: 421. 1895) to be due to sudden changes of temperature causing a precipitation of moisture on the leaves.

leaf and in the growth characters manifested in artificial cultures. The pustules are erumpent, appearing on either surface of the leaf, indefinitely located on large, withered areas, or arranged in waving concentric circles. Conidia 12–15 × 3–4μ, elliptical, 2-guttulate. Setæ rising above the pink masses of conidia characterize the genus as a Colletotrichum, which agrees in other characters with the species described by Berkeley and Curtiss as *Glœosporium cinctum*. The setæ frequently nearly obscured by the abundant masses of conidia are doubtless in some cases absent.

On sectioning portions of the leaf, the Colletotrichum was found associated with a pycnidial stage and also a minute pyrenomycetous form. The perithecia of the latter measured 48–75μ in diameter, were flask-shaped, borne singly or in clusters of two or three, on both upper and under side of the leaf. The bases of the perithecia were wholly or partly submerged, the partially emerging necks causing minute elevations in the tissue of the leaf. The spores were immature, and in sections the characters could not be well determined; they were small, elliptical, slightly inequilateral, hyaline, single-celled, and measured approximately 6–7 × 2–3μ.

Dilution cultures of the conidia were made February 16. On February 17 germ tubes arising from one or both ends of the conidium had attained a length of 15–50μ. Laboratory dried conidia which were sown later required a longer period for absorbing nutrient material before germinating. Many showed no sign of germinating twenty-four hours after sowing, except in the coarsely granular contents of the conidia. These later, however, germinated in the ordinary manner. The young colonies resulting from the conidia present a small, white center, from which proceed five or six slender radiating strands of mycelium which branch out about 2^{mm} from the central point in fan-like tufts, remaining quite distinct in some colonies, while in others they mingle more or less at the margin, if the growth is luxuriant. The mycelium does not have such a loose, undulating growth as that of *G. cingulatum* Atk., which it resembles in the open portion surrounding the center, but the colonies resemble those of the orange anthracnose (*Col. glœosporoides*).

On bean stems the fungus develops a pure white mycelium which in rich nutrient media covers the substratum with a close, white felt. In some of the tubes black perithecia-like bodies made their appearance on the stems, while in others they were mingled with pink acervuli, and again the acervuli appeared almost exclusively. On bean stems, to which transfers were made February 17, perithecia containing asci were found on March 21. In cultures two months old many of the perithecia-like bodies retain their white protoplasmic contents, the cessation of further development probably being due to the exhaustion of the nutrient media. The perithecia measure from 180–280μ in diameter, are flask-shaped, membranaceous, and cespitose. Asci aparaphysate, clavate, sessile, truncate or obtuse when mature, measuring 65–70μ in length, eight-spored. Sporidia hyaline, single-celled, elliptical, curved, measuring $15–20 \times 3\mu$. From the germinated ascospores the conidia were again obtained. The first results were verified by cultures made later from different material.

The ascigerous stage, as may be seen by comparing the description and illustrations, bears a close resemblance to the two previous forms. The characters of the colonies show a specific distinction, as well as the general appearance of the fungus on the leaf and the presence of setæ in the natural state.

It is possible that the perithecial stage obtained in artificial cultures is identical with that found in connection with the Glœosporium on the leaf. The difference in size and the presence of a stroma might be accounted for by the artificial conditions of growth.

Gnomoniopsis rubicola Stoneman (*figs. 29–30, 105–109*); *Colletotrichum rubicolum* E. & E.; on red raspberry (*Rubus strigosus*).

In December 1895 some anthracnoses were kindly forwarded me by Mr. J. B. Ellis, among them a new species, at the time unpublished, on *Rubus strigosus*, accompanied by the following description: "Forming large, dark brown patches on the upper surface of the leaf; sori small, dark, suberumpent; conidia oblong, elliptical, 12.5 × 6μ. Col. W. Va., Oct. '95, F. W Nuttall."

Conidia sown in a dilution culture of potato-agar on January 30, four hours later had developed germ tubes usually from one end of the conidium, and slightly constricted at the base, proceeding in irregularly flexous manner, occasionally septate, with little or no branching for a distance of 100–150μ. On January 16 the growth could be seen in the agar with the unaided eye, the low temperature of the laboratory possibly accounting for the slow progress of the fungus. The mycelium showed a long, narrow, loosely branched growth, 3–4^{mm} in length. A colony from one of the conidia, which had been marked at the time of germination, was transferred to sterilized bean stems. Four days later the mycelium had formed a rather dense, closely adhering weft of grayish mycelium; black fruiting bodies appeared upon the stems, which were also overspread with a mycelial growth. Upon examining these on February 10, the perithecia were found to contain mature asci, the ascigerous stage agreeing generally in appearance with the two previous forms. There is lacking in this species the conspicuous tuft of mycelium at the apex of the perithecia, which are usually larger than those of the pepper anthracnose.

The ascospores germinated in potato-agar, as had the Colletotrichum conidia, by sending out obliquely from one end a germ tube; the tube again is slightly constricted at the base, and extends from 180–200μ in length before branching takes place. This growth produces a colony, which, like that from the Colletotrichum conidia, is at first narrow, elongate, and loosely spreading. About four days after germination, conidia are delimited from the mycelium in great abundance. Later, colored swollen buds are formed. The reproduction of conidia here took place much sooner than in the original cultures of the conidia; and, inasmuch as the temperature of the laboratory was nearly uniform at the two different times, their earlier appearance may be accounted for by its gradual adaptation o the artificial environment. Certain cells in the mycelium become swollen, usually septate and dark colored, and, in many cases, the fusion, with a smaller, curved, mycelial branch suggests a process of fertilization, although no careful study of this point was undertaken. From the swollen cells numerous colored branches arise which twine about and conceal it. At these places in the mycelium perithecia are formed.

The appearance of the colonies is quite peculiar to the species. The mycelium radiates from a small central point, in a feathery manner, forming one or two fan-shaped expansions which sometimes remain quite distinct for some time, or when growth proceeds in several radiations they become more or less united, and growth is more or less uniform. The margin of the colony has an even fringe of straight, nearly parallel threads.

The colony, which is at first flesh-colored, assumes a faint greenish tinge, which becomes a dark olivaceous brown at the more central portions, while the marginal growth retains the buff or slightly salmon tinge. The darker central portion is surrounded by the black fruiting bodies which are tufted with a grayish mycelium. The peculiar development of pigment is quite unlike that found in the three preceding species, or in fact in any species yet studied.

In connection with the perithecia grown upon bean stems, large conidial cushions were formed, surrounded with dark spreading hyphæ arising from a stroma at the base of the cushion. The conidia in artificial cultures frequently become septate.

Gnomoniopsis? vanillæ Stoneman (*fig. 32*); *Colletotrichum* on Vanilla.

An anthracnose was obtained from a vanilla plant growing in the conservatory which belonged to the genus Colletotrichum. It appeared in small black erumpent pustules on both sides of the withered leaves, on the stems, and on the aerial roots. The pustules measured 150–180μ in diameter; a section through the pustules shows a well developed basal stroma, bearing closely crowded septate basidia 30–45μ in length. The setæ are colored, three or four times septate near the base. In older pustules the stroma passes up around the basidia, forming a cylinder of a compact association of rather regular rectangular cells. The pustules are somewhat superficially situated, the basidia extending nearly their whole length above the epidermis of the host.

Closely associated with the Colletotrichum was found a pyrenomycetous form. The perithecia bore a close resemblance to those described by Massee[19] in connection with another conidial form belonging to this group, the genus Hainesia. They were flask-shaped, having a membranaceous wall several layers in thickness, borne singly or in clusters, but without a stroma. Asci clavate, sessile, 75–80 × 15–16μ, attenuate at base, paraphysate, 8-spored; paraphyses long, slender, filiform; sporidia elliptical, hyaline, or slightly fuliginous, curved 21–24 × 6–7μ. The form described by Massee belonged to the genus Calospora, and differed in the presence of a stroma and in the tri-septate sporidia. The perithecia found on the leaves were not valsoid as in Calospora, but when two or three were aggregated the necks diverged.

The close resemblance of the two forms and the association of a Colletotrichum suggested an interesting study, and a dilution culture was made of the conidia in meat-agar. The leaves, which were more or less decayed, were an easy prey to saprophytic fungi, so that the first dilution was liable to be contaminated. The conidia, however, were found in great abundance in plates one and two, and germination was observed. Owing to their crowded condition, however, and the liability to contamination, these plates were discarded. Plate three contained but one colony. It had attained in eight days a diameter of 2^{cm} and was nearly uniform in growth. As frequently happens with a

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[19] Kew Bull. Misc. Information 139: 111–120. 1892.

good supply of nutriment, when a profuse vegetative growth takes place, the production of conidia is delayed. Transfers, however, were made to bean stems in order to determine its further growth characters, and to avoid the possibility of contamination from exposure to the air. As germination had not been observed it was impossible to say from what the colony had originated.

On bean stems there was developed a rather compact white mycelial growth, and black fruiting bodies made their appearance in connection with the Colletotrichum conidia. The former developed into perithecia containing paraphysate asci with single-celled, curved spores. These spores when sown produced conidia, but from the conidia the perfect stage has not yet been obtained. Further investigation will be necessary in connection with this species, and a further detailed description will be deferred to another paper.

The colonies from both ascospores and conidia, in their uniform growth, with the exception of a slightly open growth around the central point, resemble those described in connection with *Glœosporium piperatum.*

CONCLUSIONS.

I will sum up briefly some of the more important results obtained in connection with this study: The group of fungi under discussion, commonly known as anthracnoses, in many cases present, in artificial cultures, distinct characters of growth for distinct species, which may be made of value in distinguishing species whose similarity in morphological structure in connection with their host often renders their systematic position uncertain.

The artificial growth characters of a single species fluctuate within certain limits with varying conditions of temperature and nutrient media, and certain characters which are prominent may become obscured with age, so that to render the characters of taxonomic value uniform growth conditions are essential.

The formation of the so-called secondary spores or buds which are common to Glœosporium, Colletotrichum, Volutella, and Vermicularia is not a constant character, but may be absent throughout the entire cycle of development of a species, or they may be forced in these same species by a lack of nourishment.

The presence of a perithecial stage has been proven in four different species, of which the host plants vary widely in habits and structure. One of these exists as a saprophyte in a natural state (the one in connection with the vanilla anthracnose is omitted), while the other three are saprophytes in artificial cultures; whether they occur in nature has not been determined. Two of the perithecial forms were connected with species of the genus Colletotrichum, and two with Glœosporium.[20]

The colonies produced in the species with which perfect forms have been connected agree in producing a loose open growth about the center, but all show specific differences in formation of stroma, pigment, or arrangement of fruiting sori.

While the conidial forms show greater variations in structure than do the perithecial stages of the different species, the growth characters of the colonies from ascospores resemble those of the conidial stage with which they are connected more closely than they resemble each other.

The perfect forms approach the genus Gnomoniella, agreeing in the submembranaceous, subglobose, subcutaneous-erumpent perithecia; in the cylindrical, clavate, 8-spored asci; and the continuous hyaline conidia. They differ in the curved conidia, which in Gnomoniella are typically ovate, oblong subfiliform and straight, although in species of Gnomoniella, *G. amœna* (Nees) Sacc. and *G. fasciculata* (Fckl.) Sacc. they are curved. The genus under consideration does not show the slender, somewhat elongated beaks found in Gnomoniella, which are surrounded at the base with a white, cleft collar formed of the ruptured epidermis of the host, and the necks are hairy, while in Gnomoniella they are smooth. In shape the perithecia resemble the genus Camptosphæria, but they differ from this

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[20] The presence of setæ in the cultures has been so variable as to raise the question whether they form a well-founded basis for distinguishing these two genera.

genus in other characters more than they do from Gnomoniella. Excluded from these two genera its position would be in a genus between these two for which the writer proposes the name Gnomoniopsis with the following diagnosis :

GNOMONIOPSIS, n. gen.

Perithecia cespitose, membranaceous, dark brown, rostrate, of a lighter color at the apex in early stages, flask-shaped, hairy, situated upon or partly immersed in a stroma ; asci sessile, aparaphysate?, clavate, sporidia eight, hyaline, oblong, single-celled, slightly curved, elliptical, subdistichous, including the following species: conidial form, certain species of Glœosporium :

G. cingulata (p. 101), *G. piperata* (p. 104), *G. rubicola* (p. 108), *G. cincta* (p. 106), *G. vanillæ* ? (p. 110).

From the evidence of these perfect forms it is probable that the genera Glœosporium and Colletotrichum have developed from one common ancestral genus of the pyrenomycetous form described above. Since of about thirty species studied but five have developed the complemental ascigerous stage, it is suggested that they have, to a large extent, become divorced from a perfect stage, and have become so adapted to environment that they are able to maintain themselves from year to year without the intervention of this stage. Many of the anthracnoses are parasitic on garden and orchard fruits, and are thus preserved with their host during the winter. Under less favorable circumstances the conidia may tide the fungus over, since they will stand a certain amount of desiccation. The stroma and sclerotia may also assist in ther preservation.

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EXPLANATION OF PLATES VII–XVIII.

The first plate is from photographs of the Petri dish cultures, generally of pure cultures, the colonies being natural size. The pen drawings are made to two different scales, the sections of hosts and the perithecia being made all to one scale, while the conidia and details of germination are made to another scale.

PLATE VII.

FIG. 1. *Glœosporium fructigenum* Berk. from apple; culture 1, three days old.

FIG. 2. Same, four days old.

FIG. 3. Same, from quince; culture 1, three days old.

FIG. 4. Same; culture 3, six days old.

FIG. 5. *G. phomoides* Sacc. from tomato; culture 1, three days old.

FIG. 6. Same; culture 3, six days old.

FIG. 7. Same; an old colony, showing development of the stroma.

FIG. 8. *G. venetum* Speg.; culture 3, one week old.

FIG. 9. *G. naviculisporum* Stoneman; culture eight days old.

FIG. 10. Same, or *Hainesia rubi* (West.) Sacc.

G. venetum, *G. naviculisporum*, and *G. rubi* all from *Rubus* sp.

FIG. 11. *G. musarum* Cke. & Mass.

FIG. 12. *G. fœtidophilum* Stoneman; culture six days old.

FIG. 13. *G. nervisequum* (Fckl.) Sacc. from *Platanus.*

FIG. 14. *G. cactorum* Stoneman.

FIG. 15. *Colletotrichum glœosporioides* Penz.; culture three days old.

FIG. 16. *Vermicularia circinans* Berk.; colony showing beginning of stroma.

FIG. 17. *Colletotrichum lagenarium* (Pass.) Sacc. & Roumg. from watermelon; culture five days old.

FIG. 18. Same; culture from another series nine days old.

FIG. 19. *C. lindemuthianum* (Sacc. & Magn.) Scribner; culture four days old.

FIG. 20. Same; culture from another series nine days old, showing the pronounced stroma which is absent from the colonies of *C. lagenarium.*

FIG. 21. *C. lycopersici* Chester from tomato.

FIG. 22. *Volutella violæ* Stoneman, plate culture.

FIG. 23. Same; older culture.

FIGS. 24, 25. *V. citrulli* Stoneman from citron; the same plate at different ages.

FIG. 26. *Gnomoniopsis cingulata* Stoneman; colonies from conidia taken from the stem.

FIGS. 27, 28. Same; colonies grown from four ascospores; *fig. 28* shows early formation of the stroma which bears the perithecia.

FIG. 29. *G. rubicola* Stoneman.

FIG. 30. Same; culture five days old.

FIG. 31. *G. cincta* Stoneman.

FIG. 32. *G. ? vanillæ* Stoneman; from culture four days old.

PLATE VIII.

FIG. 33. *Glœosporium fructigenum* Berk.; conidia germinating three hours after sowing.

FIG. 34. Same; twenty-four hours after sowing.

FIG. 35. Same; conidia sown in water producing colored buds and anastomosing mycelium in three days.

FIG. 36; Same; old mycelium in plate culture.

FIGS. 37, 38. Same; sections of old acervuli bearing large colored bodies at tips of basidia.

FIG. 39. *G. phomoides* Sacc.; conidia.

FIG. 40. Same; conidia germinating after twenty-four hours in agar.

FIG. 41. Same; section of pustule on tomato.

PLATE IX.

FIG. 42. *G. venetum* Speg.; conidia germinating in hanging drop.

FIGS. 43–45. Same; conidia germinated in agar three days after sowing.

FIG. 46. Same; section of acervulus.

FIG. 47. *G. naviculisporum* Stoneman; section of acervulus on host (*Rubus occidentalis*).

FIG. 48. Same; conidia.

FIG. 49. Same; conidia in hanging drop; *a*, anastomosing conidia; *b*. short basidium bearing a "secondary spore."

FIG. 50. Same; conidia in agar twenty-four hours after sowing.

FIG. 51. *Hainesia rubi* (West) Sacc.; section.

FIG. 52. Same; conidia germinating.

PLATE X.

FIG. 53. *G. nervisequum* (Fckl.) Sacc.; section of leaf showing acervulus on *Quercus alba*.

FIGS. 54–56. Same; conidia and early stages of germination.

FIGS. 57, 58. Same on *Platanus*.

FIGS. 59, 60. Same; conidia showing early stages of germination in agar.

FIG. 61. Same; conidia in agar twenty-four hours after sowing.

PLATE XI.

FIG. 62. *Colletotrichum lagenarium* (Pass.) Sacc. & Roumg.; conidia.

FIG. 63. Same; conidia germinated after twenty-four hours.

FIG. 64. Same; conidium which has been in agar three days showing no swelling.

FIG. 65. Same; conidium and mycelium four days old.

FIGS. 66, 67. Same; mycelium in culture five days old.

FIGS. 68, 69. Same; section of pustule on host.

PLATE XII.

FIG. 70. *C. lindemuthianum* (Sacc. & Magn.) Scribner; conidia.

FIG. 71. Same; conidia in culture twenty-four hours old.

FIG. 72. Same; conidia, and mycelium in culture four days old.

FIGS. 73, 74. Same; section of pustule on pod of *Phaseolus vulgaris*.

PLATE XIII.

FIGS. 75, 76. *C. lagenarium* (Pass.) Sacc. & Roumg. on cucumber; section of pustule.

FIG. 77. Same; conidia anastomosing in hanging drop culture.

FIG. 78. Same; conidia in agar.

FIG. 79. Same; seta enlarged.

FIG. 80. *Volutella citrulli* Stoneman; section of citron rind showing character of pustule.

FIG. 81. Same; conidia in various stages of germination.

FIG. 82. Same; stroma formed in clusters in colonies.

PLATE XIV.

FIG. 83. *Glœosporium fructigenum* Berk.; section of pustule on fruit of quince.

FIG. 84. *Colletotrichum glœosporioides* Penz.; section of leaf of orange with pustule.

FIG. 85. *Volutella violæ* Stoneman; section of affected leaf,

FIG. 86. Same; conidia germinating.

FIGS. 87, 88. Same; stroma in agar.

FIG. 89. Same; seta enlarged.

PLATE XV.

FIG. 90. *Gnomoniopsis cingulata* Stoneman; section of leaf showing acervulus.

FIG. 91. Same; conidia germinating.

FIG. 92. Same; conidia produced in culture two days old.

FIG. 93. Same; ascospores germinating.

FIG. 94. Same; seta and conidia in old cultures from ascospores.

FIG. 95. Same; stroma produced in cultures.

FIG. 96. Same; perithecia grown on bean stems.

FIG. 97. Same; asci.

PLATE XVI.

FIG. 98. *G. piperata* Stoneman; section of fruit showing pustule.

FIG. 99. Same; perithecia from bean stem culture.

FIG. 100. Same; asci.

FIG. 101. Same; ascospores before and after germination.

FIG. 102. Same; conidia.

FIG. 103. Same; beginning of stroma.

FIG. 104. Same; conidia from ascospores in agar.

PLATE XVII.

FIG. 105. *G. rubicola* Stoneman; ascospores.

FIG. 106. Same; ascospores germinating in agar.

FIG. 107. Same; ascus enlarged.

FIG. 108. Same; beginning of formation of stroma in which the perithecia are developed.

FIG. 109. Same; section of perithecia grown on bean stems.

PLATE XVIII.

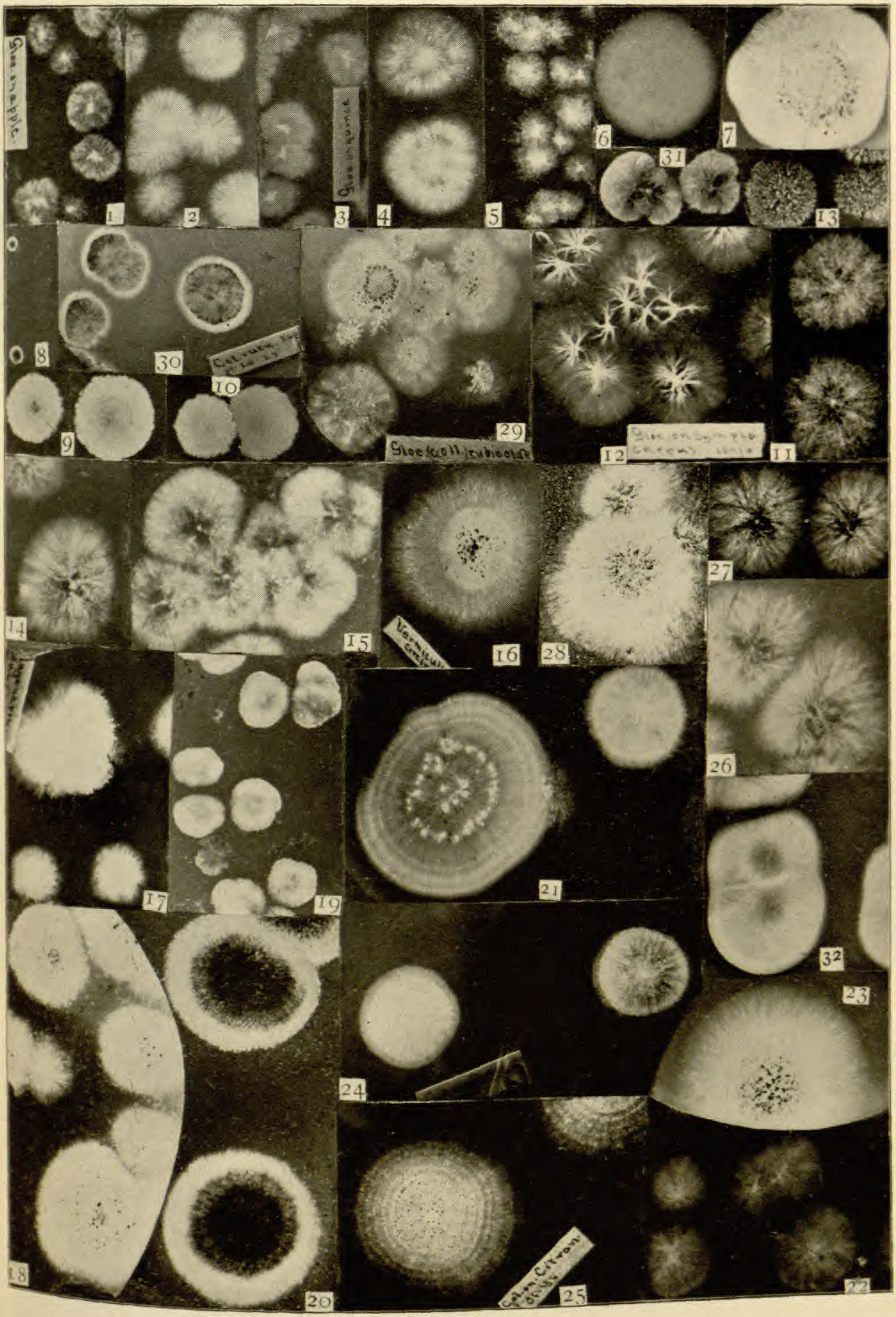
FIG. 110. *G. cincta* Stoneman; section of acervulus on leaf.

FIG. 111. Same; conidia germinating.

FIG. 112. Same; perithecia found on leaf of orchid in conservatory.

FIG. 113. Same; perithecia grown on sterilized bean stems.

FIG. 114. Same; immature ascus, and mature one with ascospores.



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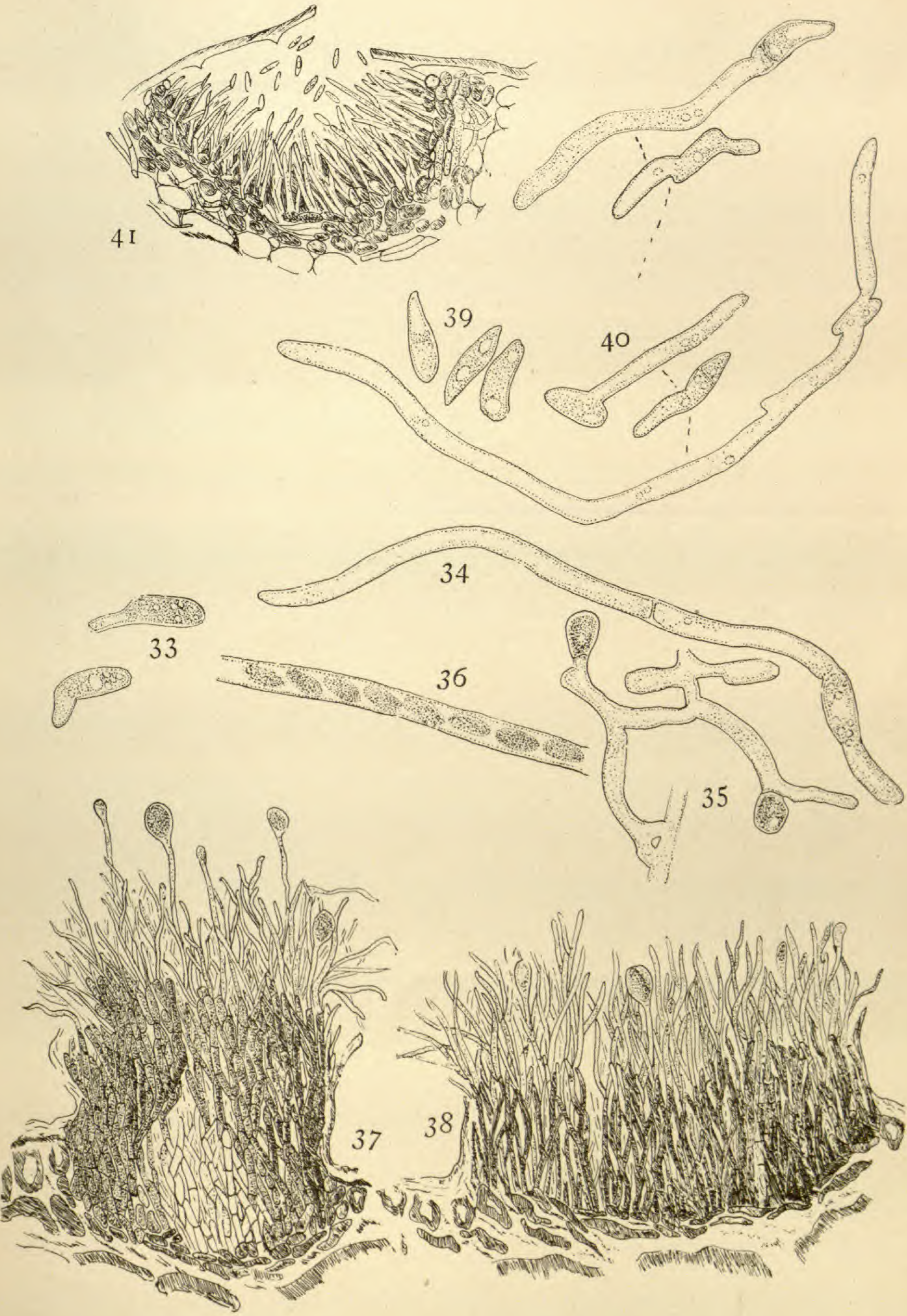

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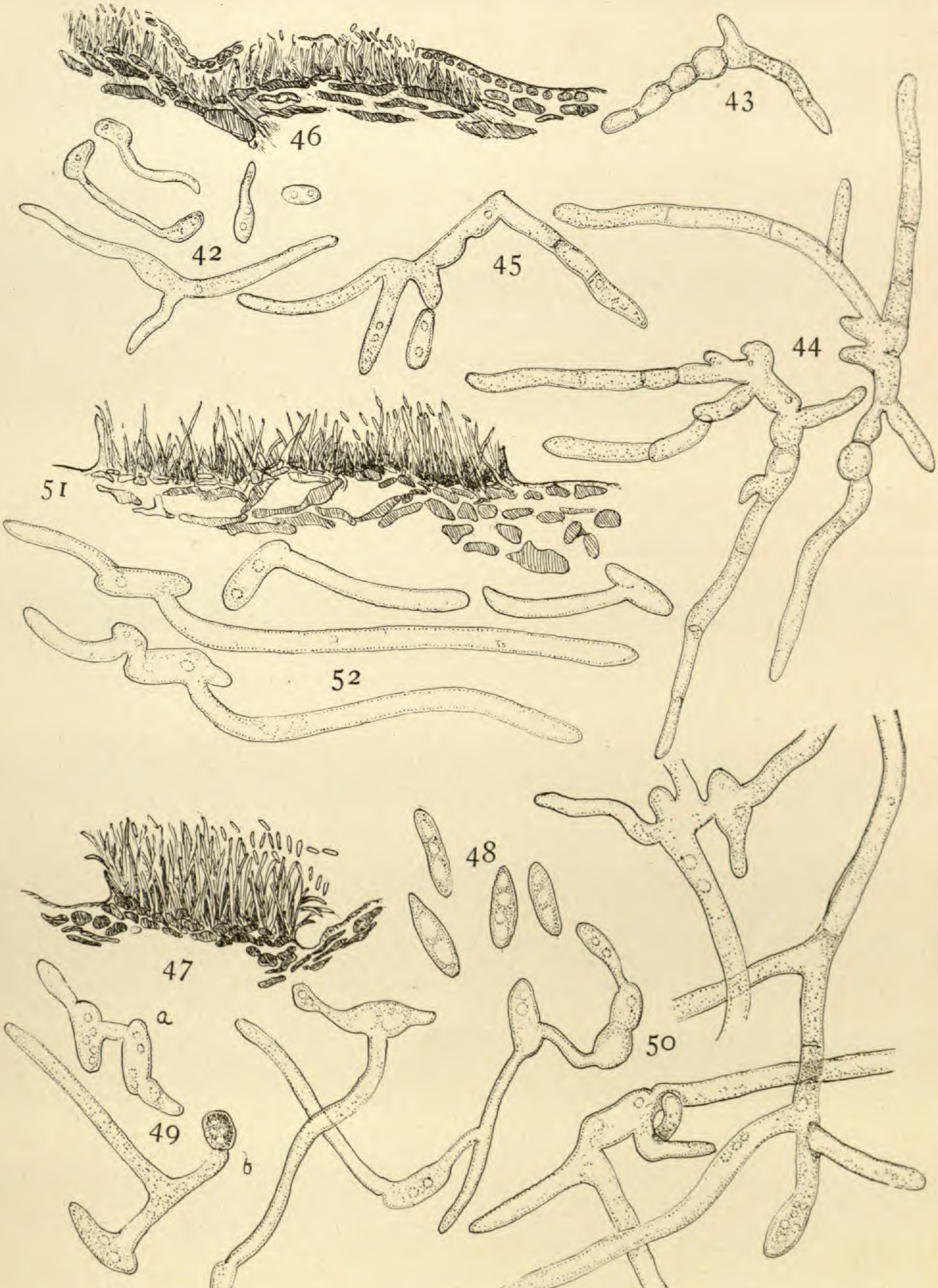

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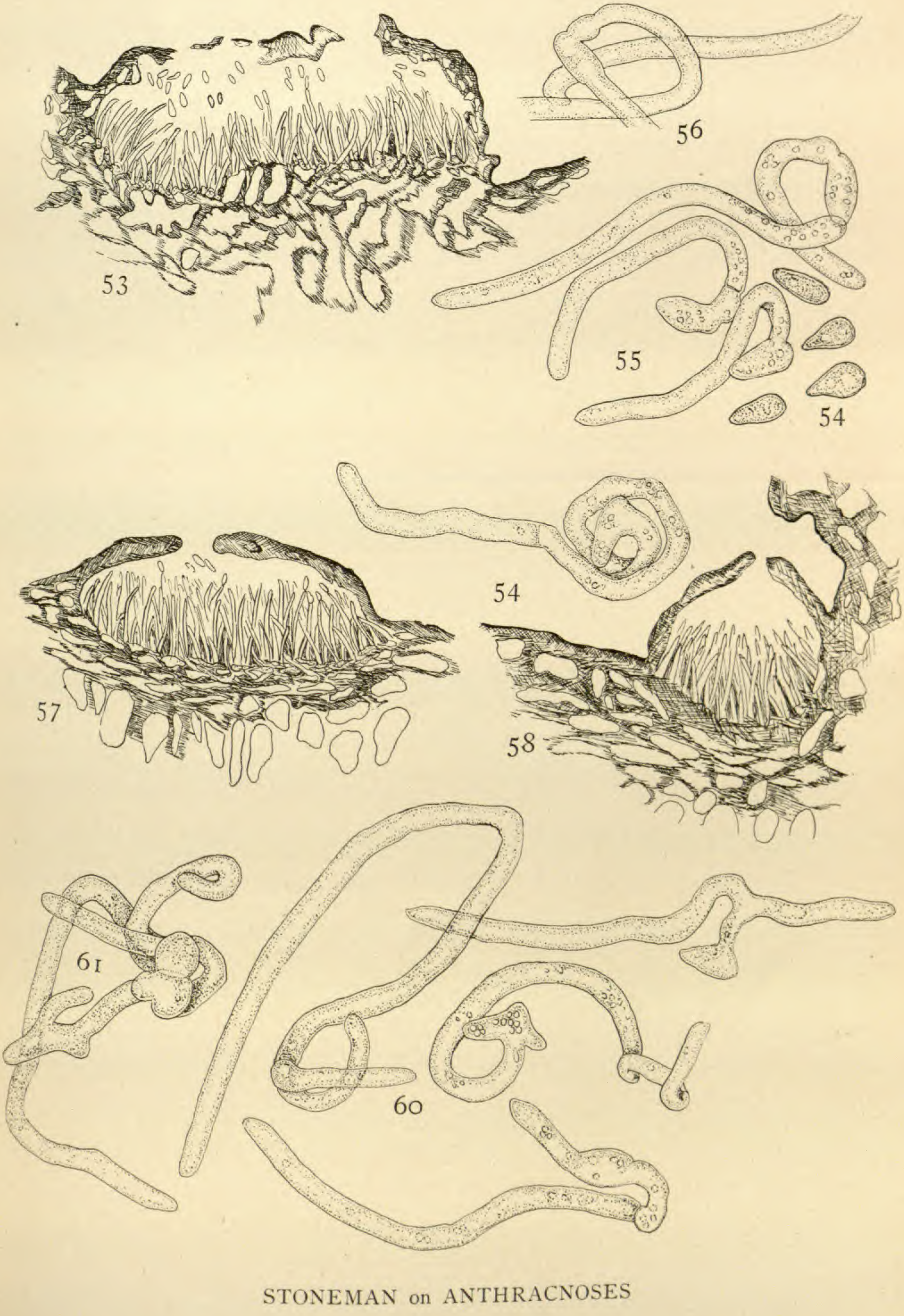

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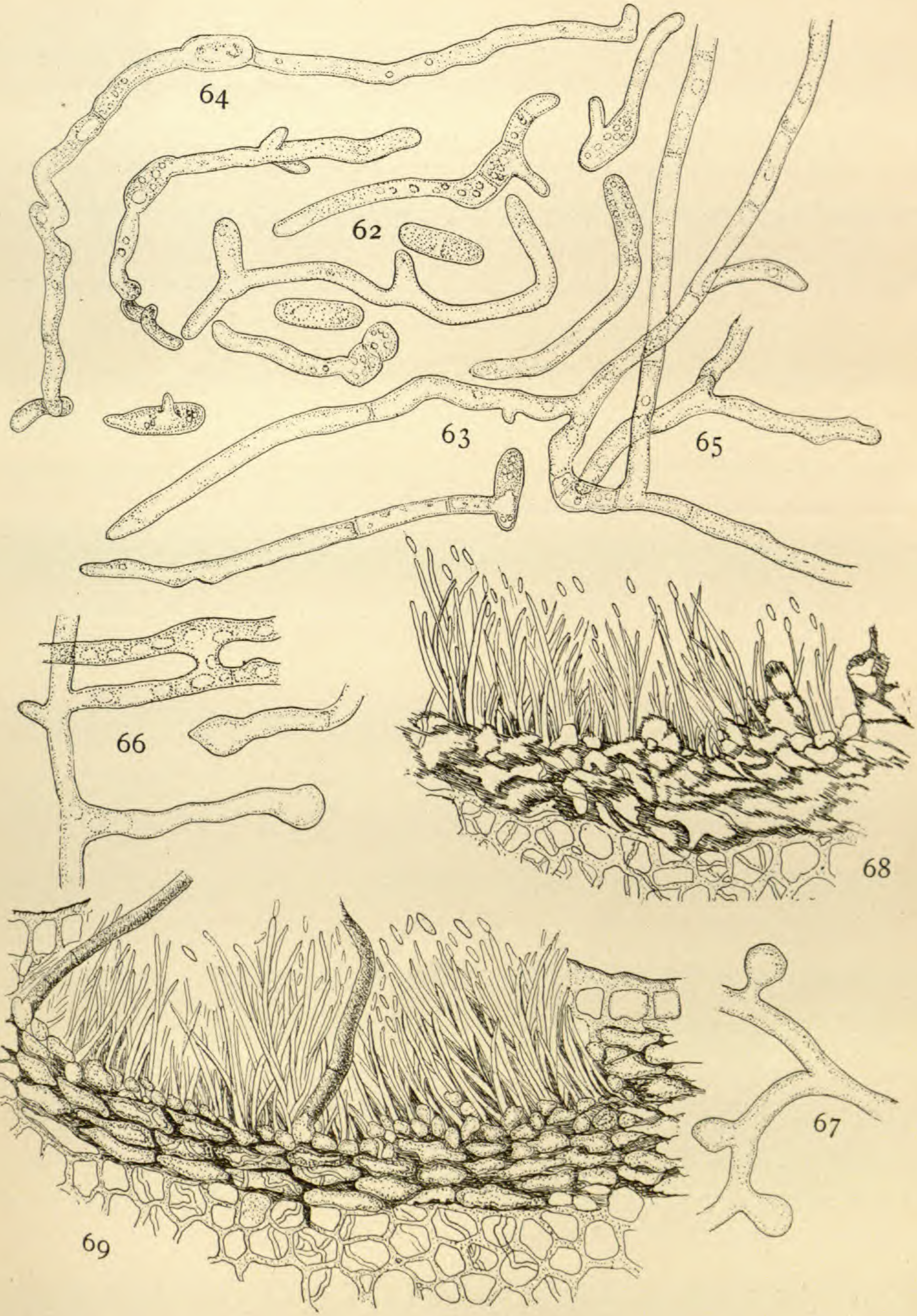

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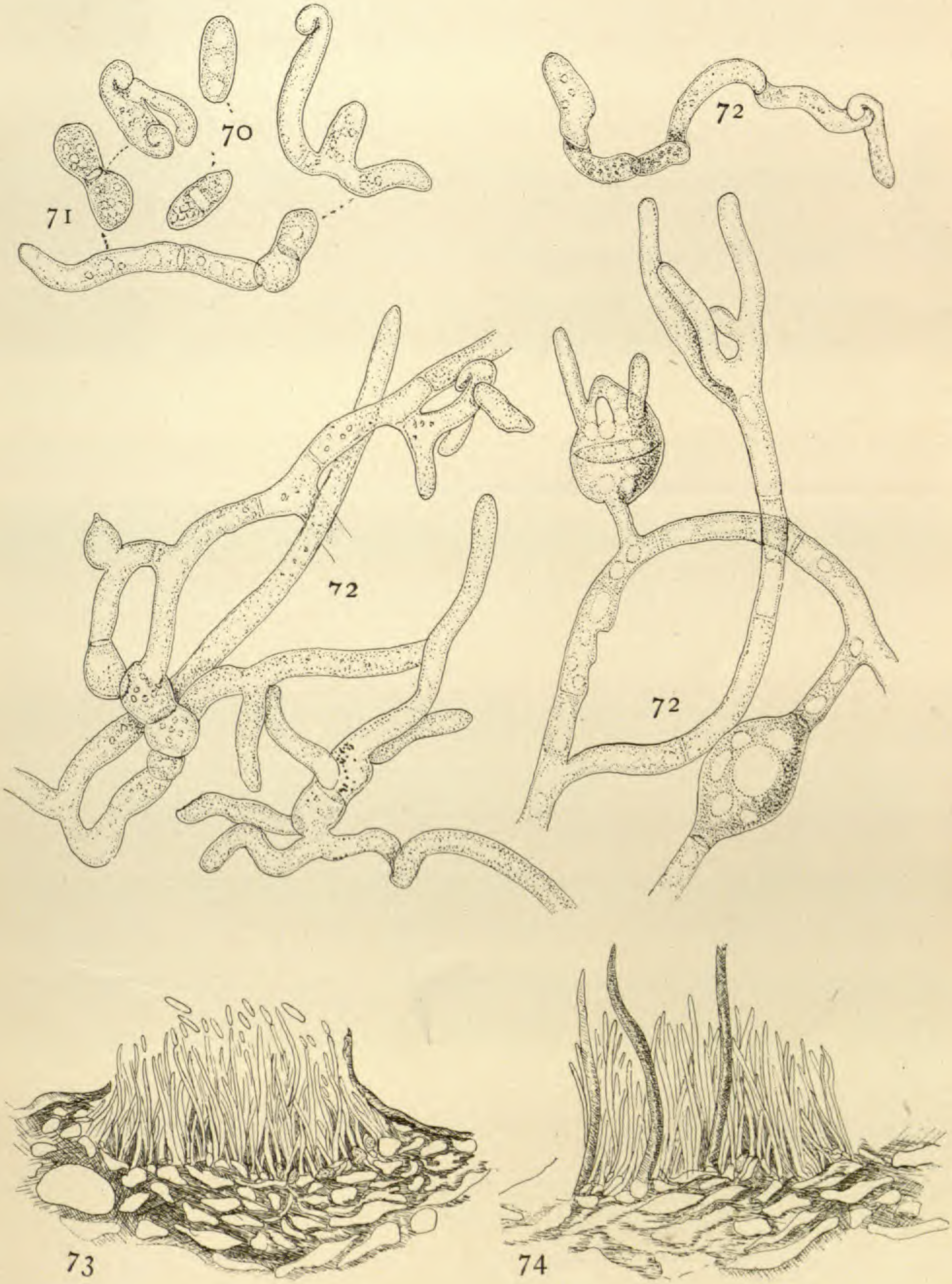

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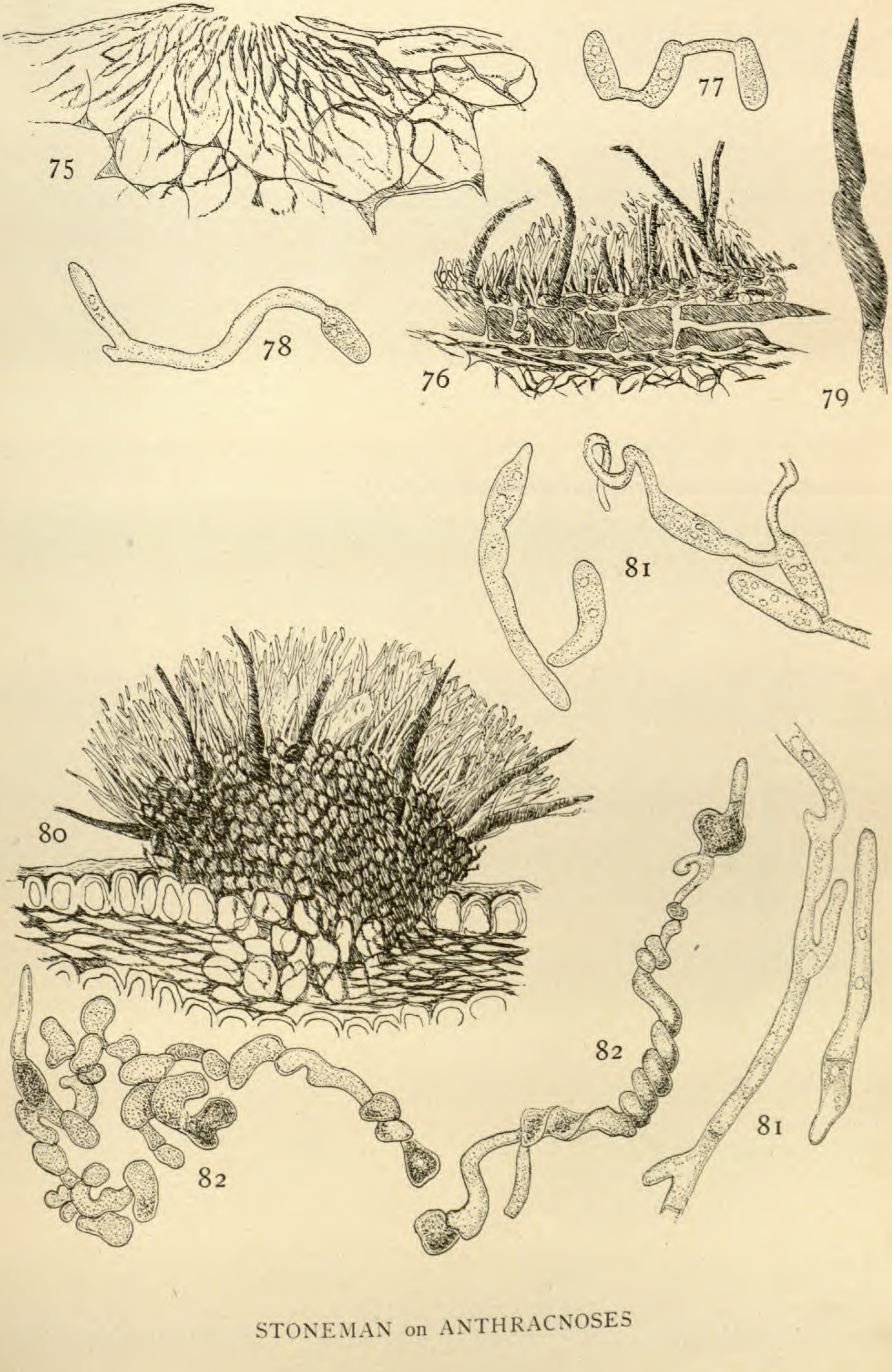
PLATE XIII



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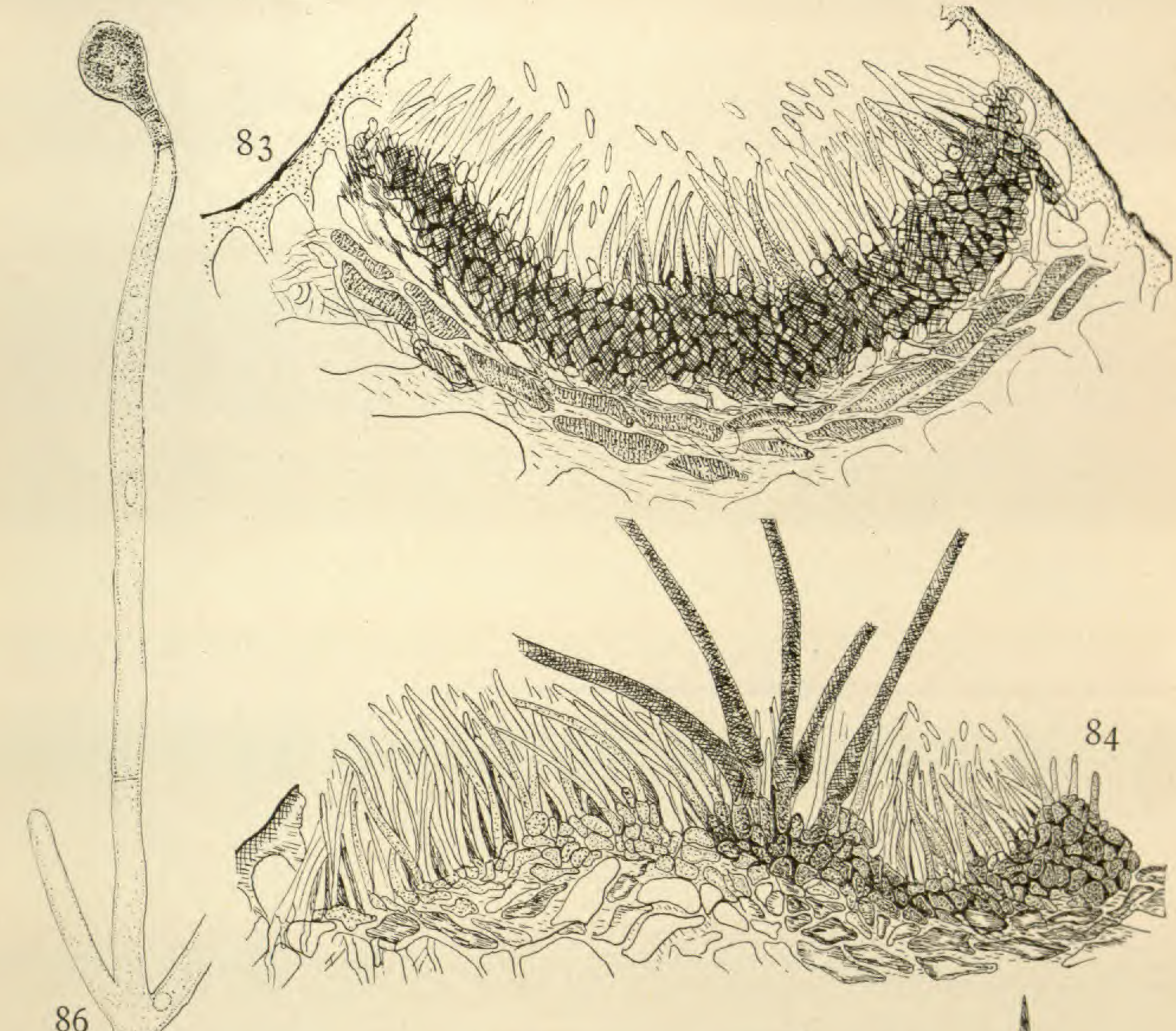

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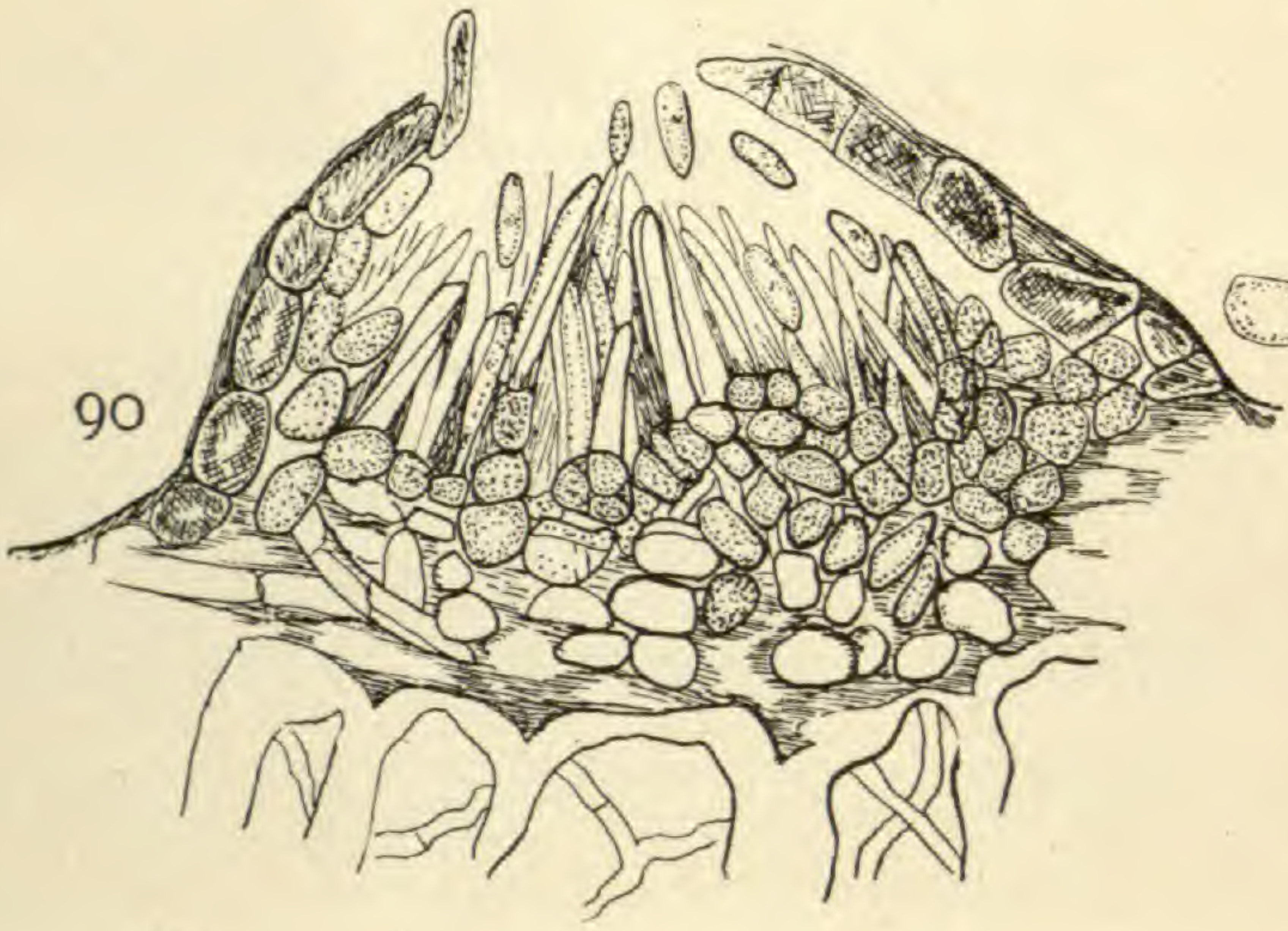
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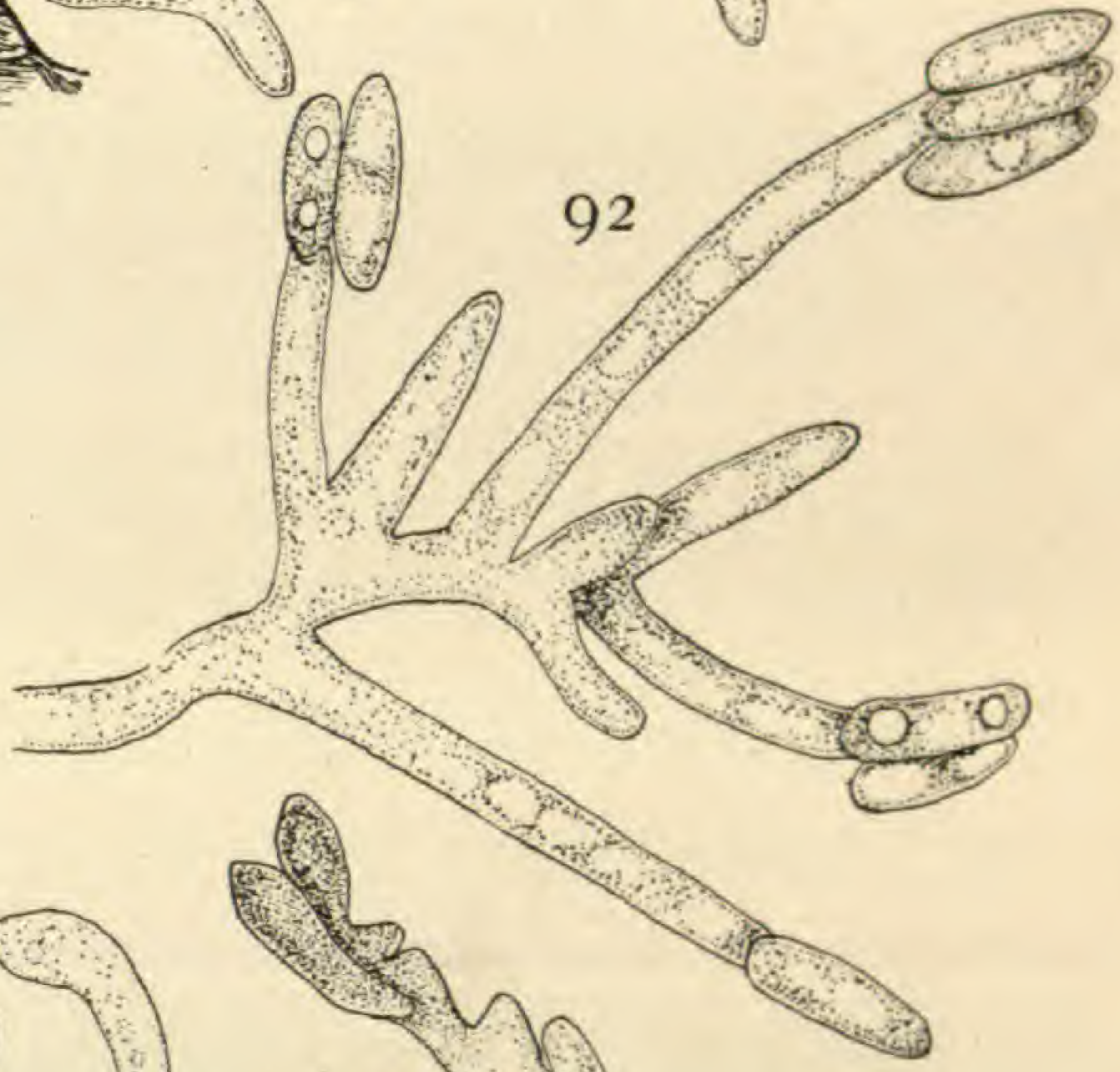
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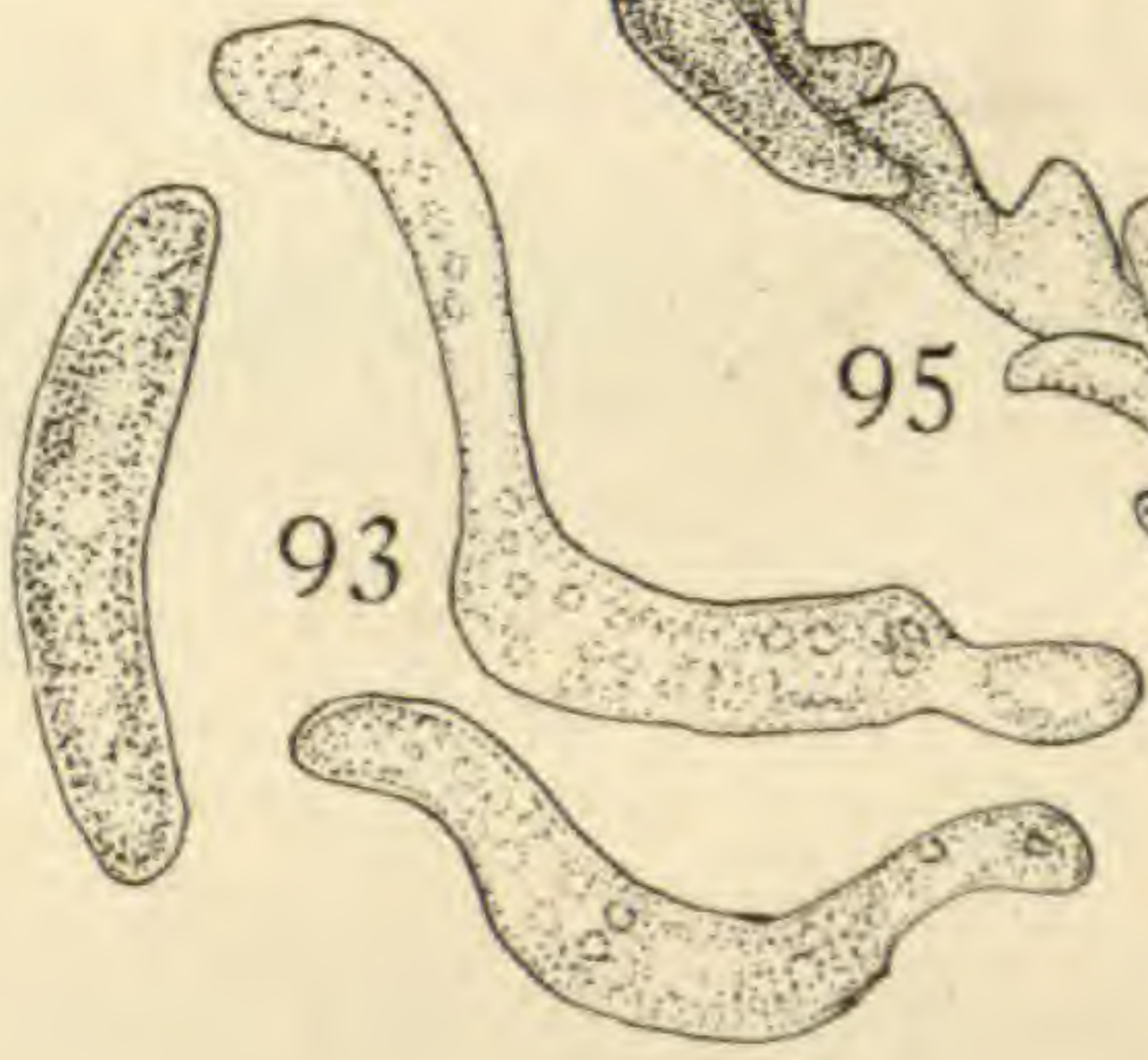
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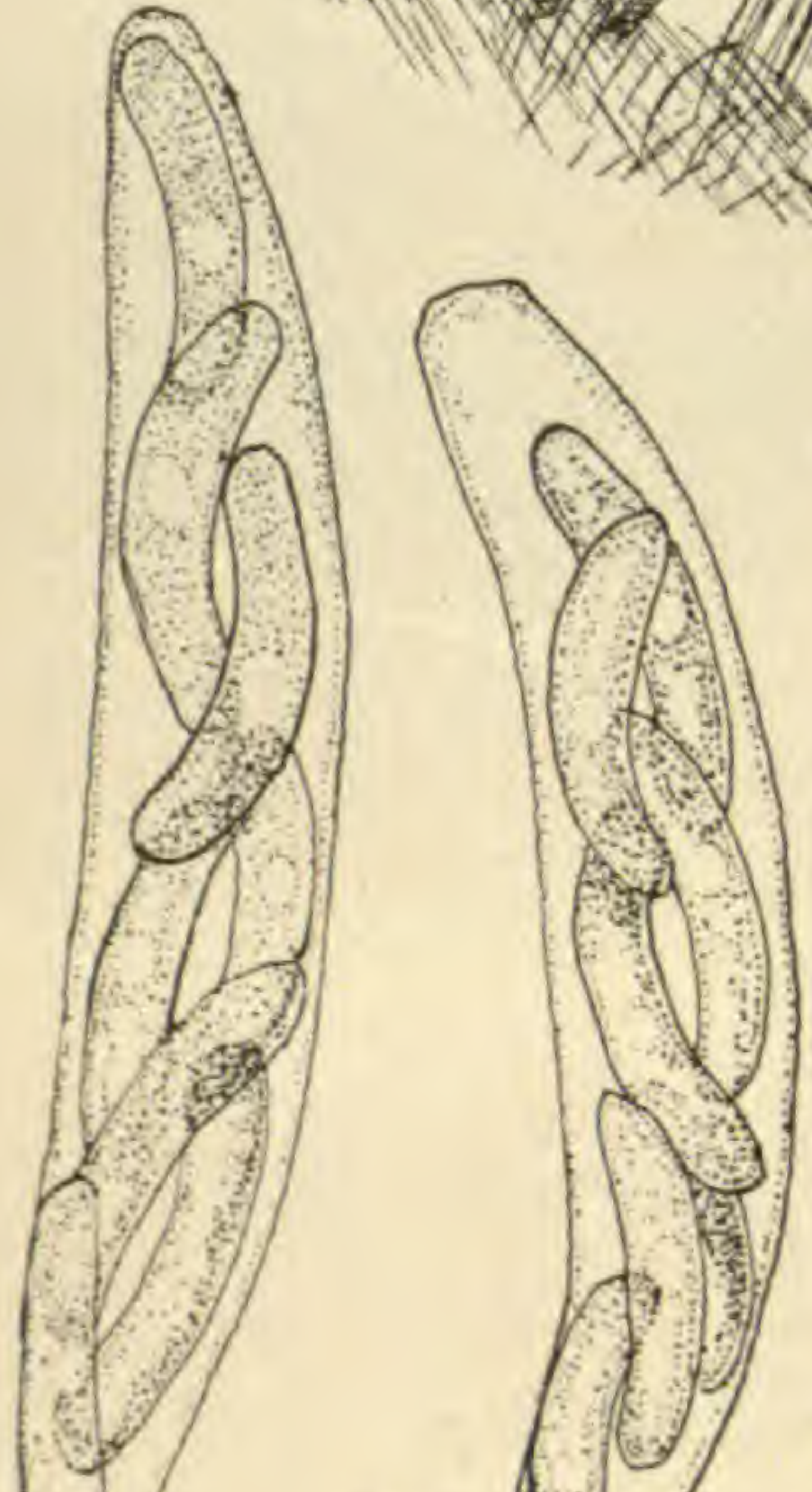
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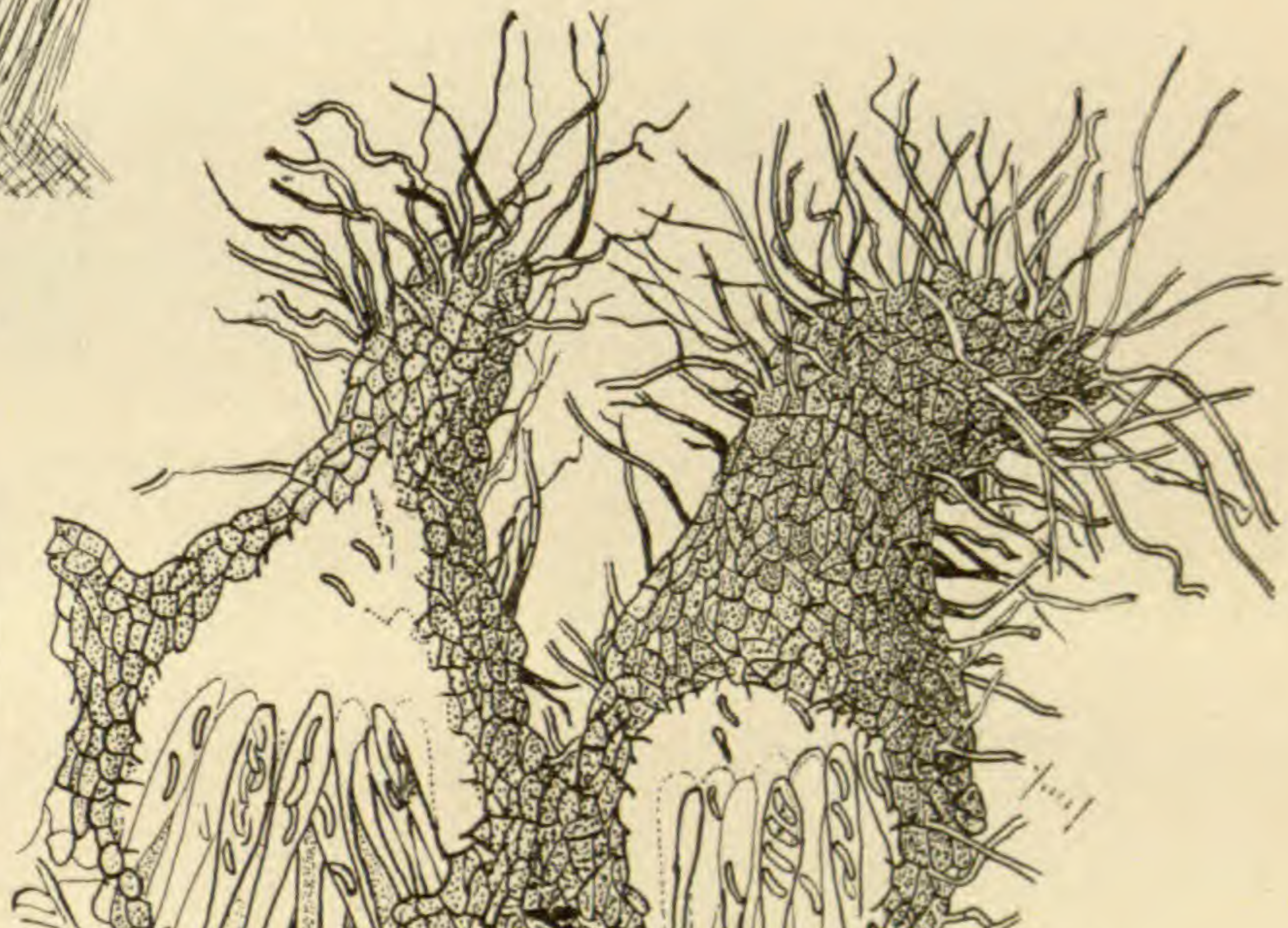
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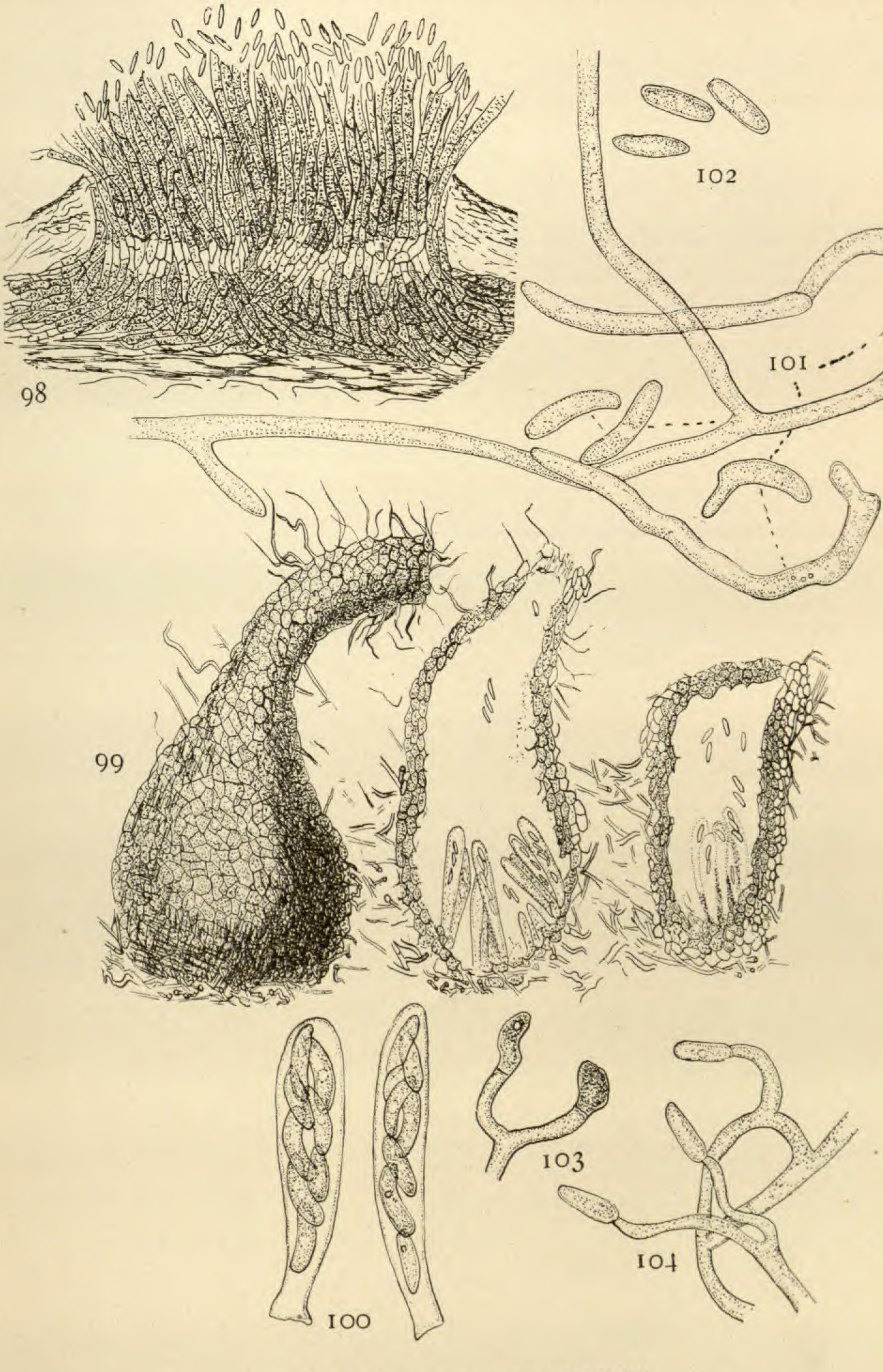

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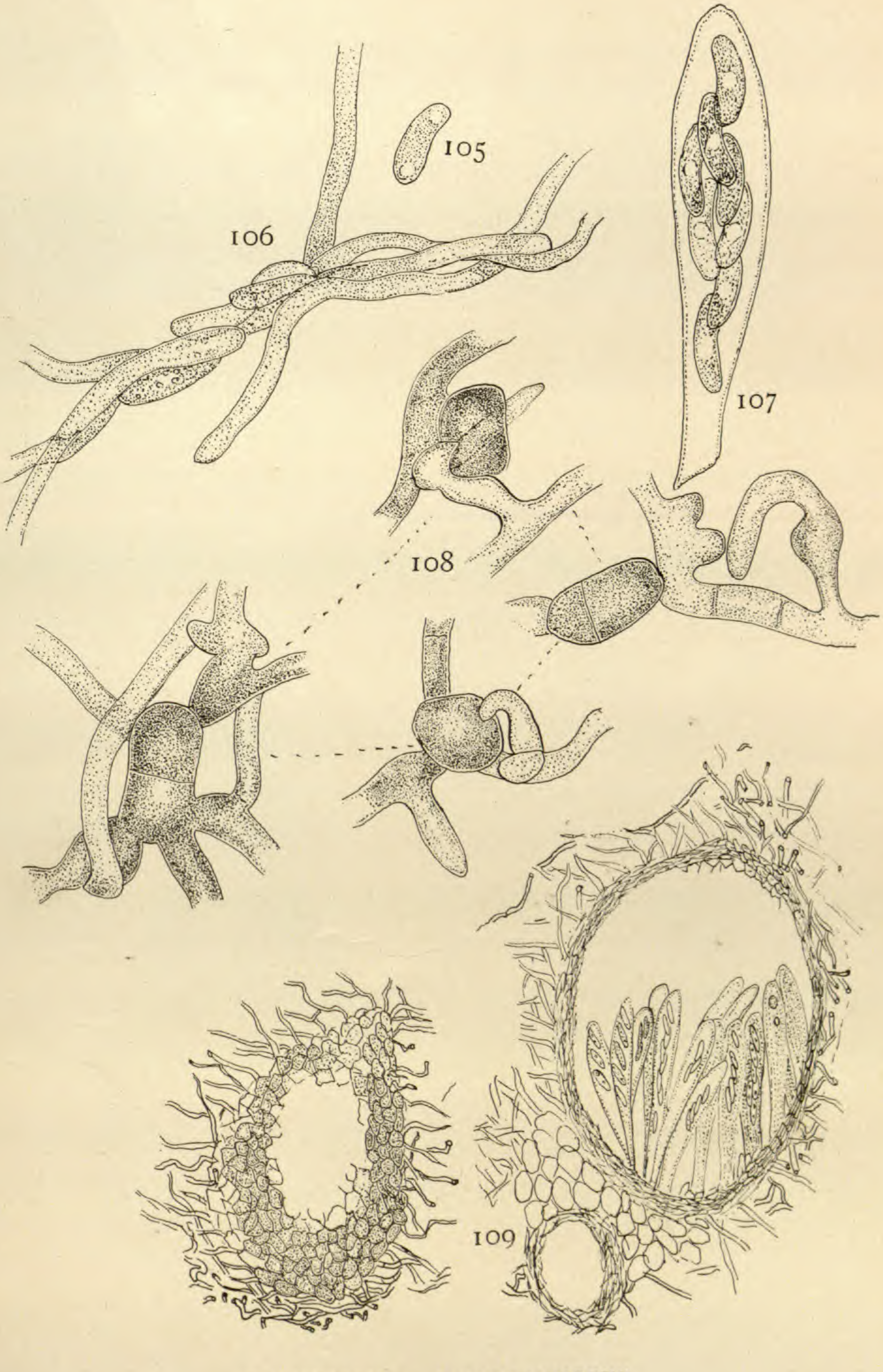

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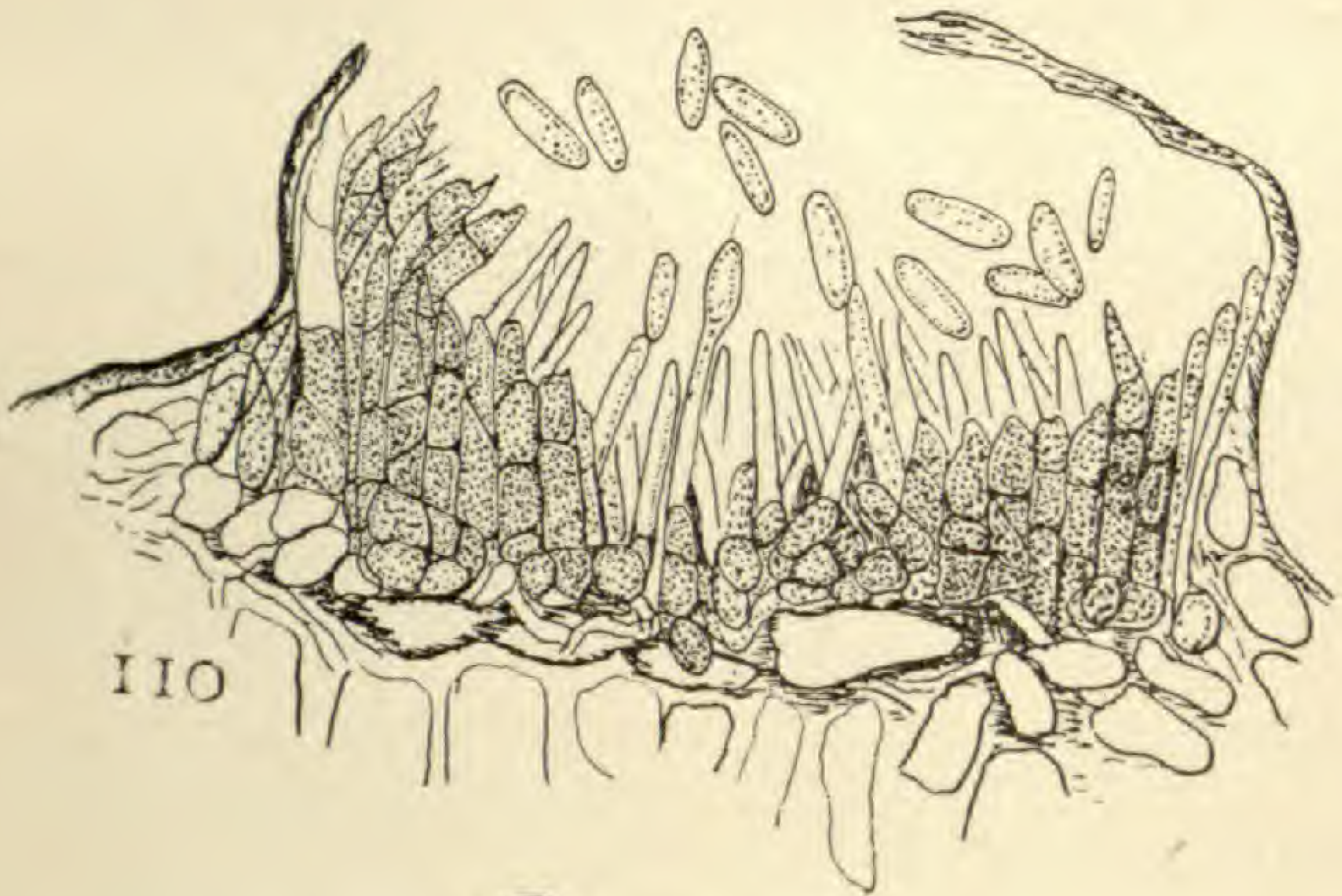

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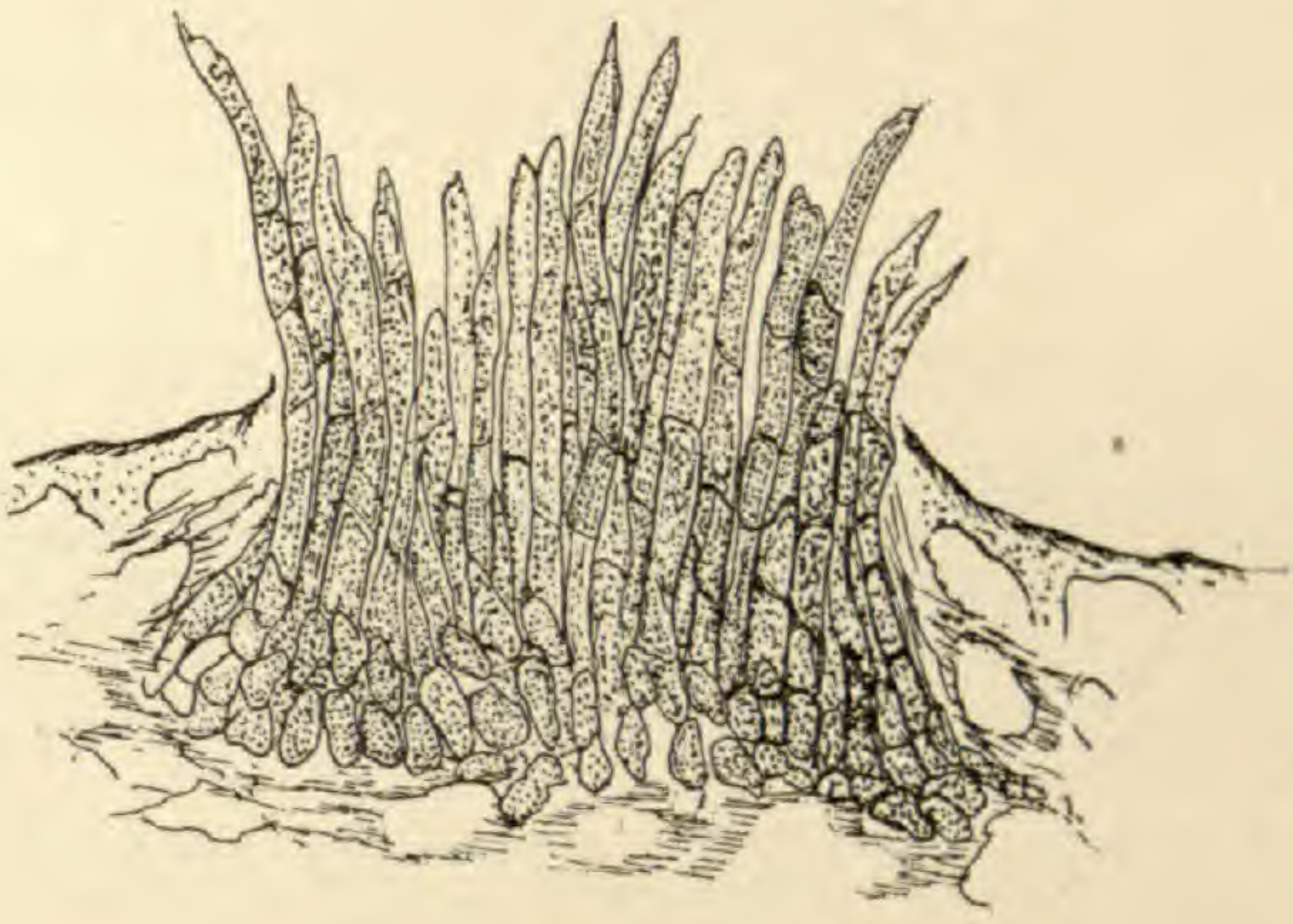

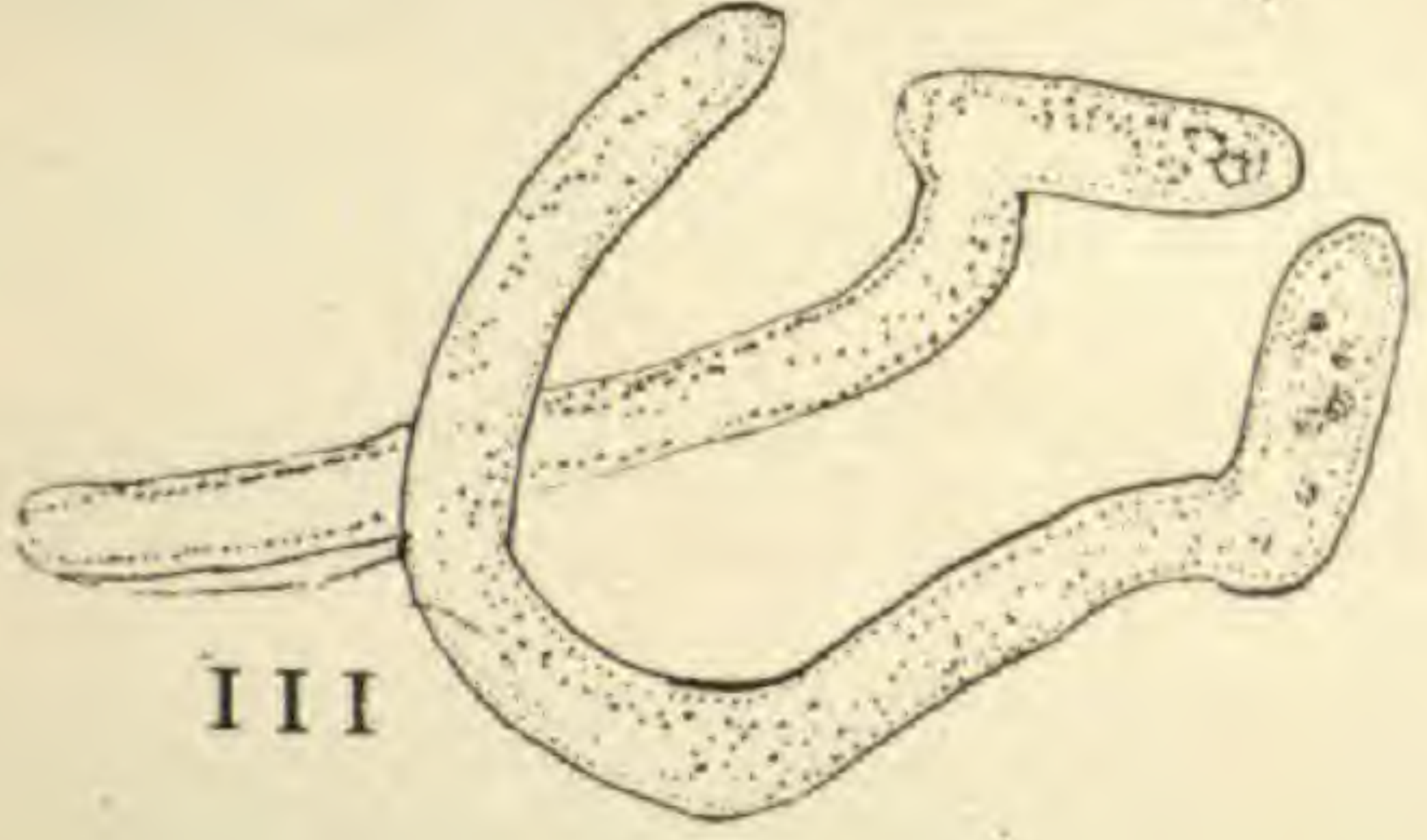

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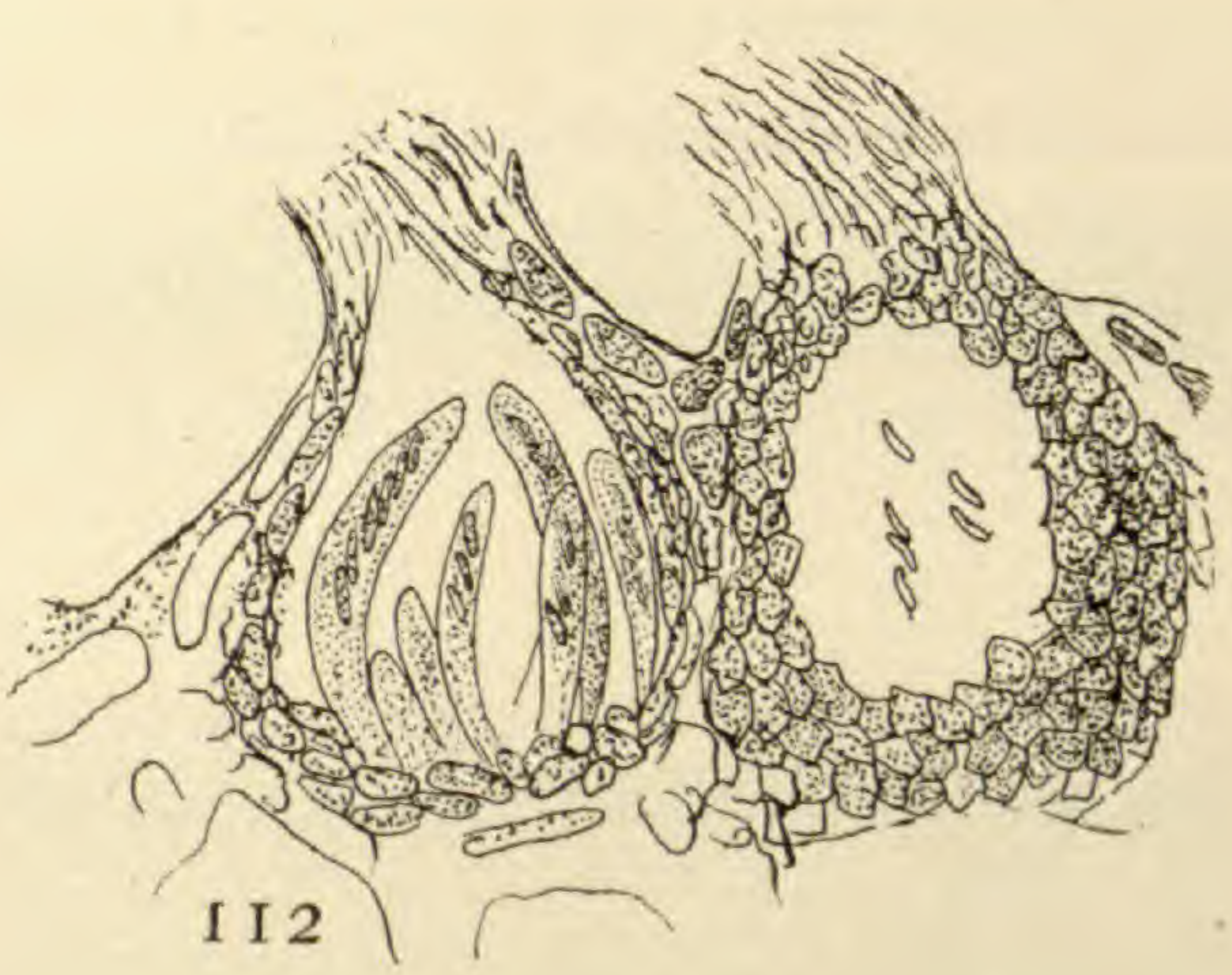

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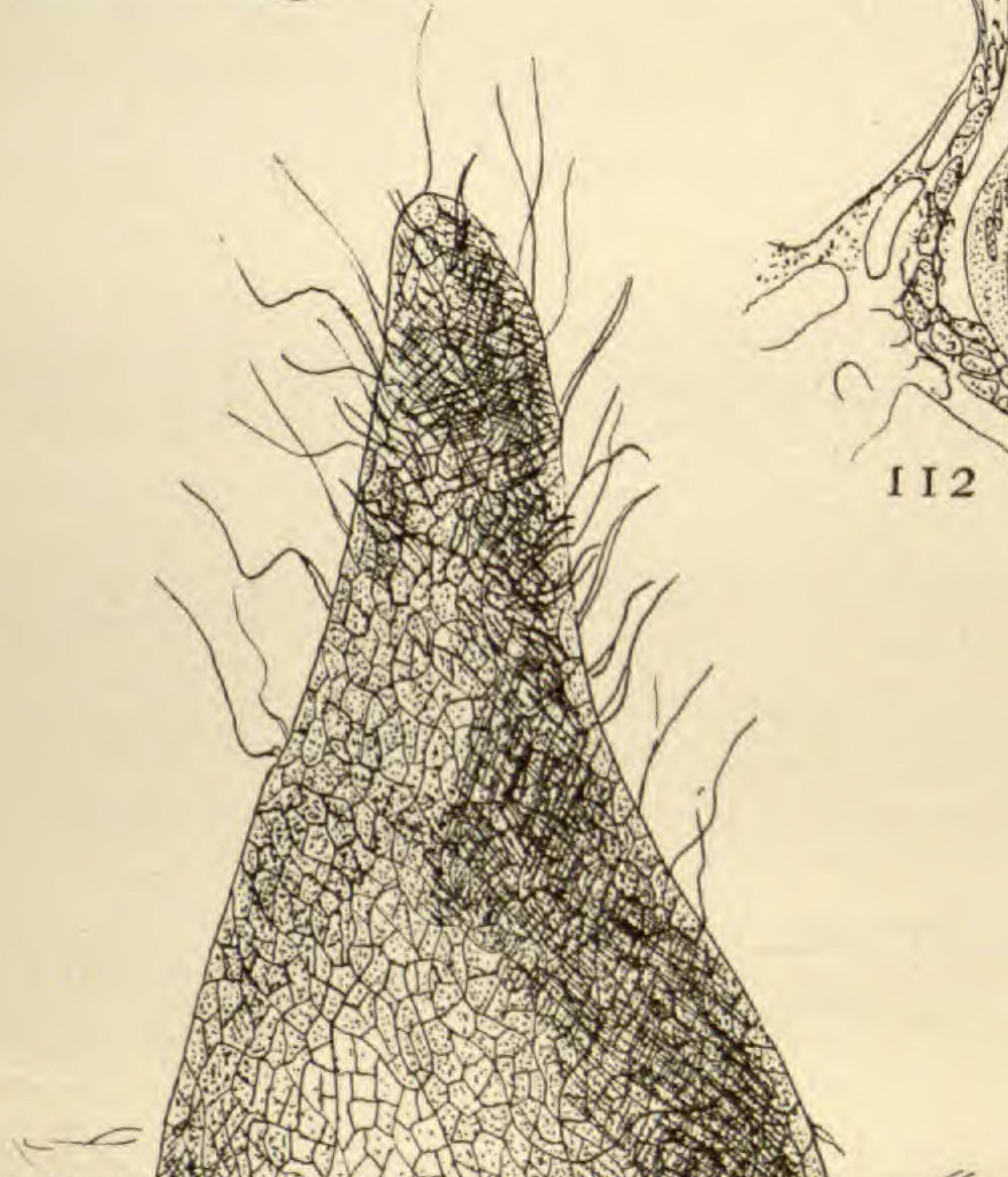

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STONEMAN on ANTHRACNOSES

ON THE RELATION OF THE FLORA OF THE LOWER SONORAN ZONE IN NORTH AMERICA TO THE FLORA OF THE ARID ZONES OF CHILI AND ARGENTINE.*

WILLIAM L. BRAY.

THE relation of the flora of extra-tropical North America to that of extra-tropical South America was first discussed by Gray and Hooker in their report on "The vegetation of the Rocky mountain region and a comparison with that of other parts of the world,"[1] under the title "North American types in South America." In this report there was printed a list of some eighty genera which contained identical or more or less closely related species in the southwestern states and south of the equator, concerning which they remark:

> Clear if not very numerous indications exist that there has at some time been greater opportunity for extension of North American types into the southern hemisphere. It appears that this has taken place along the western side of the American continent, along the central part of North America and Mexico, and the western part of South America. When our cool temperate flora flourished only along or near the southern border of the United States, the warm temperate, to which most of the plants enumerated belong, was still farther south. When the climate became again warmer, a portion of these were as well placed for southward as for northward retreat.

Two years later Professor Engler[2] defined this relation of the two floras more precisely, presenting a revised list of about eighty genera, involving many species, characterized chiefly by the fact that they were elements of the Mexican plateau and

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*For assistance in the preparation of this paper very cordial thanks are due to the management of the Berlin Herbarium, and in particular to Geheimrath Professor Adolph Engler, at whose suggestion the subject was taken up, and by whose friendly courtesy I was enabled to have free access to all of the resources of the herbarium.

[1] Bulletin U. S. Geol. and Geog. Surv. of the Territories **6**: —. 1880.

[2] Versuch einer Entwicklungs-geschichte der Pflanzenwelt **2**: 224. 1882.

portions of the bordering states, which, being mostly absent from south Mexico, Central America, and the Andes of Colombia, Venezuela, and Ecuador, reappear again first in Chili. Emphasis was laid upon the large percentage of Californian genera represented in Chili by identical or corresponding species, or even by species very distantly related, and their general absence in the intervening region.

These lists by no means included all the North American elements in Andean or extra-tropical South America, nor did they indicate that some very notable cases represented the extension of South American elements into extra-tropical North America, though of course these additional phenomena of distribution were discussed elsewhere in the *Entwicklungs-geschichte*, and it will be necessary to become familiar with them in the present paper.

More accurately defined the regions chiefly concerned are as follows:

1. In North America, the arid belt designated by Dr. Merriam[3] as the Lower Sonoran zone, including the Mexican tableland and adjacent western Texas, New Mexico, Arizona, Nevada, and Utah, with central, southern, and most of Lower California, approximately the region discussed by Professor Engler under "Das mexikanisches Hochland" and its northward extensions.

2. In South America, the desert of Atacama from about Cobija to 27° south and the less arid district south to 34°; the arid sand steppes and salt deserts of western Argentine along the east slope of the Andes, embracing in general from Catamarca at the north, Cordoba at the east, and Mendoza southward toward the Rio Colorado and Rio Negro; the "Chañar-Steppe" of Grisebach and "Monte Formation" of Lorentz.

With the above regions are also concerned the Gulf zone, with southern Brazil, Uruguay, and eastern Argentine; and the high Andes of Colombia, Venezuela, Ecuador, Peru, and Bolivia

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[3] Geographical distribution of plants and animals, Year Book Dep. Agric. 1894: 207 (and note).

above 3000^m, in the latter of which a very prominent Mexican highland and boreal element occurs.

The vegetation with which we have here to deal is above all one of xerophytic stamp. It falls into the two following categories: (1) groups distributed more or less continuously along the continental axis, always interrupted by the moist tropical and subtropical belt from south Mexico to the Andes of Colombia and Venezuela (the subandine province of Engler[4]), but with a very marked development in the arid plains and plateaus of the two extra-tropical zones in question; (2) groups not at all high mountain plants, but existing both in the Chilian or Argentine arid zones and in the Lower Sonoran zone of North America, but entirely disconnected through the intervening distance. It is evident that group (2) will furnish the more interesting and difficult questions of distribution as related to genetic affinities. It is further evident that satisfactory discussion can follow only after a critical determination of what those affinities are. In the following pages the writer presents a great deal more than he has himself determined critically, recognizing also that some excellent illustrative groups are left unmentioned.

The instances cited from Amarantaceæ, Malvaceæ, Loasaceæ, and Leguminosæ are not the results of my own study, although I have been able to compare specimens in all of them. The Loasaceæ will be very fully treated in the forthcoming monograph by Drs. Urban and Gilg. Gomphrena, Malvastrum, Sphæralcea, and Prosopis deserve more special study in comparing the species of the different regions concerned. One of the very best illustrations was found in the Zygophyllaceæ, in which, of course, I have simply used the results of Professor Engler's study of the family. In the other cases I have made a rather more detailed study of the specimens in the Berlin Herbarium.

AMARANTACEÆ-GOMPHRENEÆ.

This group of the Amarantaceæ is peculiarly the New World development of the family, finding there a subtropical and warm

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[4] Entwicklungs-geschichte der Pflanzenwelt **2**: 206.

temperate habitat in both North and South America. The more pronounced xerophytic genera occupy the Lower Sonoran zone in North America, and similar portions of southern Brazil, Uruguay, Argentine, and in a few cases Chili, being connected through the gulf region rather than along the Andes. Certain of the genera, as Pfaffia, Iresine, and perhaps Alternanthera, are more nearly tropical, and prevail in the territory encircling the gulf of Mexico. Three genera, Cladothrix, Gossypianthus, and Dicraurus, are confined to the Lower Sonoran zone. Guilleminea extends from this zone along the Andes to Peru, *G. densa* having the distribution of the genus. Frœlichia has several distinct species in the two extra-tropical zones, with one, *F. Floridana*, generally distributed and perhaps in both.

Gomphrena affords the most noteworthy case of distribution. Of the ninety species, more than sixty are of extra-tropical South America, more than ten are Sonoran, and fifteen natives of Australia. *G. globosa* is the cosmopolitan member. It appears that the Australian species are quite as closely related to the South American as are those of the Lower Sonoran zone, and all three regions would indicate a distribution analogous to that I have shown in the case of the Frankenia § Toichogonia-Cosmopolita.[5]

In so far as special contrivances for distribution are present they are as follows:

1. The stems are jointed and fragile, and the flowers easily disarticulate from the rachis.

2. The perianth is beset with long woolly hair in most of the genera.

3. The perianth is furnished with stout barbed hairs (*Alternanthera repens*) or with setose or spiny excresences (Frœlichia).

4. The bracts are long and spiny tipped (Gomphrena, Alternanthera).

These characters would aid the fruit in adhering to hairy or woolly mammals.

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[5] Geog.-Distr. of Frank. Engler's Botan. Jahrbücher **24** : 407.

MALVACEÆ.

Three genera, Sphæralcea, Malvastrum, and Sida, furnish good illustrations for our purpose. They are pronounced xerophytic genera, and have this noteworthy feature in common, that they occur in the Lower Sonoran zone, in the South American arid regions, and either in the Capland or in Australia.[6] In Malvastrum, while the type of the three regions (Sonoran zone, Argentine-Chili, etc., Capland) appears to be a common one, there occurs in the Andes of Chili and Peru the very distinct section Phyllanthophora described by Professor Schumann[7] as follows:

> In Chili, und dem Andinen Gebiete überhaupt steigen die Arten der Gattung M. hoch in die Gebirge und nehmen einen durchaus alpinen Character an; sie sind durch niedrigen, dicht rasigen Wuchs mit rosettig gedrängten Grundbl. und starke graue Bekleidung ausgezeichnet. Diese Formen haben stets Bl., welche an den Tragblättern emporgehoben sind, und aus dem Stiele derselben hervorbrechen. Sie bilden die einzige wohl abgegrenzte Gruppe, die Asa Gray als Phyllanthophora bezeichnet hat.

In this connection the distribution of several species of Sida[8] is of interest, as follows:

Sida leprosa K. Schumann (*Malva leprosa* Ortega; *Sida hederacea* Torr.).—Uruguay, Patagonia, Argentine, Cuba, Mexico, Washington to southern California, Utah, Arizona, and W. Texas.

Sida hastata St. Hil. (*S. physocalyx* Gray).—Argentine, Uruguay, Mexico, Texas to Arizona.

Sida anomala St. Hil. (*S. fasciculata* T. & G.).—Matto Grosso, Uruguay, Argentine, Bolivia, Cuba, Florida, Texas, Mexico.

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[6] Sphæralcea, four species in Capland; Malvastrum, fifteen species in Capland; Sida, seventeen species indigenous to Australia (see *Pflanzenfamilien* 3^6: —). Compare in this connection Gomphrena and Frankenia.

[7] Pflanzenfamilien 3^6: 41.

[8] This is being designated here the "Gulf zone distribution." Other illustrations are the following:

1. *Cienfugosia sulphurea* Garcke (*Fugosia Drummondii* Gray). Southwes, Texas, Mexico, southern Brazil, Paraguay.

2. *Spergularia Plattensis* Fenzl. Dallas, Texas, to southern California and south Brazil.

3. *Lepuropetalon spathulatum* Ell. Southern California, Georgia, Texas, Sonorat Chili, Uruguay, Montevideo.

4. *Polygala paludosa* St. Hil. Brazil, Paraguay, Louisiana, Texas.

The lack of mechanical devices for distribution in these genera seems not to have restricted them, which makes apparent the often substantiated fact that certain inherent ground gaining tendencies apparently render distribution independent of mechanical contrivances.

LOASACEÆ.

The Loasaceæ are almost exclusively a New World family, having, according to Gilg,[9] their center of distribution in Chili. The more extreme xerophytic genera spread thence over Argentine, and reaching North America find a second development chiefly in the Lower Sonoran zone. Four genera, Cevallia, Petalonyx, Eucnide, and Sympetaleia are endemic within this zone. Scyphanthus, Cajophora and Blumenbachia are southern extra-tropical. The largest genus, Loasa, furnishes many desert species for the Atacama and Argentine deserts, and while developed mostly in these regions and in the Andes, some species push north into Mexico (§ Saccatæ, 13 species, including *L. triphylla*, Peru to Mexico). But Mentzelia is the genus most conspicuous because of its distribution in the two zones under discussion, although quite abundantly distributed elsewhere, and particularly along the intervening Andes.

SEC. I. TRACHYPHYTUM, eight species; two Chili, one Chili-Argentine, one Argentine, four western North America, of which *M. albicaulis* reaches the plains and gulf coast.

SEC. II. MICROMENTZELIA, one species, *M. Torreyi*, in California and Nevada.

SEC. III. EUMENTZELIA, twenty-six species.

- *A.* *M. aspera*, with the distribution of the genus; *M. oligosperma*, North American, east to Florida; two Argentine species.
- *B* a. One Atacama, one California, one Florida, two Texas and north Mexico.
- *B* b I α. Two Mexico, one Chili and Peru.
- *B* b I β. Five Mexico, one Argentine.
- *B* b II α. One Mexico.
- *B* b II β. Two Mexico, one Bolivia, one Venezuela, one Colombia.

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[9] Pflanzenfamilien 3^{6a} : 106. The above account of the Loasaceæ is taken from this source.

SEC. IV. DENDROMENTZELIA, one species, a large shrub or tree, Mexico.

SEC. V. BICUSPIDARIA, four Californian species, extending to Arizona and north Mexico.

SEC. VI. BARTONIA, six species.
  A. Two species in western North America.
  B a. One species in western North America.
  B b. Three species; *M. albescens* in Argentine, Texas, and Mexico; two species in central and gulf states.

It appears from this synopsis, that although the development of the Loasacæ has proceeded in a manner to result in endemic genera in both the Sonoran zone and Chili-Argentine, still for Mentzelia, in particular, there is rather an intimate relation in distribution between the two regions.

The mechanical devices for distribution are such as to secure ready transportation by mammals or birds. The stems are exceedingly brittle, and all the younger parts are thoroughly beset with stout barbed pubescence, so that a very slight disturbance suffices to fasten the branch or capsule to the disturbing object.

LEGUMINOSÆ.

The Leguminosæ and also the Compositæ deserve special study in their distribution and relationships in the arid regions of North and South America. It suffices here simply to bring forward an illustration, and the genus selected is Prosopis, because in the remoteness of regions occupied and as a zonal genus it agrees with certain Zygophyllaceæ, *e. g.*, Larrea, Porlieria, and Bulnesia. Leaving out of account the two Asiatic and the two African species, there remain more than twenty New World species whose geographical center is in Argentine. These fall into two sections:

ALGAROBIA. Nineteen species, mostly in Argentine, but including the noteworthy *P. juliflora*, the mesquite, which in its distribution has come to occupy all of the subtropical and warm temperate, more or less arid districts of the western hemisphere. Apparently the Lower Sonoran zone would be very accurately defined by the North American distribution of *P. juliflora*, and its occurrence in the Andes, the West Indies, etc., marks those zones which enter secondarily into the discussion of distribution between extra-tropical North and South America.[10]

STROMBOCARPA. Six species; *P. torquata*, *P. strombulifera*, and *P. reptans* in Argentine; *P. heterophylla*, *P. cinerascens*, and *P. pubescens* in the more arid portions of the Lower Sonoran zone (west Texas, Mexico, and westward). Of *P. pubescens* Dr. Merriam[11] says:

> This mesquite, commonly known as "screw bean," is widely distributed over the deserts of the southwest, usually in company with the preceding (*P. juliflora*).

While the Sonoran and Argentine species of Prosopis are more nearly related than the wide geographical separation would seem to allow, only in the case of *P. juliflora* does there seem to have been ready interchange between the regions.

The genus is favored for a wide distribution by reason of the sugary mesocarp, which makes an article of food for herbivorous animals, the hard indigestible seed being in this way carried in the alimentary canal uninjured, and left with excrement in favorable situations for germination. This is more especially the case in § Algarobia, and above all in *P. juliflora*, of which Dr. Havard[12] says:

> The ripe pod or "bean" contains more than half its weight of assimilative nutritive principles, and is therefore a valuable article of food. The most important of these is sugar, in the proportion of 25 to 30 per cent. Most herbivorous animals, but especially the horse and mule, are fond of this pod and thrive on it. In the field it is a welcome though imperfect substitute for grain. The mesquit "bean" is one of the staple foods of Mexicans and Indians.

These facts would seem sufficient to insure a very general distribution. That the Strombocarpa species are not wanting in

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[10] Compare Bulnesia and Heterostachys.

[11] Shrubs of the Death Valley Exped. North Amer. Fauna **7**: 300.

[12] Report on flora of S. and W. Texas. Proc. U. S. Nat. Mus. **8**: 498.

[13] Op. cit. 499.

a similar quality is shown by the following, also from Dr. Havard:[13]

> The twisted pod or bean contains a spongy and nutritious pulp, rich in sugar, and is used as food by the Mexicans and Indians.

POLYGONACEÆ-ERIOGONEÆ.

This group of the Polygonaceæ, embracing eleven genera, is notably characteristic of southern California and the adjacent arid regions. Kœnigia is an exception, being an arctic and subarctic species. Of the remaining ten genera, six are confined to southern and Lower California and adjacent islands. Eriogonum, by far the largest genus, is distributed over the whole of western United States, although its chief center of development is also California. Lastarriæa has one species found in both California and Chili. Oxytheca has five Californian species, of which one is in Chili. Chorizanthe embraces some twenty-five Californian species (Euchorizanthe), of which one is in Chili; while there is a peculiarly Chilian group, Chorizanthopsis, of about ten species, none of which are in California.

Southern California appears clearly the center of development of Polygonaceæ-Eriogoneæ, and the Chilian representatives, therefore, may be referred to this region for their immediate or more or less remote origin.

Lastarriœa Chilensis, although described as a Chilian plant, is evidently Californian originally. It possesses a very wide distribution in the coast and hill country of Chili, likewise throughout southern California. The plants of the two regions are so nearly identical that a very recent distribution must be supposed. This has probably occurred in connection with the shipping of stock, particularly of sheep, as the plant is especially adapted for such means of distribution (1) by the recurved hooks of the involucre, and (2) by the easy breaking off of the younger parts of the stems.

Oxytheca dendroidea Nutt. falls in the same category as *L. Chilensis* Remy; and the same may be said of *Chorizanthe com-*

missuralis Remy, which, being one of the Euchorizanthes of California, occurs in Chili without noticeable variation. All of these species are fitted especially for distribution by cattle or sheep; but by whatever means they have come to Chili, it is safe to infer (1) that they are Californian, and (2) that this distribution has occurred in very recent times.

But comparing Chorizanthopsis with Euchorizanthe, the case is fundamentally different. Any intimate connection between these sections must be referred to an age long past. This is shown by the totally different methods by which they have adapted themselves to xerophytic conditions. The Californian species are all short-lived annuals, adapted for growing in the very driest places. The whole time of growth, flowering, and maturing seed lasts but a few weeks. With the approach of rainless parching weather their work is completed.

Of the Chilian species, all are shrubby, and often in sandy places form dense patches as a means of mutual protection. They are wholly different in habit from the Californian species, and are the one exception in Polygonaceæ - Eriogoneæ where stipules are produced. This section would appear to be an offshoot from Euchorizanthe, as Oxytheca and Eriogonum are, although the change is not, as in those, within the involucre, but in the vegetative structure. In its shrubbiness Eriogonum is very similar to subgenus Chorizanthopsis. The same circumstances which witnessed the rise and spread of Eriogonum over western North America may have witnessed also a more general distribution of the group into the southern hemisphere, of which the Chilian Chorizanthes are the remnant.

It is interesting to note in connection with this group that several genera which have special devices for distribution are narrowly endemic. Pterostegia and Harfordia have the bracts developed into bladder-like structure, for wind distribution; Centrostegia has wing-like, spurred involucral bracts; Nemacaulis and Hollisteria have woolly involucral bracts and perianth; while Phyllogonum has neither bracts nor involucre. All of these are limited to southern California and adjacent islands. Kœnigia, which has no special mechanism for distribution, is the most widely distributed of all.

FRANKENIACEÆ.[14]

The Frankeniaceæ are typically halophytic plants, represented in the new world as follows :

FRANKENIA § TOICHOGONIA-COSMOPOLITA, six species in Chili on the coast and in the alkali regions inland. Of these *F. grandifolia* is abundant on the California coast, about salt lakes of southern California, and eastward to southern Arizona, New Mexico and northern Mexico, the inland type being var. *campestris* Gray.

F. § TOICHOGONIA-ISOLATA, three species : *F. farinosa*, about Cobija in northern part of desert of Atacama ; *F. triandra*, the Puna region, at 3500 to 4000^{m} ; *F. vidali*, islands of San Felix and San Ambrosio, Chili.

F. § BASIGONIA, two species : *F. Palmeri*, Lower California to San Diego bay ; *F. Jamesii*, east foot of Rocky mountains in Colorado and western Texas.

NIEDERLEINIA : *N. juniperoides*, salt steppes of Argentine ; nearly related to *Frankenia* § *Basigonia*.

The Frankeniaceæ illustrate two features in the relation between the two regions of North and South America now under discussion.

1. That a very recent distribution has taken place in the case of *F. grandifolia*, which belongs to a section notable for the number of closely related species. This distribution may be due to birds, since the plant is found so widely distributed inland and at a considerable height above the sea (1000^{m}).

2. That *F. Palmeri*, *F. Jamesii*, *F. triandra*, and others, and *Niederleinia juniperoides* are isolated species, which we may regard as remnants of a previously widespread development; and therefore no interchange between the regions occupied has occurred under present geological conditions.

CHENOPODIACEÆ.

The Chenopodiaceæ should be considered in this connection,

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[14] For detailed discussion of the geographical distribution of the Frankeniaceæ see Engler's Jahrb. **24** : 394. 1897.

notwithstanding the fact that there are many cosmopolitan species. A very useful instance is furnished by the genus Spirostachys, of which *S. occidentalis* is the North American form, occurring throughout the salt steppes of the Lower Sonoran zone; and *S. vaginata* and *S. Patagonica*, two nearly related South American species from the Argentine salt steppes, where they are abundant and conspicuous. I am inclined to believe there is no recent connection between the species of these two regions. *Heterostachys Ritteriana* merits mention here, because, aside from Spirostachys, the other nearly related genera are in the central Asiatic salt steppes and Australia; and the plant further illustrates the phenomenon of Gulf zone and southern Brazil distribution, being described from Central America, northern South America, the West Indies, southern Brazil, and Argentine.[15]

ZYGOPHYLLACEÆ.

The critical work done by Professor Engler on this family[16] makes it of special value for our purpose. He has shown that there is a very considerable development of the Zygophyllaceæ in the New World, of which the larger portion form the consistent group Guajacineæ, which is the present expression of a branching off from Old World Zygophyllaceæ in geological times. With few exceptions the Zygophyllaceæ in the western hemisphere are limited to the Lower Sonoran zone in North America and its corresponding zone in Argentine and Chili. The regions in addition are savannas of Venezuela and Colombia, southern Florida, West Indies, and southern Brazil; exactly the previously mentioned Gulf zone distribution.[17] Following is a tabular arrangement of the Zygophyllaceæ, based upon Professor Engler's study of the family:

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[15] See under Malvaceæ.

[16] Pflanzenfamilien 3^4: 74; Geog. Verbr. der Zygoph. im Verh. zu Syst. Glied. Abh. Kön. Preuss. Acad. Wiss. zu Berlin, 1896.

[17] Compare Prosopis, Heterostachys, and references under Malvaceæ.

	Sonoran zone, North America	W. Indies, S. Brazil, northern S. America	Chili-Argentine xerophytic zone	Means of distribution
1. Fagonia *cretica*	var. *Californica;* San Diego, Los Angeles bay, N. Mex. (val de las Palmas)		var. *Chilensis;* N. Chili (Coquimbo, Tarapaca, Atacama, etc.). var. *aspera;* Quebrada de Gaihuano.	Mucilaginous seed coat with spirally coiled projectile hairs, fitted for adhering when moistened.
2. Guajacum	*G. parvifolium;* Mexico. *G. Coulteri;* Mexico.	*G. officinale;* Fla,, Antilles, Guiana, Venez., Colombia (arid coasts). *G. sanctum;* Fla., Bahamas, Antilles, Guatemala.		Thin fleshy exocarp which birds would eat.
3. Porlieria	*P. angustifolia;* Texas, Mexico.		*P. hygrometrica;* N. Chili, Peru. *P. Lorenzii;* Argentine steppes.	
4. Pintoa			*P. Chilensis;* N. Chili.	No special mechanical device for distribution.
5. Bulnesia		*B. arborea;* a high tree in savannas of Col. and Venez.	*B. bonariensis;* Santiago del Estero; west slope of Sierra de Cordoba. *B. Schickendantzii;* Catamarca. *B. Chilensis;* Atacama. *B. foliosa;* Catamarca. *B. macrocarpa;* dune sand, campos of Catamarca. *B. Sarmientii;* Gran Chaco, Argent.	Broad winged fruit,adapted for distribution in open, arid steppes.

	Sonoran zone, North America	W. Indies, S. Brazil, northern S. America	Chili-Argentine xerophytic zone	Means of distribution
6. Plectrocarpa			*P. tetracantha;* salt regions from Catamarca to Mendoza.	Carpels with curved spines.
7. Larrea	*L. Mexicana.*		*L. divaricata;* covers exclusively great areas of Cordoba and Mendoza. *L. cuneifolia;* salt deserts, Cordoba to Rio Colorado. *L. nitida;* Argentine.	Carpels with long, thick-walled hairs.
8. Metharme			*M. lanata;* Tarapaca, N. E. Chili.	
9. Tribulus *terrestris*	In both hemispheres in warm temperate xerophytic zones.			Carpels tuberculate, or rough spiny in some cases, which would aid in transportation by mammals. Compare Malvas of a similarly wide distribution, which have no mechanical device for transportation.
	T. Californicus; S. Ariz., Lower Calif. *T. brachystylis;* N. Mex.; Guaymas, Mexico.			
10. Kallistrœmia		*K. tribuloides;* Brazil and Argentine.		
	K. maxima; Texas, N. Mex. *K. grandiflora,* Texas to Calif.	*K. maxima;* Bolivian Andes northward through Central America and West Indies		

	Sonoran zone, North America	W. Indies, S. Brazil, northern S. America	Chili-Argentine xerophytic zone	Means of distribution
11. Viscainoa	*V. gemmulata*: Lower Calif.			Fruit of four splitting capsules, not winged, still light enough to be carried by winds.
12. Chitonia	*C. Mexicana*; Montezuma river.			Fruits large and winged, splitting at maturity.
13. Sericodes	*S. Greggii*; N. Mexico.			Woolly carpels.
14. Peganum	*P. Mexicanum*; N. Mexico; nearly related to Chinese species.			Like Fagonia.

The distribution of *Fagonia cretica* vars., Tribulus, and Kallistrœmia is similar to that of *Frankenia grandifolia*, *Chorizanthe commissuralis*, *Oxytheca dendroidea*, *Lastarriœa Chilensis*, etc.; that of Larrea and Porlieria is like the isolated Frankenias, Spirostachys, etc. Larrea may be cited as the best case illustrating that phase of distribution in which there is absolute separation of the species both in a geographical and a genetic way. No other species are more reliable determinants of zonal areas that those of Larrea;[18] which is also to say that distribution from one zone to another over thousands of miles in which Larrea could not grow is very improbable, and this is clearly indicated by the distinctness of the species. Professor Engler expresses the opinion[19] that the present condition of Larrea, and indeed of the Guajacineæ,

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[18] MERRIAM, North American Fauna 7 : 293; Engler, Pflanzenfamilien 3^4 : 86.

[19] Geogr. Verbr. der Zygophyllaceæ, etc. Abh. Preuss. Akad. Wiss. — : 17. 1896.

represents remaining parts of a prehistoric, more general development, *e. g.:*

> Nun haben wir bei Larrea die eigenthümliche Verbreitungserscheinung, das *L. Mexicana* Moric. vom Colorado-Gebiet Californiens, bis zum westlichen Texas und im trockneren Mexiko verbreitet ist, während drei andere Arten in den Sandsteppen und Salzwüsten Argentenien von den Anden bis Cordoba in ausgedehnten Beständen auftreten. Diese Arten sind sowohl von einander, wie auch von der mexikanischen sehr verschieden, so dass die Entstehung dieser Arten sehr alten Datums sein und eine grössere Anzahl von ausgestorbenen Arten angenommen werden muss, welche sowohl morphologische wie räumlich de jetzt lebenden Larrea-Arten mehr verknüpften.

REVIEW OF HALOPHYTIC ELEMENTS.

Following is a tabulation of halophytic species occurring beyond the tropics in North and South America. Certain endemic species of Suæda and Atriplex are believed not to be related through the cosmopolitan coast species. In no other genus, except Prosopis, are species known to occur in the intervening distance, *i. e.*, over 40° of latitude:

Lower Sonoran halophytic	Chili-Argentine halophytic
Spirostachys occidentalis.	Spirostachys { vaginata; Argentine. Patagonica; "
Suæda; *e.g.* S. Torreyana and S. suffruticosa	Suæda; *e. g.* S. divaricata.
Atriplex; *e. g.* A. canescens.	Atriplex; *e. g.* A. Chilense (Chili) (*cf.* A. cinereum; Austral.)
Frankenia grandifolia, - - =	F. § Toichogonia-cosmopolita; Chili.
F. Jamesii, F. Palmeri, related to	Neiderleinia juniperoides; Argentine.
Fagonia cretica Californica.	Fagonia cretica { Chilensis; Chili. aspera; Chili.
Larrea Mexicana.	Larrea divaricata; Argentine. " nitida; " " cuneifolia "
	Metharme lanata; Chili.
Prosopis § Algarobia; P. juliflora.	Prosopis § Algarobia; P. juliflora and many others, mostly Argentine.
§ Strombocarpa, 3 species.	§ Strombocarpa, 3 species; Argentine.

In the above will be noted (1) the greater number of common genera in Argentine and the Lower Sonoran zone; (2) that most species have no special mechanical devices for seed transportation.

BORRAGINOIDEÆ-ERITRICHIEÆ.

The Borraginoideæ-Eritrichieæ of the *Pflanzenfamilien* include seventeen genera, of which two, Lappula and Eritrichium, possess a broad distribution in the temperate zone of both hemispheres. Seven genera are chiefly E. Asiatic. Eight other genera occur in western North America, of which four recur in Chili. The geographical center of this group would appear to have been eastern Asia. From here the migration would have been along the chain of islands, Aleutian, etc., joining Asia and America, or by Behring strait and along the continental axis to extra-tropical South America; and hence the group would fall in with the boreal element represented in the Andes of Bolivia, Peru, and Chili. But the group has attained a distinct development in the Lower Sonoran zone of North America, and in the Atacama-Chilian arid zone, and for that reason is discussed here in some detail. It is to be noted that at one time or another, almost all of the west American development of Borraginoideæ-Eritrichieæ (both north and south) has been referred to the genus Eritrichium (excepting, of course, Amsinckia), and this fact may be made important in interpreting the present condition of the group in the western hemisphere. The Eritrichium type still prevails in a few species, and these are notable for being high mountain forms distributed along the continental axis from Alaska to southern Chili, with a considerable interruption from southern Mexico to Ecuador, while the forms referred to distinct genera represent apparently the variations resulting from the occupancy of a vast arid tract.

In the *Synoptical Flora* (191–199, ed. 1), Asa Gray included all of North American Borraginoideæ-Eritrichieæ under Eritrichium, Echidiocarya, and Amsinckia. In *Proc. Amer. Acad.* **20**: 264, and *Syn. Fl.* Suppl. 423–433 (ed. 2), the two latter are retained, while Eritrichium in North America practically disappears in Krynitzkia and Plagiobothrys. Later, Professor Greene[20] defines the following genera: Allocarya, Eremocarya, Piptocalyx, Sonnea, Plagiobothrys (incl. Echidiocarya), Oreocarya, Cryptanthe, and Amsinckia. This is the arrangement adopted in the *Pflanzenfamilien.* Professor A. Philippi[21] describes one hundred Chilian species in twelve groups under Eritrichium, besides recognizing Amsinckia and Plagiobothrys. The one hundred species of Eritrichium fall under Allocarya, Eremocarya (?), and Cryptanthe.

In the following tabulation species are grouped under those characters which best emphasize the relation of the Chilian to the North American species:

	Western N. America	Chili
1. Cotyledons two-lobed AMSINCKIA. (boreal species.)	A. echinata } = A. intermedia }	A. angustifolia.
2. Nutlets rugose, depressed from above; scar in middle of concave ventral face; lower leaves opposite. ALLOCARYA.	A. stricta } = A. trachycarpa }	(E.) uliginosum.
	A. chorisiana } = A. plebeia }	(E.) procumbens. (E.) humilis. (E.) sessifolium.
3. Nutlets very strong, thick, depressed (as in 1), very broad; stipe in middle of ventral face. PLAGIOBOTHRYS.	P. rufescens = ((E.) fulvum.)	P. rufescens. ((E.) tinctorium?)
4. Nutlets united in pairs to an elongated stipe-like base. ECHIDIOCARYA.	E. Arizonica.	None.

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[20] Pittonia, pts. 1, 2, 3. 1887.

[21] Plantæ Nuevas-Chilensis, 1893.

	Western N. America	Chili
5. Nutlets with rugosity prolonged into barbed spines.	Two species.	None.
6. Nutlets with very thin, often crustaceous or pearly dotted or tubercled pericarp attached to gynobase along the whole grooved ventral face, or at base by triangular area; fitting together by plane faces. CRYPTANTHE. EREMOCARYA.	Many species.	Many species.
(1). Nutlets unlike or only one or two maturing: calyx articulated with and easily falling from rachis.	Cryptanthe angustifolia. C. crassipetala.	(E.) aspera. (E.) Bridgesii. (E.) congesta. (E.) carrizalensis. (E.) minutiflora. (E.) glareosa.
(2). Four nutlets maturing: not of extreme xerophytic habit.	Many North American species of Cryptanthe.	(E.) chætocalyx. (E.) debilis ? (E.) axillare ?
More xerophytic.	Eremocarya micrantha.	(Eritrichium) parviflora.
(3). Nutlets very large, protruding beyond calyx; pericarp crustaceous, silvery white.	Cryptanthe Jamesii.	(E.) gnaphalioides, and most amphicarpous species.
(4). Calyx circumscissile.	In several groups.	None.
(5). Calyx lobes with long, foliose tips, mostly thickly beset with long, needle-like hairs: more extremely xerophytic.	C. Torreyana. C. leiocarpum. C. intermedium. C. ambigua. C. barbigera.	(E.) longiseta. (E.) micrantha. (E.) calycina. (E.) diffusum. (E.) diplotrichium.
(6). Species with amphicarpous nutlets.	None.	Fourteen species.

The foregoing synopsis of characters does not always bring together plants of similar habit, as, for example, *Cryptanthe Jamesii* (N. America) and *C.* (*Eritrich.*) *gnaphalioides* (Chili), but it does aid in showing (1) that the Chilian species are an expansion of the North American development, and (2) that while identical species exist in the two zones there was also possible a distribution long enough ago to permit noticeable individuality to arise in the Chilian group.

To summarize briefly: More than 130 species of Borraginoideæ-Eritrichieæ have been described in western North America, of which over 60 per cent. are confined to the Sonoran zone. Fewer than ten of these species pass into northern Mexico; but one into southern Mexico. In the Chilian xerophytic zone, from 23° S. to 34° S., more than one hundred Borraginoideæ-Eritrichieæ have been described, of which five or six are high mountain forms of a wider distribution southward and northward, especially in the high Andes of Peru, Bolivia, and Ecuador. But there remains a region of more than twenty degrees latitude from which Borraginoideæ-Eritrichieæ are absent, or in which they occur very sparingly.

The southward extension of this group may be ascribed in part to glacial agency, inasmuch as some species belong to the high Andean boreal element. Mechanical arrangements for distribution are found in the easy disarticulation of the fruit, and its needle-like hairiness in Cryptanthe and Eremocarya; in the roughened or spined carpels of certain species; and in the long, sharp-haired calyx lobes of others.

With the Borraginoideæ-Eritrichieæ may be presented also the genus Pectocarya. The genus embraces the two sections Ktenospermum and Gruvelia.

KTENOSPERMUM has the same species, *P. linearis*, in California, Utah, Arizona, and in Chili. From California north to British Columbia is var. *penicillata*, and in Peru a similar var. *lateriflora*.

GRUVELIA has *P. setosa*, a distinctly marked species confined to southern California and Nevada. There is a more common and widely distributed form of this section which Gray added to the Chilian *P.* (GRUVELIA) *pusilla.* It is not identical with *P. pusilla*, and to call it a variety of that species hides the essential fact that the Chilian plant is a southward migration of the common form of GRUVELIA.

The flat light carpels of Pectocarya are admirably adapted for clinging to birds or mammals because of the pectinate margin with its recurved setæ.

POLEMONIACEÆ.

The Polemoniaceæ duplicate the characteristics of the Borraginoideæ-Eritrichieæ in being a boreal group with a marked development in the Lower Sonoran zone of North America, repeated in a less marked degree in the Chilian zone. Except for the genus Gilia the family would scarcely come within the scope of this discussion, being in their South American distribution high mountain species.

Gilia includes some eighty North American species, falling under thirteen sections; and about fifteen Chilian species, mostly included in Eugilia, Navarretia, and Dactylophyllum, but, as in Cryptanthe, having an individuality of species that indicates a prehistoric as well as modern distribution.

Western N. America	Chili
§ EUGILIA.	*Gilia laciniata,* described originally from S. Amer.; occurs likewise in western N. Amer.
Gilia multicaulis, western California, is of *G. laciniata* type; straggling laciniate-leaved forms doubtless=	*G. laciniata.*
Gilia capitata and *Gilia achillæfolia* are more extreme California and Oregon species, related to - -	*G. laciniata.*
Gilia inconspicua, Wyoming to western borders of Texas, and west to California and British Columbia; forms with laciniate radical leaves very close to - - - -	*G. crassifolia.* *G. copiapina.* *G. longifolia.*

Western N. Amerfca	Chili
	Gilia fœtida, distinct Chilian species.
	Gilia glabrata and *G. ramosissima* are Chilian species of common Eugilia type.
§ NAVARRETIA.	
Gilia intertexta, plains of Columbia river to California and the Rocky mountains - - - - =	*G. involucrata* (incl. *G. Navarretia* Steud., and *G. eryngioides* Lehm.).
Gilia minima, of arid portions of interior of Oregon and Nevada to Colorado and Dakota - - =	dwarf forms of *G. involucrata* in Chili.
§ DACTYLOPHYLLUM.	
Gilia pusilla, Guadaloupe island, and var. *Californica*, Sacramento to Nevada, - - - - - =	*G. pusilla*, in Chili.
COLLOMIA.	
Collomia linearis Nutt., Saskatchawan, Oregon, Washington, and Utah, - - - - - =	*Collomia coccinea* Lehm., Peru, Bolivia and Chili.
Collomia grandiflora Dougl., similar to preceding, plains from Rocky mountains to California and Nevada.	
Collomia gracilis, Alaska to Chili.	
POLEMONIUM.	
Polemonium micranthum - - =	*P. antarcticum.*

In the preceding tabulation the more extreme xerophytic species do not appear, because it is only the mountain species which have the extended distribution, and among which, therefore, the same or closely related species occur in both Chili and western North America. The method of distribution is of interest here. Commonly in the Polemoniaceæ the seed is furnished with a layer of cells whose walls become mucilaginous by contact with water, expelling forcibly the spirally thickened hair-like processes which cause the seed to adhere firmly to moistened objects (*e. g.*, feet of birds) and thus secure transportation. So far as I was able to examine, all the South American species of Polemoniaceæ possess these mucilaginous seeds. *Gilia minima* and dwarf forms of *G. involucrata* (Chili) grow in little dense mats in arid spots. On the addition of moisture the seeds are gradually pushed up from the dense enclosure of bracts until they stand exposed and ready to adhere to any disturbing object. In the section Navarretia the bract development itself would be sufficient to bring about extended distribution by clinging to the hair of mammals. The absence of these genera from both north and south Mexico is noteworthy.

SUMMARY.

1. Most of the genera just considered are of pronounced xerophytic or halophytic character.

2. Characteristic American groups, such as Zygophyllaceæ, Guajacineæ, Borrag.-Eritrichieæ, Amarant.-Gomphreneæ, and Loasaceæ, tend to a development in both extra-tropical xerophytic zones, often with the same, and generally with nearly related species in both zones.

3. For some genera each zone has its characteristic group of endemic species, indicating an independence from the other reaching into prehistoric time, *e. g.*, Malvastrum, Chorizanthe, Larrea, etc.

4. The halophytic genera in particular indicate that in some cases no distribution has occurred from one region to the other under present geological conditions, *e. g.*, *Frankenia Palmeri*, *F. Jamesii*, *F. triandra*, *Niederleinia juniperoides*, Spirostachys, Larrea, etc.

It is evident from a study of the plants concerned that distribution by natural methods has occurred and is occurring under present physical conditions. It is further evident that distribution has been greatly facilitated by what may be called, in contradistinction, artificial means, namely, as a result of commerce.

Again, one must suppose the present conditions, or others as favorable, to have endured far back into the history of the present plant world to allow time enough for the isolation of such groups as Chorizanthopsis, Malvastrum § Phyllanthophora, or even for the Chilian development of Borrag.-Eritrichieæ.

But how does it occur that the high andean flora is chiefly boreal? And how have the arctic-alpine plants reached the southern high Andes from the Rocky mountains? Further, how have the sharply defined and isolated species of Larrea, Frankenia, Prosopis, etc., come to be in both regions?

Gray and Hooker supposed that in the glacial time there was a driving of boreal and warm temperate elements southward, as a result of which some plants were placed favorably for migration farther south. Engler suggests that the southward migration of animals caused by the glacial encroachment was very notable in aiding the distribution of plants southward over the isthmus.

It has been suggested that geological conditions have allowed a more general extension along the west American coast of an arid plateau similar to that of middle and northern Chili. Referring to a chart of ocean depths along the Pacific coast it is clear that by an uplift of 3000 feet a series of abrupt step-offs or shelves would be exposed extending to the Californian coast, and making the isthmus region a broad belt of land. This, besides offering a highway for xerophytic elements, would also bring about that union of the Pacific islands off the Californian coast with the continent which Sereno Watson[22] supposed must have prevailed in order to give the similarity of island flora to that of California. He suggested that the relations to the adjacent continent indicate a former flora which spread over a wide region now submerged, from which ancient flora the elements common to California and Chili were derived.

Such a condition of emergence along the west coast would be very favorable as an explanation for many of the phenomena of distribution, but I am not convinced that it is either necessary or possible to assume this. One must bear in mind that an elevation of the coast of South America by 3000 feet would in all

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[22] On the flora of Guadaloupe islands. Proc. Amer. Acad. 11: 112. 1876.

likelihood mean an elevation of the Andes much higher above their present summits than we are warranted in ascribing to them. Professor Engler[23] says that the Andes of Venezuela, Colombia, and Ecuador could not have been completely glaciated during the glacial period, for in this zone we find peculiar tropical genera which, without doubt, date from the oldest times. In this event these mountains could not, within the era of present vegetation (dating presumably from somewhere in the Tertiary period) have had a much greater elevation than at present. On the other hand, there is conclusive evidence of a state of submergence during the Tertiary period and of subsequent upheaval, a fact significant in the present discussion. He says[24] in effect: If the geological conclusions be correct, we have in the Tertiary period the Andes representing an island separated from the Guiana-Brazilian triangle of land by an arm of the sea, narrow at the north, wider at the south, and from Central America by a strait. Central America was united with western North America, which latter was separated from eastern North America by inland seas. In these conditions an exchange of tropical elements between Central America, West Indies, Guiana-Brazil, and the Andes could occur. With the progress of upheaval of the Andes and consequent changes of climatic conditions the tropical nature of these mountains was modified, only those forms remaining which could adapt themselves to the extremes of greater altitude. With this elevation, in particular, the flora of the north pushed southward over a newly opened territory, peopling the Andes in such numbers that the present high andean vegetation is to be reckoned with the boreal. This southward wandering of North American species was at first of the hygrophilous elements, embracing many forms coming from the Himalayas to North America, and so explains the presence of Himalayan types in the Andes. But, as the Andes began to attain their present elevation, the moisture of the trade winds was withdrawn, and a pathway for more xerophytic elements was

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[23] Entwicklungsgeschichte der Pflanzenwelt 1 : 198.

[24] ENGLER : Entwicklungsgeschichte 1 : 196–198.

opened, and so the xerophytic hosts, which had previously found favorable territory for expansion and variation in western North America, pressed southward; for example the Sonoran Compositæ, Polemoniaceæ, Cactaceæ, Borragineæ, etc. These, by the agency of birds and mammals, were carried over the equator to the extra-tropical regions of Chili, where again they found a broad, open territory favorable to a varied development.

Three important propositions result from the foregoing:

1. We are carried back to a time when the isolated groups, like § Chorizanthopsis and Malvastrum § Phyllanthophora could have branched off from the North American stem.

2. Conditions following the appearance of land along the eastern base of the Andes might account for a more general distribution of those genera like Frankenia, Niederleinia, Larrea, and other Zygophyllaceæ, Spirostachys, and some other Chenopodiaceæ, which are now widely separated and genetically distinct.

3. Animals, particularly birds and mammals, have probably played a prominent part in the distribution of plants across the equatorial and isthmus regions.

In the following tabulation the devices for securing distribution are brought together for a general view:

I. Adaptation for wind distribution:
  1. By winged fruits: Bulnesia, Chitonia, Centrostegia, Pterostegia, Harfordia.
  2. By light, woolly hairs: Larrea.

II. Adaptation for distribution by animals.
  1. Probably by birds.
    (*a*) As food; fleshy exocarp: Guajacum, Porlieria.
    (*b*) Seeds with mucilaginous covering and elastic coiled slime hairs: Gilia, Collomia, Fagonia, Peganum.
    (*c*) Seeds very small; without special devices for clinging, yet possibly adhering to birds' feet in mud or slime: Frankenia, Spirostachys.
  2. Probably by mammals.
    (*a*) As food; nutritious mesocarp: Prosopis.
    (*b*) By devices for clinging to wool or hair.

(1) Involucral bracts with recurved hooks ; stems fragile at joints: Chorizanthe, Oxytheca, Lastarriæa.
(2) The whole plant beset with barbed hairs ; stems very brittle : Loasaceæ.
(3) Rough or spiny projections on calyx or carpels : Tribulus, Kallistrœmia, some Cryptanthes, Frœlichia.
(4) Calyx with sharp, sometimes recurved stiff hairs ; fruits easily falling away ; many Borrag.- Eritrichieæ.
(5) Carpels flat, with hooked setæ : Pectocarya.
(6) Fruits adhering by woolly covering: Gossypianthus, Frœlichia, Gomphrena.

For most species, then, the distribution and relationships in the two zones are such as can be accounted for from data that are reasonably well established. The element which remains rests upon very much the same basis of speculation as the relation of New World to Old World Zygophyllaceæ, or Australian and South American Chenopodiaceæ, or, indeed, the relation of the great salt desert regions of the world to each other.

UNIVERSITY OF TEXAS.

CURRENT LITERATURE.

NOTES FOR STUDENTS.

ALFRED J. EWART[1] continues to hold it as proved, in spite of Kny's objections, that isolated chlorophlastids may continue to assimilate for a short time after removal from the parent cell.—J. M. C.

IN HIS INTRODUCTORY presentatation of the pteridophytes, Sadebeck[2] outlines five main groups, FILICALES, SPHENOPHYLLALES, EQUISETALES, LYCOPODIALES, and CYCADOFILICES. The three groups of FILICALES are *Fil. leptosporangiatæ* (with the natural isosporous and heterosporous subdivisions), *Marattiales*, and *Ophioglossales*. The EQUISETALES are subdivided, on the basis of isospory and heterospory, into *Euequisetales* and *Calamariales.* The LYCOPODIALES have as their main divisions *Lyc. eligulatæ* and *Lyc. ligulatæ;* the subdivisions of the former being *Psilotineæ* and *Lycopodiineæ;* of the latter, *Selaginellineæ*, *Lepidophytineæ*, and *Isoetineæ*. The taxonomist who delights in uniformity of group names, and also names that indicate the rank of groups, will not be pleased.—J. M. C.

THE INTERESTING discovery of a set of the plants collected on the Lewis and Clark expedition and named by Pursh forms the subject of a paper by Mr. Thomas Meehan.[3] Pursh in his *Flora* refers to 119 as having been collected, many of which were new. The fate of the collection was unknown, the general understanding being that Pursh took the plants to England, and left them to Lambert, an officer of the Linnean Society, and that upon the distribution of Lambert's herbarium the plants were scattered. The occurrence of a large number of types in the collection made the loss of it a serious one. It seems that two years ago Professor C. S. Sargent suggested to Mr. Meehan that some of the material might be in the custody of the American Philosophical Society. After a long search the original packages were found unopened, some of them in bad condition, but the collection as a whole fairly preserved. Pursh's labels and notes made the discovery certain. The collection was sent to the Gray Herbarium for final identification, and Mr. Meehan includes in his account the very full and satisfactory report by Dr. B. L. Robinson and Mr. J. M. Greenman. Several interesting discoveries were made which will correct certain current identifications. In presenting the report parallel columns are used, one giving the present name of the plant, the other the treatment of the plant in Pursh's *Flora*. The discovery

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[1] Bot. Centralbl. 75: 33-36. 1898.

[2] Engler and Prantl's "Die Natürlichen Pflanzenfamilien" 1^4: 1-48. 1898.

[3] Proc. Acad. Nat. Sci. Philad. 12-49. 1898.

of this important collection of North American plants and its deposit in the Academy of Sciences of Philadelphia is a matter of congratulation among taxonomists.—J. M. C.

MR. HENRY H. DIXON[4] has published recently some very interesting papers upon transpiration, which deal with the results of experiments which satisfy the author that transpiration is a "vital" process rather than a physical one. By "vital" processes he means "those which cannot be accounted for by the immediate energy-relations of the organism to the external world, but those in which energy previously stored by the organism, *e. g.*, oxidizable materials, is utilized, and which only take place during the life of the organism." During transpiration, therefore, the elevation of water in the vessels resembles the raising of water in plants by root pressure. The phenomena of transpiration responded sufficiently to oxygen and to anæsthetics to suggest that it is connected with vital phenomena. The conclusions drawn from experiments in a saturated atmosphere are as follows:

1. The elevation of the water of the transpiration current, when the leaves are surrounded with a saturated atmosphere, is effected by pumping actions proceeding in the living cells of the leaves.

2. The observations on the drying back of branches furnished with dead leaves renders it highly probable that these vital pumping actions are partially or wholly responsible for the elevation of water even in an unsaturated atmosphere.

3. These pumping actions are capable of raising the water against an external hydrostatic pressure.

4. In common with other vital actions, they are accelerated by a moderately high temperature, and are dependent on the supply of oxygen.

5. The cells adjoining the terminal portions of the water conduits appear to possess this activity, and, in plants provided with water-glands, the pumping actions are not limited to the secreting tissues of these glands.—J. M. C.

THE GENETIC RELATIONSHIPS between the phanerogams and cryptogams in the light of the most recent investigations are discussed by Belajeff.[5] As the title would indicate, the paper presents no new facts. Little attention is paid to the sporophyte, but the evolution of the male and female gametophyte, from the bryophytes to the spermatophytes, is presented in a masterly way. The female gametophyte shows a gradual transition from independence in the bryophytes to complete dependence in the gymnosperms and angiosperms, and the archegonia which it bears show a gradual transition from forms with the neck and venter free to forms with the entire archego-

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[4] On the effects of stimulative and anæsthetic gases on transpiration, Proc. Roy. Irish Acad. III. **4**: 618–626. 1898; Transpiration into a saturated atmosphere, *l. c.* 627–635.

[5] Biol. Centralbl. **18**: 209–218. 1898.

nium imbedded. The homologies of the embryo sac structures of the angiosperms are not yet cleared up.

Up to 1885 there is nothing in literature to justify the assumption of such a gradual transition in case of the male gametophyte. Belajeff investigated antheridia of Selaginella and Isoetes in 1885, and the antheridia of the heterosporous Filicineæ in 1890. The small cell cut off from the germinating spore of Selaginella and Isoetes is the male gametophyte, the homologue of the prothallium which bears the antheridia in the homosporous Filicineæ. The antheridium which this much reduced gametophyte bears consists of several peripheral cells forming a wall enclosing inner cells in which spermatozoids are formed. The peripheral cells later coalesce. In the heterosporous Filicineæ the more complex male gametophyte shows that the transition from cryptogams to phanerogams is not to be sought here but rather in the heterosporous lycopods.

In the gymnosperms Belajeff investigated only the conifers. In the Abietineæ the small cells cut off from the germinating microspore represent the male gametophyte. The rest of the spore consists of an inner small cell surrounded by a large outer cell which develops the pollen tube. The inner cell divides into two, the hindmost of which disorganizes; the other again divides, giving rise to two cells which are the homologues of the mother cells of the antheridia of Selaginella and Isoetes. In the Cupressineæ the male gametophyte is entirely suppressed, the pollen grain transforming itself directly into an antheridium. In the Taxineæ the simplification is carried still further.

In the angiosperms the conditions are the same as in the Cupressineæ, the pollen grain dividing into two cells, the larger representing the antheridium wall, which stretches into a tube, the smaller dividing into two generative cells.

In 1897 the studies of Ikeno and Hirase threw new light upon the relationships of the cryptogams and phanerogams. Hirase found that the two generative cells in the pollen tube of Gingko develop into ciliated spermatozoids, and Ikeno made the same discovery in Cycas. Webber recently made similar observations on Zamia, his description of the development of the spermatozoids corresponding with Belajeff's description of these structures in Equisetum and ferns, thus adding another proof of the relationship between the cryptogams and cycads. Of course these observations break down the old division into zoidiogams and siphonogams, since Cycas, Gingko, and Zamia would belong to both groups.— CHAS. J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: Recent numbers of the *Bulletin of the Torrey Botanical Club* contain descriptions of new species of Asclepias and a recasting of *A. verticillata* and its allies, by Anna Murray Vail (25: 171–182. 1898); some new species of liverworts, with two plates, by Marshall A. Howe (*l. c.* 183–192); descriptions of various new species from the west, with three plates, by A. A. Heller (*l. c.* 193–201, 265–271); descriptions of various new Wyoming plants, with plate, by Aven Nelson (*l. c.* 202–206, 275–284, 373–381); a revision of the N. Am. Eurhynchia, by A. J. Grout (*l. c.* 221–256), in which *Cirriphyllum* is proposed as a new genus including the species (four) with the concave filiform-tipped leaves, *Bryhnia* Kawin recognized to include two species with papillose leaves, and *Eurhynchium* retained to include the remaining nine species, one of which is new; miscellaneous new plants from New Mexico, by E. O. Wooton (*l. c.* 257–264, 304–310); miscellaneous new plants, by John K. Small (*l. c.* 316–320); about three dozen new fungi, by Chas. H. Peck (*l. c.* 321–328, 368–372); a presentation of the genus *Syntherisma* (often called the Digitaria section of Panicum) in North America, by George V. Nash (*l. c.* 289–303), twelve species being recognized, two of which are new, and most of the others with new combinations.—M. L. Fernald (*Proc. Boston Soc. Nat. Hist.* **28**: 237–249. 1898) has been studying the much discussed genus Antennaria and presents a synopsis of the New England species, all included in our manuals under the "polymorphous" *A. plantaginifolia,* recognizing thirteen species and varieties. The same author (*Erythea* **6**: 41–51. 1898) has also attacked the species complex known as *Castilleia parviflora,* and recognizes fourteen species and varieties, eleven of which are new.—C. V. Piper (*Erythea* **6**: 29–32. 1898) has recently described some miscellaneous new species from Washington.—B. L. Robinson (*Proc. Am. Acad.* **33**: 305–334. 1898) has published revisions of Mimosa and Neptunia. The North American and Mexican species of Mimosa are presented, sixty-seven being recognized, nine of which are new. A new subgenus, ASTATANDRA, is established to include *M. tequilana* Wats. Four North American species of Neptunia are recognized, one of which is new.— J. M. Greenman (*Proc. Amer. Acad.* **33**: 455–470. 1898) has published revisions of Galium and Relbunium, so far as species of Mexico and Central America are concerned. Twenty-five species of Galium are included as belonging to the region, five of which are new. Relbunium, included by Dr. Gray in Galium, includes seven species, one of which is new. The same author (*l. c.* 471–489) has also described numerous miscellaneous new and critical species from Mexico. —W. Willard Ashe (*Jour. Elisha Mitchell Sci. Soc.* **14**: 51–54. 1898) has described a new Robinia (*R. Boyntonii*) from the southern Alleghanies. —E. L. Greene (*Pittonia* 3: 313–328. 1898) has recently described six more new species of Viola, five new forms of Antennaria, six new species of Convolvulus, and reëstablishes Rafinesque's *Polycodium*, including the *stamineum* group of Vaccinium (six species), and Nuttall's *Batodendron,* with *V. arboreum* as a type and two new species.— Dr. A. Weber continues his publications on Cactaceæ (*Bull. du Mus. d'hist. nat.* 1898; nos. 2 and 3), dealing with the genus Echinocactus in Lower California, and with Pereskia and the Pereskia-like opuntias of Mexico.—J. M. C.

NEWS.

PROFESSOR W. W. BAILEY, after twenty-one years of continuous service at Brown University, has been granted leave of absence for the first term of 1898–9.

ILLUSTRATIONS of the inflorescence and dissections of Welwitschia (Tumboa), made from a plant growing at Kew, are published in the *Gardener's Chronicle* (III. **24**:62–63. 1898).

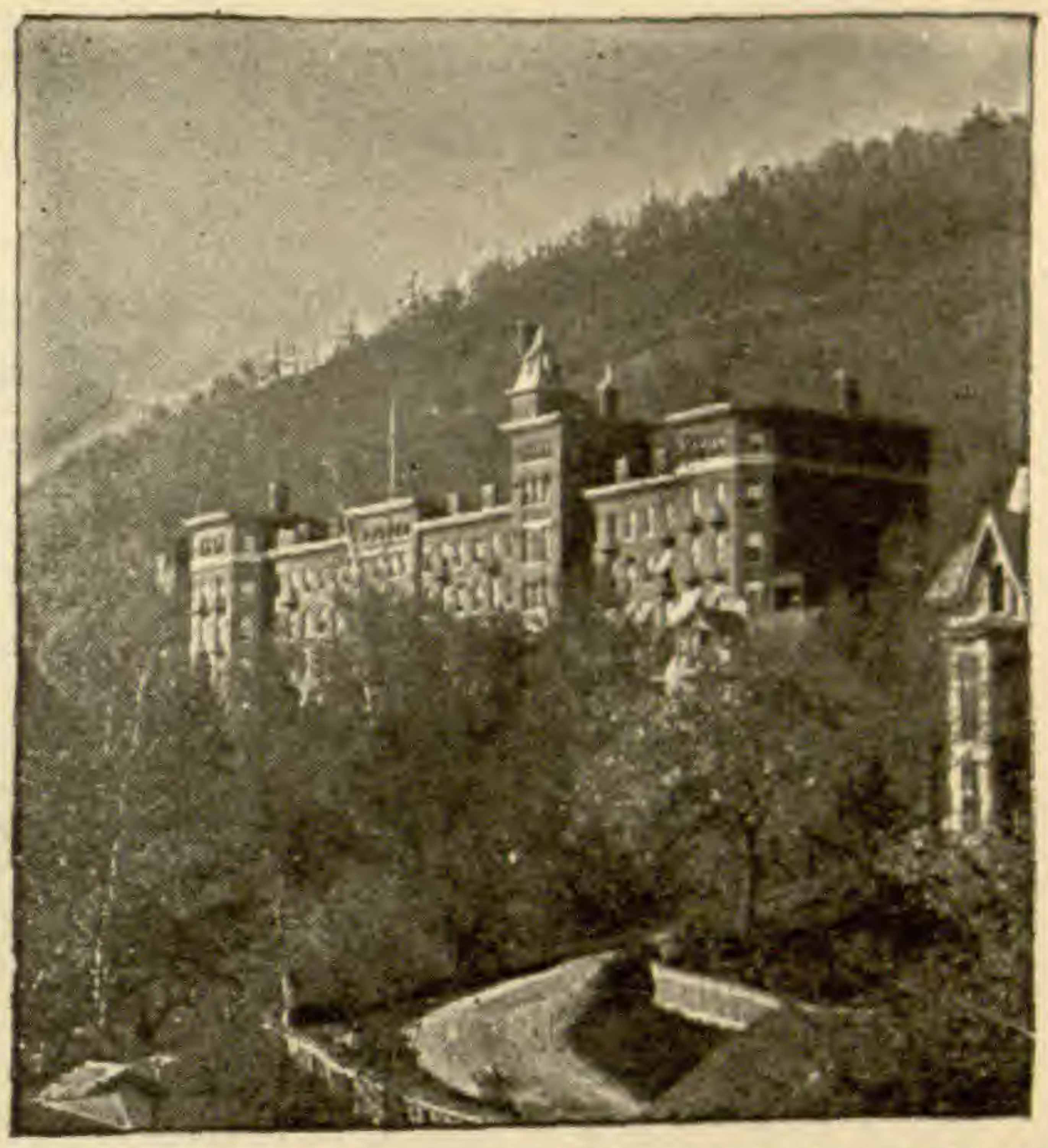
THE DIVISION OF BOTANY of the Department of Agriculture has issued a bulletin (no. 20), prepared by V. K. Chestnut, which describes and illustrates the principal poisonous plants of the United States.

MR. JOHN W. HARSHBERGER has published his lecture upon the uses of plants among the ancient Peruvians. Among the prehistoric remains are found the maize, peanut, potato, sweet potato, and coca.

THE LAST FOUR NUMBERS (171–174) of Engler and Prantl's *Natürlichen Pflanzenfamilien* contain a continuation of the Umbelliferæ, by Drude; a continuation of the Hymenomycetineæ, by Hennings; and the beginning of the Pteridophyta, by Sadebeck.

THE BERLIN ACADEMY OF SCIENCE has made the following grants for botanical work: 2000 marks to Professor Engler for the continuation of his work on East African plants; 600 marks to Professor Graebner, for the continuation of his work on German heaths; 500 marks to Dr. Loesner, for the completion of his monograph of the Aquifoliaceæ.

DURING THE LAST COLLEGE YEAR the following botanists have passed their doctorate examinations at the University of Chicago: W. L. Bray, thesis "The xerophytic flora of Texas;" Otis W. Caldwell, thesis "Morphology of *Lemna minor*, with ecological notes;" Henry C. Cowles, thesis "The ecological relations of the sand dune flora of northern Indiana;" W. D. Merrell, thesis "Contribution to the life history of Silphium."

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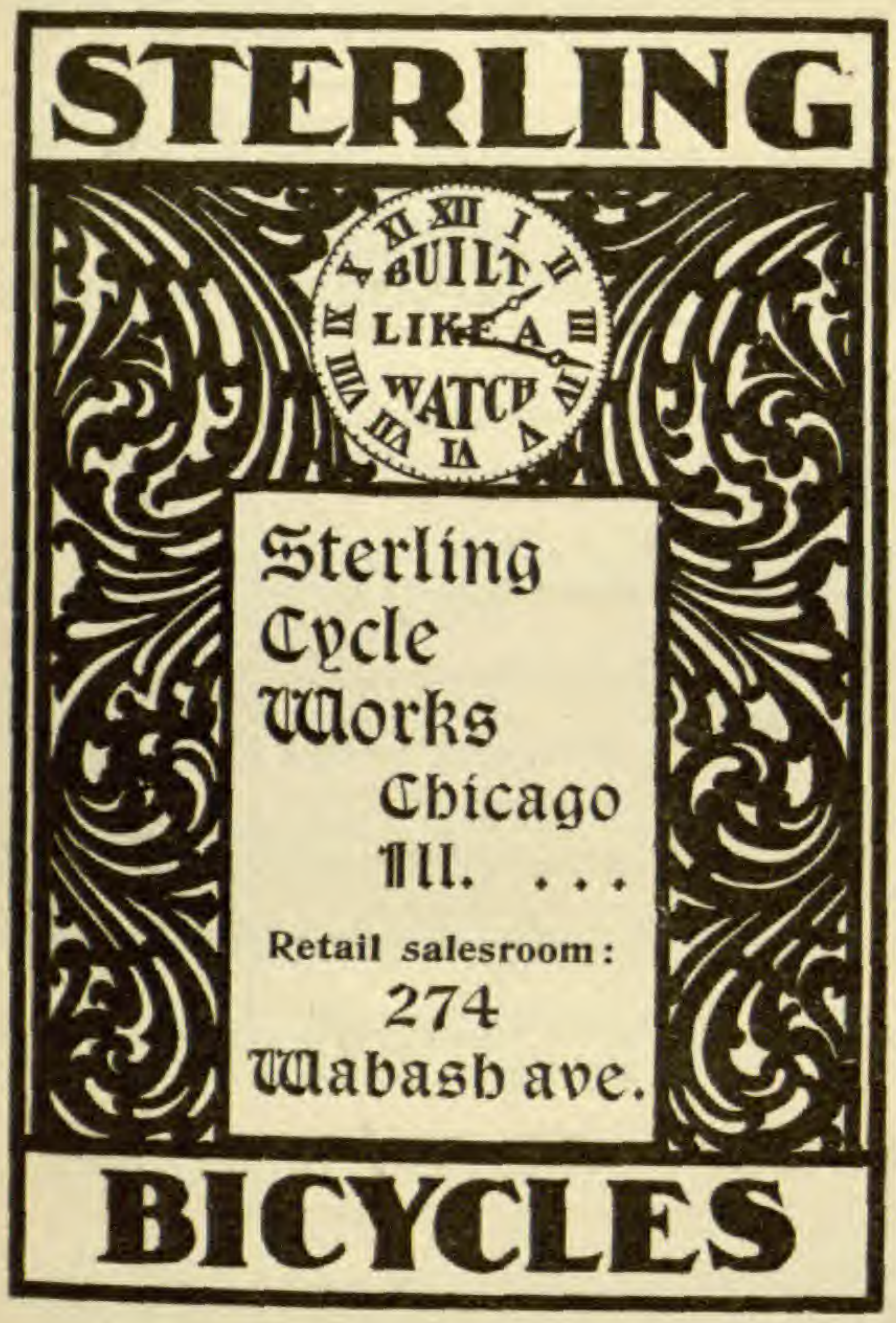

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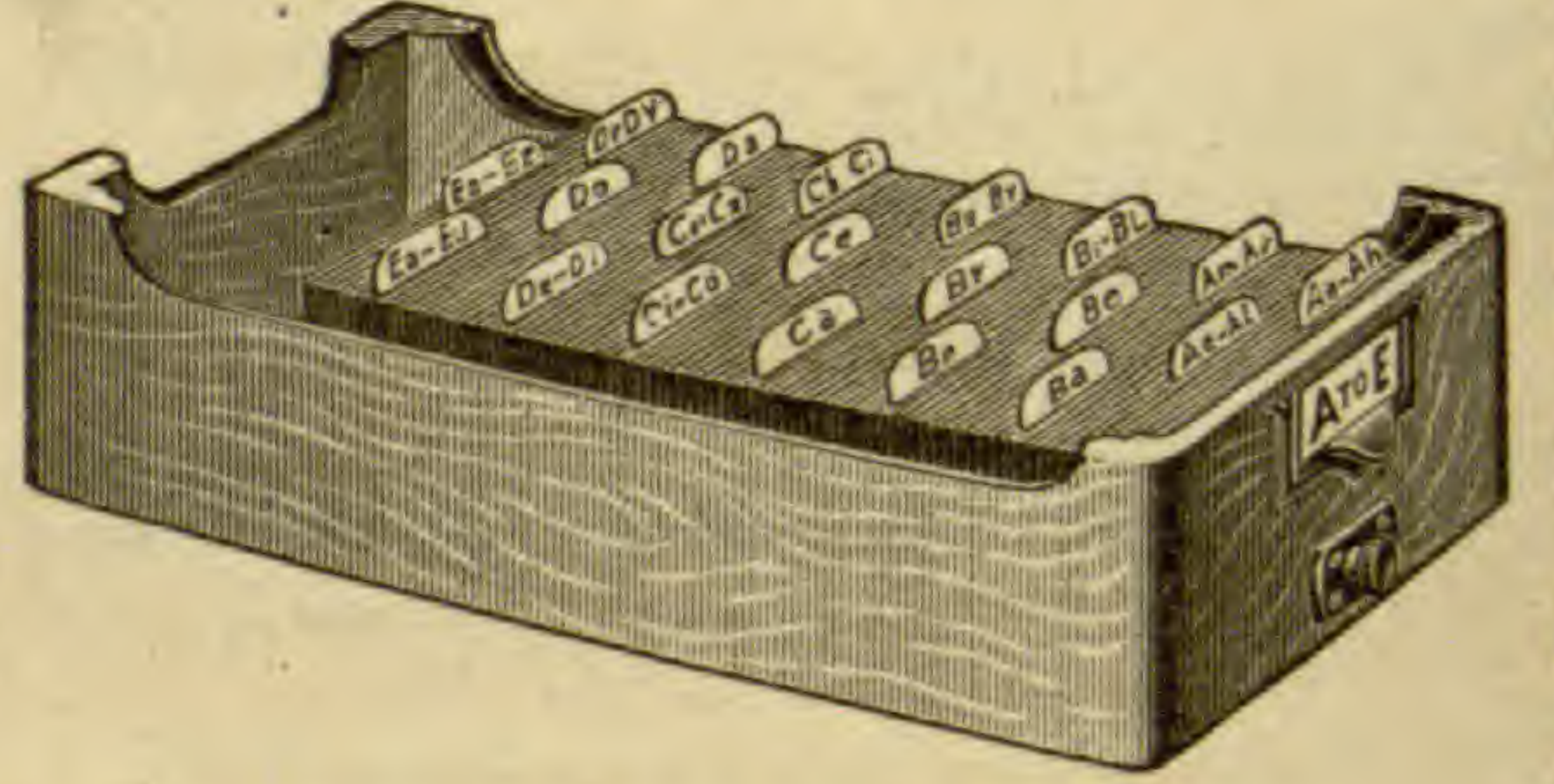

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VOLUME XXVI NUMBER 3

BOTANICAL GAZETTE

SEPTEMBER 1898

THE ORIGIN OF GYMNOSPERMS AND THE SEED HABIT.[1]

JOHN M. COULTER.

INTRODUCTORY.

THE most difficult as well as the most fascinating problem in connection with any group is its phylogeny. The data upon which we base opinions concerning phylogeny are never sufficient, but such opinions usually stimulate research and are necessary to progress. Any statement dealing with this problem is merely an expression of our knowledge of comparative morphology, and of our judgment concerning the phylogenetic importance of certain structures.

To my mind, the most conspicuous error in many schemes of phylogeny is the tendency to focus attention upon very few structures. It may be that the structures selected are the most significant, but the organism is a plexus of structures, and must be considered in its totality. Very different structures have been laid hold of by the processes of evolution, and it may not be possible to relate the resulting forms properly upon the basis of any one or two structures. A conspicuous example is furnished by the liverworts, in which one line gave special attention to the structure of its gametophyte body, another to the

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[1] Address of the retiring President of the Botanical Society of America, delivered at Boston, August 19, 1897.

form of its gametophyte body, a third to the structure of its sporophyte body. Any attempt to relate these to one another upon the basis of a single structure, even so important a one as the sporogonium, is essentially misleading. But when we consider the totality of structure, we are led to the opinion that these lines possibly diverged from an archetypal plexus in which there were gametophyte bodies as simple as that of Aneura, and sporophyte bodies as simple as that of Riccia. Another illustration is the recent attempt of Arnoldi to associate Isoetes with Selaginella largely upon the basis of endosperm development, without regard to great diversities in habit and anatomical details. The association may be perfectly proper, but the reason given for it is inadequate.

In dealing with problems of phylogeny it is also important to remember that the origin of a prominent group of living forms from another group of living forms is extremely improbable. We can point out resemblances in structures which we have come to regard as essential, but this is not likely to mean the origin of the one group from the other. It may mean that the two groups can be traced to one, probably now extinct, which combined the characters now differentiated. Most living groups are best regarded as divergent rather than consecutive series.

But even this apparently sure ground has become very uncertain from the fact, becoming more and more apparent, that similar changes in structure, even very important ones, may have appeared independently in different lines. The response of organisms in structure to their environment is deeper seated than we were once inclined to believe, and testimony from the similarity of certain structures, when contradicted by the majority of other structures, argues feebly for recent community of origin. Such similarities in structure argue more for physiological conditions than for phylogeny. For instance, from the standpoint of evolution, the appearance of heterospory among the pteridophytes is one of the most important contributions to plant progress made by the group, but it is impossible to escape the conclusion that heterospory was attained independently by several lines. To put into the same genetic group all heterosporous pteridophytes would be regarded as a morphological absurdity. If heterospory appeared independently in several lines, the same conclusion must be reached in reference to its natural outcome, the seed, and the polyphyletic origin of the spermatophytes becomes extremely probable.

This increases the perplexities of phylogeny, but it broadens its horizon, and introduces another possibility. To continue the same illustration, in our search for the origin of seed-plants we have narrowed attention to the existing heterosporous pteridophytes, when some of the spermatophyte groups, as for example the gymnosperms, may represent an entirely distinct line in which heterospory and then the seed appeared, and may not be related directly to any existing heterosporous pteridophyte. In such a case we are permitted to look to some group of living homosporous pteridophytes as possibly containing the best living representatives of the group from which gymnosperms have been derived.

With all these possibilities in mind, I wish to discuss the phylogeny of the gymnosperms, not so much to reach a clear phylogeny, as a clearer understanding of the complexity of the problem, and the uncertainty of conclusions. This is a field in which no one can afford to be dogmatic.

THE ORIGIN OF GYMNOSPERMS.

From Hofmeister's classic researches to the discovery of gymnosperm spermatozoids by Hirase, Ikeno, and Webber, the fact has become increasingly apparent that gymnosperms are very closely related to pteridophytes. It was natural, for a time, to regard gymnosperms as phylogenetically intermediate between pteridophytes and angiosperms, for it was not easy to believe that such a structure as the seed appeared in more than one genetic line; but it is probably not going too far to say that there is now no serious opposition to the view that the gymnosperm and angiosperm lines are genetically independent.

However, such a discussion does not lie within the scope of this paper.

That gymnosperms have been derived from pteridophyte stock is hardly open to discussion, at least we must assume that this is true, or all attempts at phylogeny are useless. The first question which confronts us, therefore, is whether the very divergent gymnosperm lines have had a common origin in this pteridophyte stock or not. Was there a single group of archaic gymnosperms, derived from pteridophytes, which subsequently differentiated into distinct lines? The existing gymnosperm groups are so very diverse that one of two things seems evident: either they differentiated into divergent lines from a common gymnosperm stock in very ancient times, or they originated independently from the pteridophyte stock. From this discussion I wish to exclude the Gnetales, as we do not possess sufficient data concerning their early history, or concerning the morphology of the very dissimilar living forms, to justify any opinion as to their origin. They are such dissimilar fragments, living in such extreme conditions, that their origin is totally obscure. In some respects they are more cycad-like than conifer-like, but in most respects they are so unlike both that a separate origin seems possible. It may be even true that the three genera belong to groups of independent origin, which is certainly the easiest way of disposing of their differences; and their common characters of true vessels, the so-called perianth, and elongated micropyle, may have been attained independently as readily as was heterospory; but the combination of characters in common does not seem to justify such a disposition of them, and the three genera had better be regarded as of common derivation, wonderfully diversified by ancient separation, isolation, and extreme conditions.

Approaching the subject from the historical standpoint, the great group Cordaites seems to be the first with sufficient data to justify consideration. The structure of the vascular bundles, especially those of the leaves, is said to suggest those of conifers, cycads, Isoetes, and Ophioglossum; and the sporophylls are organized into a strobilus, a character common to pteridophytes and gymnosperms. But such characters can be used only as cumulative testimony. In such evidences as we have of the structure of the male gametophyte, however, we obtain some valuable suggestions. Within the mature microspore there appears a considerable group of polygonal cells. In living groups of gymnosperms, so far as investigated, there is no such structure; and if we look to pteridophytes for suggestion, we are constrained to believe that this group of cells is either prothallial or sperm mother cells. In either event, it would represent a condition of things much nearer pteridophytes than is shown by any living seed plant. In view of the discovery of spermatozoids in Cycas, Zamia, and Ginkgo, taken in connection with the peculiar structure of the male gametophyte just described, I am of the opinion that the Cordaites also developed spermatozoids. With either hypothesis as to the nature of the cells developed within the microspore of Cordaites, in seeking for the pteridophyte origin of the group, we are led away from such heterosporous pteridophytes as now exist, for in them the male gametophyte is much more reduced than in Cordaites, in fact, more reduced than in most living cycads and conifers.

Additional testimony to the same effect is furnished by sections of the seeds of Cordaites. In addition to the remarkable nucellus beak, which probably has no phylogenetic significance, the large pollen chamber is the most conspicuous feature. This is sometimes so extraordinarily large that it occupies the whole upper portion of the nucellus, and has been observed to contain numerous pollen grains. The pollen chamber is a well-known Cycad feature, and seems to be associated with the early development of siphonogamy. By means of it, the tubular outgrowth from the antheridium wall is reduced to a minimum, and may coexist with spermatozoid development, as shown by Hirase, Ikeno, and Webber.

The testimony all indicates that in Cordaites we have the beginnings of a siphonogamic line, brought about by the retention of the megaspore, which still develops its exine in Cordaites and some cycads.

As to the pteridophyte group from which the Cordaites were derived, data are not sufficient to make opinion other than a pure hypothesis. I think it is clear that such heterosporous pteridophytes as are living today must be set aside in this search, by the testimony of both of their gametophytes, especially the male. They stand for lines which have very much reduced the male gametophyte, have variously modified the female gametophyte, but have not developed siphonogamy by retaining the megaspore. It may be that the lycopod forms of the Carboniferous and earlier formations represent the pteridophyte plexus from which Cordaites were derived, but we know too little of their morphology to make any assertion. My judgment is that the Cordaites represent an independent heterosporous line, and that if they were associated in origin with the lycopod forms at all, it was before the latter had developed heterospory, which seems never to have been extensively developed in the lycopod line until recent times.

I believe that we must regard either the ancient homosporous lycopod forms or the abundant Palæozoic Marattia forms as responsible for the origin of Cordaites, and my own inclination is toward their Marattia origin, perhaps for no better reason than that in such an origin I see more opportunity for the development of such a group as cycads; but such a view is further supported by the discovery that the spermatozoids of cycads, and their ally, the ginkgo, are of the multiciliate type, and not biciliate, as in living lycopod forms. Just what stress should be laid upon this I do not know, but when opinion is fairly balanced it would seem to help to a decision. It seems satisfactory, therefore, to regard the origin of cycads as from the homosporous-eusporangiate plexus of Filicales, represented today most abundantly by Marattia and its allies. It would seem further that this has been brought about without the intervention of such Cordaites as we recognize, which, with probably similar origin, were developing a very different type of body, that finds its modern expression in the conifers. In the acknowledged Cordaites, therefore, I recognize a transition region between the homosporous-eusporangiate plexus of Filicales and the more modern conifer series; while in the cycads we have a line which continued more of the fern habit and structure, recognizable not merely in its foliage leaves and general port, but in its occasional vascular bundles of concentric type, and its multiciliate spermatozoids. The Cordaites, however, must have included forms that we have not recognized as such, for it is only when they become differentiated from the fern habit that in the main we are able to distinguish them. This very fact of their sharp differentiation means that they had made a decided departure, and we are probably able to recognize only the most highly specialized forms. Of course, in what I have said I may have been using the name Cordaites in a much more inclusive sense than taxonomy would justify. As ordinarily defined I would see in them the first distinct beginnings of a type which afterwards gave rise to the conifers; as used in this paper, they refer to a plexus of forms derived from the homosporous-eusporangiate Filicales which gave rise to both cycads and conifers as divergent lines, one retaining more nearly the fern habit and structure and culminating earlier, the other departing more widely from the habit and structure and culminating later. I believe that some Palæozoic forms now regarded as ferns will be found to be more closely related to the Cordaites. How many other lines arose from this large Cordaites plexus, as I have defined it, we have no means of knowing, but it seems to be responsible at least for all of the living gymnosperm forms.

It is important to obtain such historical evidence as we can in reference to the gymnosperm lines, restricted in this paper to the Cordaites, conifers, and cycads. If a historical sequence can be established which conforms to the views expressed here as to the interrelationship of these lines, the conclusion will have additional support. I need not apologize for the paucity of data furnished by paleobotanists. They have done what they could, and we are greatly in their debt. Morphologists recognize, however, that the structures usually preserved are not the most convincing as to relationships, and that nowhere are appearances more deceitful. While we have no sympathy with wild generalizations based upon fragmentary material, there is an increasing accumulation of data which furnish a substantial foundation for some conclusions. It seems to be clear that during the Palæozoic there was an increasing display of gymnosperms. The fragments which bear this testimony became very abundant in the later periods of the Palæozoic, and are regarded, for the most part, as Cordaites. Associated with these forms is the great display of Marattia and its allies. A distinct type of leaf and of stem is attributed to each of these great groups, and when seeds or sporangia are associated with them the case seems clear enough, but apart from such association the uncertainty is profound. Intergrading forms between the two are to be expected, but with material so fragmentary and non-committal it would be a rare chance that would lead to its definite demonstration. In the Coal Measures the cycad type becomes apparent, but not prominent. This would seem to indicate either an early differentiation from the Cordaites plexus, or a late differentiation from the Marattia plexus. I see no difficulty in the former view, as I see no advantage in multiplying the independent heterosporous and seed lines until forced to do so by incontrovertible evidence. The domination of cycads during the Mesozoic, and their subsequent decline are well-known facts.

More suggestive, however, is the history of the conifers. It is generally stated that this line, in its modern expression, began during the Palæozoic, and that our modern genera have been recognized by stem and leaf anatomy. Such methods of determination we know to be untrustworthy, as there is the greatest possible amount of anatomical diversity even in contiguous regions of the same organ, much more in different organs and at different ages. In examining the claim that modern coniferous genera appeared during the Coal Measures, I find no evidence that seems to be worthy of serious consideration excepting that with reference to Ginkgo, and it is an interesting fact that Ginkgo is no longer regarded as a conifer. Long before the evidence of spermatozoids was discovered it seemed perfectly clear to me that Ginkgo was more cycad-like than conifer-like. In the light of our present knowledge the appearance of Ginkgo in association with the Carboniferous cycads seems natural enough. It is a matter of very secondary importance whether we are to regard it as an independent line or not. I am inclined to believe that while during the Palæozoic heterospory and the seed were both attained, siphonogamy was in its beginnings, and that the spermatozoid habit was for the most part still continued in the seed lines. There is no conclusive evidence, therefore, that any of our modern coniferous genera appeared during the Palæozoic, during which the Cordaites were the dominating seed plants. During the last Palæozoic periods undoubted conifers did appear, and in considerable abundance, and we may recognize the beginnings of distinct lines represented today by Abies and its allies, Taxodium and its allies, and Taxus and its allies, but the genera are not those of today. In the lower Mesozoic, however, modern araucarian and abietinous genera appear; and the Taxodium and Taxus lines become more distinct, but not modern until the later Mesozoic. At that time Cupressus forms also appear, but not of modern genera. Further details are not necessary, as the point to be made is that the conifer type was not recognizable until late in the Palæozoic, and then not in its modern expression. It certainly suggests a later departure from the Cordaites stock than do the cycads.

Another fact is interesting to note in connection with the evolution of the conifer forms. In existing conifers there is considerable variation in the development of the male gametophyte. In some forms, as the Abietineæ, the development of two or three prothallial cells, distinct from the large antheridial cell, is a well-known fact, an amount of prothallial development not shown by any other living heterosporous forms, even the heterosporous pteridophytes. In other forms, as Cupressineæ and Taxeæ, the reduction of the male gametophyte is greater, no sterile prothallial cells appearing, the whole structure being an antheridium, as in the angiosperms. Our historical evidence accords with this progressive reduction of the male gametophyte, the Taxus and Cupressus lines having attained modern expression after the Abies line ; and back of the Abies line we find the Cordaites, with probably a still greater development of the sterile region of the male gametophyte indicated. To derive the Cordaites or Abies lines, with their two or three to many-celled sterile tissue of the male gametophyte, from such heterosporous lycopod forms as we know today, with their constantly more reduced male gametophytes, is not within the bounds of probability. Besides, the reduction of the male gametophyte seems to be so prompt a response to heterospory, that its partially reduced condition in certain conifers, and probably in Cordaites, would seem to argue for their near derivation from some homosporous type.

The development of a suspensor in the lycopod forms has also suggested a genetic connection with gymnosperms, in which the suspensor development is so conspicuous. This organ, however, seems to have no morphological constancy. In gymnosperms it may be developed from a plate of cells formed in the oospore, as in most conifers ; or from a mass of cells formed basally or parietally in the oospore, as in cycads ; or from free cells formed within the oospore, as in Ephedra ; or from the elongation of the oospore itself, as in Gnetum ; or from the downward elongation of the archegonium, as in Welwitschia. The suspensor, therefore, seems to be a temporary organ of the embryo, of various morphological origin, intended to relate the embryo properly to its food supply, and not of phylogenetic significance.

The testimony of history and morphology seem to combine in pointing to a very generalized Palæozoic type as the origin of gymnosperms. This type is characterized by its advancement towards seed production rather than by its habit, which must have been extremely varied to have given rise to such types as cycads and conifers. The usually recognized Cordaites show but one tendency of a much more extensive group, for which the name Cordaites may be extended for convenience. Cordaites in this larger sense occur in such association with groups of homosporous eusporangiate Filicales, and approach them so much nearer in the important morphological structures mentioned than they do living heterosporous Filicales, that an independent heterosporous line is suggested. If such be the case, in the passage from the Marattia forms to the Cordaites form both heterospory and the retention of the megaspore were attained, and probably siphonogamy begun.

THE SEED HABIT.

The evolution of heterospory seems simple enough. The physiological differentiation of the spores was complete when prothallia became persistently diœcious. This division of labor is to be expected in the case of two such distinct functions as the production of antheridia and archegonia. A prothallium producing both sex organs equally well may be regarded as in a state of equilibrium, an equilibrium which is disturbed by any conditions which favor the production of one sex organ rather than the other, in this case probably nutritive conditions. This disturbance of the equilibrium of a bisexual prothallium would certainly find an expression first in a diœcious tendency, and finally in a diœcious habit. With the habit once fixed the morphological differentiation of spores becomes inevitable, since the nutritive requirements of the two prothallia are so different. The evolution of heterospory seems to be one of the simplest of selective processes, with inequalities of nutrition to furnish the variations. From this point of view it would seem natural to expect that it may have been derived frequently from homospory.

The retention of the megaspore, however, does not seem to be so simple a problem. In a certain sense it is correlated with the reduction of the gametophyte, since retention would not seem practicable until reduction had proceeded far enough to make the gametophyte endosporic. Even greater reduction, however, is attained by the male gametophyte, but the spore is shed. It should be noted that even in the case of the microspore the male gametophyte is usually completely organized before pollination; but the fact remains that the reduction does not compel retention. It has seemed to me that this phenomenon is to be explained by Bower's law of sterilization, developed in reference to the strobilus. This law certainly finds expression in the megasporangia of heterosporous pteridophytes, in which the sterilization of mother cells is conspicuous. This method of increasing the nutrition of the fertile cells is too common a phenomenon to need illustration; but it is a tendency that would seem very consistent with the development of megaspores, whose peculiar work holds so definite a relation to abundant nutrition. For this very reason high numbers of microspores may be continued, and a diminishing number of megaspores produced. This would reach its culmination in the production of but a single megaspore by a sporangium, and a proportionate increase in the size of the megaspore. With the development of a single spore imbedded in a sterile tissue, shedding becomes not only mechanically difficult, but meaningless, since the necessity of scattering a brood of gametophytes, to avoid competition, has disappeared. It is further true that the development of such a spore involves nutritive supplies from numerous neighboring cells, and a certain amount of retention becomes necessary for this reason. Still further, the advantage to a single megaspore in being retained, thus securing more abundant outside nutrition during germination, would fix the habit if any selective process were at work. For these various reasons it would seem evident that when the sterilization of a megasporangium had reached its extreme limit, by organizing a single spore, retention is likely to follow sooner or later. If this line of reasoning be true, the seed habit might have been developed in any heterosporous line.

With the retention of the megaspore pollination became necessary, but its gymnosperm expression differs in no way from the scattering of aerial spores in all the lower groups. The new feature demanded by the retention of the megaspore, therefore, was not the scattering of the microspores, but the development of siphonogamy. That the first retained megaspores were exposed to the microspores can hardly be doubted, and in such cases we now know that the spermatozoid habit must have been retained, and that no tube, or a very small protuberance of the antheridium wall, was needed to discharge the spermatozoids sufficiently near the oosphere. If chemotropism can explain the guidance of a pollen tube through much intervening tissue, it would certainly be sufficient to cause the protrusion of an elastic antheridial wall. In the very few illustrations of Cordaites obtained, the megaspore is but slightly covered by sterile tissue at the bottom of a deep pollen chamber, and a very slight development of tube is necessary. The same condition is continued in the cycads, and thus the habit of siphonogamy may have been gradually built up. As siphonogamy developed, the gradual failure of the sperm mother cells to organize spermatozoids followed, and presently, almost exclusively now in gymnosperms, sperm mother cells are found to function directly as male gametes, without further organization.

The secondary results which followed the retention of the megaspore were numerous. The well-known effect of fertilization upon adjacent tissues necessarily involved at least the sporangium, and the seed resulted. The presence of abundant available nutrition and favorable conditions induced the immediate germination of the oospore, which the development of a resistant tissue about the sporangium checked. As a consequence, the development of the embryo was thrown into two stages, the intra-seminal and the extra-seminal.

In the case of the angiosperms, however, another tendency was connected with the retention of the megaspore, namely, the tendency of the sporophyll to enclose the megasporangium, a tendency so evident in such pteridophytes as Isoetes and Marsilea, that the direct pteridophyte origin of the group seems more natural than an origin from so specialized a type as the gymnosperms. Given the reduction of spore production to a single megaspore and the persistent enclosure of the sporangium by the sporophyll, and the angiosperm peculiarities follow. The profound effect of these conditions upon the germination of the megaspore is so remarkable, and intergrading stages so completely unknown, that there seems to be no clue to the sequence of changes. That an endosporic gametophyte might eliminate the archegonium seems evident, for the tendency is shown among gymnosperms by Gnetum, where oospheres are organized by free endosperm cells. That the reproductive region of the female gametophyte may be organized earlier than the nutritive region, when the gametophyte is supplied with outside nourishment by the retention of the megaspore, is hinted at among the heterosporous pteridophytes and gymnosperms. These tendencies have found full expression in the angiosperms, where archegonia have disappeared and the reproductive tissue of the female gametophyte is persistently organized before the nutritive tissue. Evidence as to the details of the evolution of this tendency is lacking, and may not be in existence, but the tendency has certainly reached a remarkably definite expression. The unvaried appearance and movement of eight free nuclei or cells, and the remarkable fusion of two of them, represent habits so fixed through such an enormous group that they baffle explanation, and argue both for the monophyletic origin of angiosperms, and against their derivation from so divergent a line as gymnosperms.

The earlier evolution of the gymnosperm line is probably to be explained by ecological conditions. The body as a rule is organized to endure extreme conditions. It is certainly not a mesophytic type, and its evolution was certainly not in response to prevailing mesophytic conditions. On the contrary, the angiosperm type is essentially a mesophytic one, with great foliage display, and probably expanded in response to widely prevalent mesophytic conditions. This might explain the habit peculiarities of the two groups, but whether the more recondite morphological differences hold any relation to these or not is too obscure to permit even speculation.

SUMMARY.

1. A great Cordaites plexus, more extensive than the one usually included under that name, represented the characteristic Palæozoic seed plants.

2. It was probably derived from homosporous-eusporangiate Filicales, represented today most abundantly by the Marattia forms and their allies, and was the most common Palæozoic type of Filicales.

3. From it the gymnosperm lines, at least the cycads and conifers, were derived, the usually recognized Cordaites representing a transition stage towards conifers.

4. The frequent independent appearance of heterospory is to be expected, as it probably results from inequalities of nutrition in connection with the development of antheridia and archegonia.

5. The retention of the megaspore, resulting in the seed habit, follows the extreme sterilization of the megasporangium, which is attained with the organization of but one megaspore. With the development of a single megaspore imbedded in sterile tissue, shedding becomes mechanically difficult, unnecessary, and even disadvantageous from the standpoint of nutrition.

6. The retention of the megaspore was followed by the development possibly of seed coats, through the well-known effect of fertilization upon adjacent tissues; by immediate germination of the oospore, on account of the favorable conditions and the abundant supply of available nutrition; and by the checking of the developing embryo by the mature seed structures, resulting in the characteristic intra-seminal and extra-seminal stages of germination.

7. The first retained megaspores were doubtless directly exposed to the microspores, and in Cordaites and cycads a pollen chamber of varying depth and extent is associated with the

early stages of siphonogamy, with which spermatozoid habit was more or less associated.

8. The pollination of gymnosperms is but a continuation of the ordinary method of dispersing aerial spores employed by cryptogams, the chief result of the retention of the megaspore upon the male gametophyte being the development of siphonogamy.

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A STUDY OF REGENERATION AS EXHIBITED BY MOSSES.

FRED DE FOREST HEALD.

(WITH PLATES XIX–XX)

I. INTRODUCTION.

THAT the sexual generation of the bryophytes is endowed with a remarkable power of regeneration is a well-known and oft-stated fact. The extent to which this is true for the liverworts has been shown by the investigations of Vöchting[1] "Über die Regeneration der Marchantieen" and of Schostakowitsch[2] "Über die Reproduktion und Regenerationserscheinungen bei den Lebermoosen." As far as the mosses are concerned, the generalizations have been based upon scattered and isolated observations by Schimper, Goebel, and others, and not upon any detailed investigation. The present work has been carried out with the intention of showing to what extent these generalizations in regard to the vegetative reproduction from stem and leaf are true, and also to throw some light on the physiology of regeneration.

Before proceeding with theresults of my own investigations, brief mention will be made of some of the observations previously recorded.

II. HISTORICAL.

The first record of the formation of protonemata by the leaves is by Kützing[3] for *Bryum pseudotriquetrum*. The leaves produced an abundant protonema growth and after a period of eight weeks, buds appeared.

Schimper[4] obtained a growth from the basal portion of

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[1] Jahrb. f. wiss. Bot. **16** : 367. 1885.

[2] Flora, Ergänzungsband 1894 : 350–384.

[3] Phycologia generalis 282. 1840.

[4] Recherches anatomique et morphologique sur les mousses 19. 1848.

detached leaves of *Funaria hygrometrica*, but no buds were produced. He also makes the very broad statement: "Chaque feuille et même chaque portion de feuille detachée de la plante-mere et placêe dans les conditions convenables peut produire des filaments proembryonnaires, par la multiplication d'une ou de pleuiseurs de ses cellules parenchymatuses." Goebel[5] also mentions the ability of Funaria leaves to produce protonemata, when they are detached and kept moist. Limpricht[6] states that almost every leaf can by proper culture be made to form secondary protonemata. Also in the case of plants with brittle leaves, as *Leucobryum glaucum*, *Barbula fragilis*, *Campylopus fragilis*, and *Barbula ruralis*, one can find in nature on the detached leaves the beginnings of protonemal filaments.

It is to be noted that in all of the cases above mentioned, regeneration only occurred when the leaves were detached from the stem. That this is not necessary in all cases is shown by the observations of Goebel[7] on the leaves of several species. In *Oncophorus glaucus* a thick felt of tangled filaments appears on the fertile summits of the plants, which prevents their further growth and eventually gives rise to patches of young plants. The marginal cells of *Buxbaumia aphylla* leaves are able to produce protonemata which will completely envelop the leaf. According to Limpricht,[8] the apex of the end bud in Leucobryum has been known to produce a protonemal growth, and H. Schulze has observed a luxuriant growth of protonemata from the leaf apices of *Hypnum giganteum*.

Mention should be made here of the formation of brood-bodies on different portions of the leaf, now apex, now costa, in various species of Orthotrichum, Ulota, Barbula, Grimmia, Syrrhopodon, and Calymperes.[9] These brood-bodies are apparently formed in the younger stages of the leaf and are homol-

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[5] Sitz.-Ber. d. mat.-phys. Classe d. k. bayr. Akad. d. Wiss. **26**: 463. 1896.

[6] Laubmoose von Deutschland **1**: 64.

[7] Outlines of Classification 173. 1887.

[8] *Loc. cit.*

[9] GOEBEL, Outlines of Classification 172–173. 1887. LIMPRICHT, Laubmoose **1**: 64.

ogous with protonemal productions. They become detached from the leaf and under proper conditions grow out into protonema filaments, although in some cases growth may begin before detachment.

The formation of a protonema and the later production of a new plant has been observed from the calyptra of *Conomitrium Julianum*. According to Goebel[10] the formation was from the inner side, and according to Schimper,[11] from the outer surface. Limpricht[11] has also recorded the production of protonemata by the detached calyptrae of Phascum.

Limpricht[12] ascribes to all parts of the moss plant a very great power of regeneration since he says: "Alle Teile der Mosspflanze besitzen die Fähigkeit, sekundäre Protonema zu erzeugen," and specifically in regard to the stem: "Auch jede Zelle der Stengeloberfläche ist fähig einen Protonemafaden zu bilden." In a great majority of cases, however, an intervention of rhizoid production occurs. The sessile or stalked brood-bodies of *Pleuridium alternifolium* originate from the stem. *Bryum erythrocarpum*[13] produces axillary brood-bodies, and *Webera annotina* and W. *Ludwigii*[14] produce axillary bulbils which detach themselves from the stem and grow without the intervention of any protonemata. Schulze[15] records the production of bulbils by the stem of *Hypnum aduncum* which detach themselves and grow in a similar way. The brood-bodies of Aulacomnium and of *Tetraphis pellucida* also originate from the stem. Mention should also be made here of the work of Müller-Turgau[16] on the production of "Zweigvorkeime."

Not only the gametophyte, but also various parts of the sporophyte are able to produce protonemata. This has been observed by Stahl[17] from the capsules and setae for *Ceratodon purpureus*, and by Pringsheim[18] for *Hypnum serpens*, *H. cupressiforme*,

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[10] *Op. cit.* 173.

[11] LIMPRICHT, Laubmoose 1:65.

[12] *Ibid.*, 61 and 63.

[13] SCHIMPER, Rech. anat. et morph. sur les mousses 19. 1848.

[14] *Ibid.*, 7.

[15] Bot. Centralblatt 31:382–384. 1887.

[16] Arb. d. Bot. Inst. Würzb. 1:475–499. 1874.

[17] Bot. Zeitung 34:690. 1876.

[18] Jahrb. f. wiss. Bot. 11:1–46.

and *Bryum cæspiticium*, all in artificial cultures, and by Brizi,[19] in nature for *Funaria hygrometrica*. According to Brizi, some of the setae of Funaria which had come into contact with the earth produced an abundant growth of protonemata with numerous buds.

III. METHOD.

In course of the experiments described below three different methods were used. The leaves and stems to be used as cultures were carefully washed in sterilized water in order to render them as free as possible from bacteria and fungi, and then placed either in Petri dishes upon several thicknesses of filter paper which had been saturated with a nutritive solution, or upon pieces of flowerpots placed in crystallizing dishes. In the third method the leaves were placed upon soil in either Petri or crystallizing dishes. The filter paper was carefully sterilized in boiling water and then placed in the Petri dishes which had been previously sterilized in the dry-oven. The pieces of flowerpots were first boiled and then sterilized together with the crystallizing dishes in the dry-oven. The dishes containing the soil were also sterilized in the same way. All of the cultures were supplied with a ¼ pro mille normal nutritive solution, and were kept at a temperature varying between 19–21° C.

IV. EXPERIMENTAL.

In course of my investigations the following species were used: *Mnium rostratum* Schwägr.; *Funaria hygrometrica* Hedw.; *Bryum capillare* Hedw.; *Bryum argenteum* Linn.; *Barbula muralis* Timm.; *Atrichum undulatum* P. Beauv.; *Polytrichum commune* Linn.; *Brachythecium rutabulum* Bry. Eu. and variety; *Leptobryum pyriforme* Schimper; *Phascum cuspidatum* Schreb.; *Ceratodon purpureus* Brid.; *Fissidens bryoides* Hedw.

In addition to these, cultures of *Plagiochila asplenoides* and *Lophocolea bidentata* were made for comparison with those of Schostakowitsch.

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[19] Annuar. Istituto Orto botan. Roma 5: 53–57. 1892.

I. MNIUM ROSTRATUM.

On account of the size of its leaves and the consequent ease of manipulation Mnium presents a very favorable specimen for experimentation. In its power and manner of regeneration it stands alone among all of the species investigated. At first two cultures were made for exposure to light; the leaves were carefully stripped from the stems and in one case placed with the dorsal surface uppermost, in the other with the ventral surface uppermost. These cultures were placed upon a table in the middle of the laboratory. Two similar preparations were made and enclosed in a dark chamber.

After an interval of a week the first appearance of rhizoids from the leaves was noted. An examination of the specimens grown in the light showed that the rhizoids proceeded almost exclusively from the contact surface, and in general from the periphery of the leaf, although they were not entirely absent from the middle and costal region. An examination of the cultures in the dark showed nearly the same manner of growth except that a considerably larger number of rhizoids originated from the side uppermost, the proportion being about one to ten. The rhizoids from the very first, both in light and dark, were devoid of chlorophyll and the cell walls were distinctly brown. As growth proceeded, those in the light developed an abundance of chlorophyll bodies and showed in nearly every case oblique cross walls. In the course of two weeks the rhizoids in the light had branched considerably, while in the cultures in the dark they rarely branched, and the cells were more elongated. At the end of three weeks the first appearance of buds was noted; and in cultures in brighter light in the window after a lapse of two weeks. The buds originated exclusively from the illuminated side and directly from a leaf cell without the intervention of any protonemata. The buds generally made their appearance near the periphery of the leaf, and the cell from which the bud originated had previously given rise to a rhizoid from the contact side. This is shown in cross sections of the leaf in *figs. 2* and *3*. The mother cell of the bud first produces a protuberance which becomes divided very soon by an oblique wall, and the insertion of the successive walls then follows in rapid order. Buds may occasionally originate as side branches of the rhizoids from either surface, although this is rare in the normal development. At the end of six weeks the specimens in the dark showed no sign of buds, and the long unbranched rhizoids had attained a length of about one centimeter. The peculiar method of regeneration shown in these experiments is especially noteworthy, since Goebel [20] states that the vegetative reproduction of mosses has this peculiarity, that the formation of a new leafy shoot is always preceded by the production of a protonema.

From the above experiments it is demonstrated that there is no inherent tendency to the production of rhizoids or buds from a particular side of the leaf; also that buds are not produced in darkness, either because the photosyntactic processes cannot be active or because light in itself is necessary. The greater production of rhizoids from the free side of the leaf in the dark would indicate that illumination exercised a retarding influence upon their production. The growth of the rhizoids from the contact surface of the leaf may be due either to contact or gravity, or both.

In order to determine the part which contact and gravity play in the direction of rhizoid growth, the following experiments were carried out. Leaves were placed on filter paper and grown in the dark in an inverted position, and in these cultures the same as in the ordinary position, the leaves produced rhizoids mostly from the contact surface. In order to render the supply of moisture of both surfaces as nearly equal as possible, the leaves were grown in a saturated atmosphere. Other leaves grown in both light and dark between two sheets of filter paper showed a production of rhizoids about equally from both surfaces. Again, leaves which were grown in a vertical position produced rhizoids radially in all directions. These experiments then show that the rhizoids are not influenced as to their point of origin by gravity,

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[20] Outlines of Classification 170. 1887.

but rather by contact. Leaves were also grown in soil with about the same result except that a greater number of rhizoids originated from the surface of the leaf nearest the air. The formation of buds upon the leaf in the ordinary manner was naturally prevented and when the rhizoids reached the surface of the soil and were exposed to light, they gave rise to an abundance of protonema-like branches and numerous buds.

A culture of leaves with long, sparsely branched rhizoids which had been grown in the dark was removed to the light and allowed to undergo further development. When examined a week later the rhizoids had produced in the apical region an abundance of branches, part of which were still rhizoidal in character. A large number of the branches were, however, distinctly protonemal, the cell-walls colorless, the cross walls perpendicular, the cells short and filled with an abundance of oval chlorophyll bodies. The rhizoids also contained chlorophyll bodies but they were fewer in number and of an elongated lenticular form. An enormous number of buds was also formed, and in one of two ways: either as a direct modification of a side branch from a rhizoid cell, or as a side branch from one of the lateral protonemal branches. This is plainly illustrated in *figs. 6* and *7*. Occasionally a bud was formed later near the leaf, but the great majority made their appearance towards the distal extremity of the rhizoids.

A question which now presented itself was: Is the continued exposure to light necessary to call forth the production of buds? In order to determine whether buds would be produced by light induction, leaves were grown in bright light for nearly two weeks and then carefully examined to see that no buds had been formed. They were then placed in the dark chamber and after five days the formation of buds was observed. The number was much less than from those leaves in the light, and on account of a lack of food material only a limited growth occurred. Whether this light induction is due to physical or chemical changes in substances already present in the leaf, or to the accumulated products of photosyntax, cannot be stated with certainty, but the experiment which follows would indicate that the products of photosyntax are not necessary to call forth the production of a leafy shoot.

In order to determine whether the products of photosyntax as obtained from the use of the free CO_2 of the atmosphere are necessary to call forth bud production, a culture of leaves was made in CO_2-free air in an apparatus similar to that figured by Pfeffer.[21] At the end of three weeks the leaves showed a very abundant production of buds. It has long been known that plants are able to use the CO_2 of respiration as material for photosyntax. Since this is so, the above experiment does not prove conclusively that light is necessary to effect physical or chemical changes in material already present, for on account of the size of the Mnium leaf, the CO_2 produced by destructive metabolism would be considerable, and a small amount of carbohydrate food might be formed. Later experiments with other species tend to show that it is the accessible supply of plastic material upon which the production of buds is dependent, and not upon physical or chemical changes in the material already at hand.

Experiments with leaves in colored light by the use of double-walled bell-glasses filled with the solutions of potassium bichromate and ammoniated copper oxide, showed the production of buds as well in the strongly refrangible rays as in the less refrangible. The photosyntax would be greatly suppressed in the leaves exposed to the blue end of the spectrum, and thus this result points to a chemical or physical change in material already at hand. Since Klebs[22] has pointed out a difference in the relation of spore protonemata and leaf protonemata to light in a specific case, we might reasonably expect to find a difference in the leaf productions from different species. Another point which may be noted in the case of the cultures in the rays of different refrangibility is that, in both the strongly refrangible and less refrangible rays, the leaves produced a much greater

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[21] Pflanzenphysiologie 1 : 191. 1881.

[22] Biologisches Centralblatt 13 : 646–648. 1893.

number of rhizoids from the surface uppermost. This would tend to corroborate the statement already advanced that light retards the production of rhizoids, since here each culture was only subjected to half the rays of the spectrum.

In all of the cultures the buds only originated from the illuminated side of the leaf, and the question naturally suggests itself: Is this due to illumination or to the negative geotropism of the moss shoot? In order to determine this, a series of leaves was illuminated from below by a mirror, so that light and gravity would be acting in the same direction. After the usual length of time buds made their appearance, and that only from the illuminated surface. Bastit[23] has shown that the moss-plant is distinctly negatively geotropic, but that with illumination from below, the shoots grow towards the light, the influence of gravity being overcome by that of light. This I have been able to substantiate in the case of plants grown from the leaves. Another series of experiments was carried out with leaves illuminated from both surfaces. In order to effect this, the leaves were placed in a Petri dish and irrigated by means of narrow strips of filter paper alternating with rows of the leaves. The dish was placed upon a ring-stand and illuminated from below by a mirror. In this experiment I found that the buds originated from both surfaces, thus showing the dependence upon illumination. In another series of cultures the leaves were placed in a vertical position in the soil and in such a manner that the leaf surfaces were parallel to the incident rays of light. These, as well as the previous experiments showed the production of buds from both surfaces.

In the case of whole leaves the buds appeared only near the periphery and within the leaf margin, the cells of the border never producing any growth. The cutting of the leaves transversely did not alter their power of regeneration, both rhizoids and buds being produced in as great abundance as in the whole leaves. In order to show whether it was possible for the cells from the costal region to give rise to buds, the lateral halves

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[23] Rev. gén. de Botanique 3 : 406–411. 1891.

were split away from the costa, and both portions cultivated. The result was that buds appeared from the costal region as well as from the lateral halves, showing that in the whole leaf the power to produce buds was only suppressed. Again with reference to the power of young and old or fully mature leaves to regenerate. Series of leaves from the mature to the very smallest that could be dissected from the end bud were subjected to culture, with the result that the leaves from ordinary size to about half way through the series produced buds and rhizoids in abundance. Those from this point on to the very minute leaves produced only rhizoids, and these mostly from the region of the costa. It was evident that the plastic material was not present in sufficient abundance to produce a further development, or that being an embryonic organ, the young leaf used its available supply of food material towards the growth of its own cells.

So far as I have observed, the leaves of Mnium in nature never give rise to rhizoids when still in connection with the stem. In order to afford experimental proof of this, whole plants were subjected to exactly the same conditions as the detached leaves, but no rhizoid productions resulted. Again, it might be thought that the formation of rhizoids and buds was called forth by the injury to the leaf. That the cutting of the leaf is not effective in the production was shown by those experiments in which the leaves were cut and still left in connection with the stem; even in these leaves no new growth resulted. Another series of experiments was made in which the costa was cut near the base of the leaf while the lateral halves were still left in connection with the stem, with the idea that the severing of the costa might cut off the path for the transport of food material. No rhizoid growth was called forth, and hence the previous experiments show that nothing but the complete separation of the leaves from the stem is able to call forth the power of the leaf to regenerate. When the leaf is still in connection with the stem, the plastic material can be transported to other younger and growing parts; in the detached leaf on the other hand the escape is cut off, and thus may favor the production of rhizoids and buds. The simple cutting of the leaf in itself seems to be, however, the important factor, that is, the complete separation of the leaf from the stem affords the stimulus for growth, which is then applied to the production of rhizoids and new leafy shoots.

When the stems of Mnium are stripped of leaves and kept in conditions favorable for growth, they will produce new shoots which originate as axillary branches. As is often noticed in nature, the stems produce an abundance of rhizoids and these in greater abundance from the region of the stem which has given rise to a shoot. In no case, however, was a production of protonemata direct from the stem to be observed, and the rhizoids grew for months without giving rise to any protonemal branches. The production of new shoots from the stems occurred as well in the dark as in the light; in the dark, however, the new shoots produced smaller leaves, and were more slender and elongated. The shoots used for experimentation were laid horizontal, and the lateral shoots grew erect, both in the dark and in the light, thus showing a well marked negative geotropism. The production of the new shoots was not called forth by the defoliation, but only accelerated thereby, since whole plants subjected to the same conditions produced new shoots as lateral branches, according to the manner of branching in nature. The stems also showed quite a distinct tendency to the production of shoots from the region of the morphological apex. Defoliated stems were grown in a vertical position in a moist chamber, part with the morphological apex uppermost, part with it directed downwards. The result was that in the majority of cases the new shoot appeared a short distance below the apical end. In some cases the stems gave rise to several shoots, and some of these were often well removed towards the basal end. The new shoots produced from the stem as well as those produced from the leaves were distinctly positively heliotropic. By reversing the leaf cultures from time to time after they had reached the length of a few millimeters, the stem was made to assume a zig-zag form due to the heliotropic curvatures.

It may be noted here that the leaves generally formed ten to fifteen buds, but only two or three of these continued their development to any considerable size. It has been already noted, that leaves in which the bud production was prevented by darkness, produced protonemata from the apical portion of the rhizoids when subjected to light. In case, however, the normal production of buds direct from the leaf was allowed to be carried out, the rhizoids did not produce any protonemata, and ceased growth soon after the new plants had been formed.

2. FUNARIA HYGROMETRICA.

The production of protonemata by the leaves of Funaria has already been mentioned in the references to the researches of Schimper, Goebel, and Klebs. Goebel states that he obtained protonemata in great abundance from Funaria leaves, but my experiments do not show the leaves to be endowed with a very great power of regeneration. The plants used were taken from the greenhouse and were apparently in vigorous condition. Cultures of leaves were made in the same way as for Mnium, and placed in both light and dark. On an average of about one out of every six leaves showed signs of protonemata. In all the cases noted in the first series of experiments, the growth was entirely from the cells of the base and only from those which had been directly attached to the stem. The cultures which were grown in the dark showed growths of a decided protonemal nature, the cell walls colorless, the cross walls generally a little inclined and cells filled with bodies irregular in outline, and without any green color. The filaments remained long and almost unbranched, and reached a length of about 1^{cm}. Several cells of a filament grown in the dark are shown in *fig. 9* for comparison with those grown under normal illumination.

In one or two cases the leaves produced structures which were more rhizoidal in nature, and these in the cultures both in the light and in darkness. In all of the cultures no buds were produced in the dark, while under normal illumination they appeared after ten days to two weeks. The protonema very soon after its origin from the leaf, often gave rise to a bud as a lateral branch, and numerous cases were observed in which this bud formation occurred from the second protonemal cell. This is illustrated in *fig. 8*.

In two cases out of all the experiments which I carried out, I found a protonema production from other than the basal cells, so it would seem that the cells of the basal portion of the leaf are more inclined to produce protonemata than those from other parts. In the preparation of the cultures the leaves were stripped from the stem with a pair of forceps, and occasionally portions of the stem were torn away with them. A very abundant production of protonemata occurred from these portions of the stem. In order to show whether the power of regeneration was localized more in the basal cells of the leaf, a series of cultures was made in which the entire basal portion of the leaves was cut away. These cultures were kept for six weeks, and at the end of that time no formation of protonemata had occurred. That the power of protonema production is not confined entirely to the basal cells is shown by the two cases already mentioned where protonemata were produced from the region of the tip. Hence, the experiments only show that the leaf cells adjacent to the stem produce protonemata more readily.

Whole plants brought under exactly the same conditions as the detached leaves did not produce any protonemata from the leaves, and again plants with the leaves cut away at the tip showed no signs of protonema production. From the experiments it must be concluded that the complete separation of the leaves from the stem is necessary in order to call forth the formation of protonemata.

The experiments with the leaves which had portions of the stem torn away with them showed the stem cells to have a remarkable power of protonema production. A series of cultures was made in which the leaves were entirely stripped from the stems and the stems cultivated in both light and dark. The stems produced new shoots as lateral branches with remarkable rapidity. After a lapse of only three days the new shoots had reached a length of nearly two millimeters. No distinct tendency to the appearance of the new shoots from the region of the morphological apex of the old shoot could be detected. Generally, however, a shoot was formed just back of the apex, but in the majority of cases they were produced at other points along the stem, and even from the very base. Occurring at the same time with the production of new shoots was an abundant growth of protonemata from the stem for its entire length. The regeneration by new shoots was always in the way of axillary branches, in a manner similar to that which often occurs in nature. The protonemata were not, however, confined to the leaf axils, but grew as well from cells removed from the axillary regions. In the cultures in the light they originated generally from the side of the stem which was uppermost, while rhizoids were produced from the contact side and in greater abundance from the region of the stem which had formed a new shoot. This is shown in *fig. 12*. The cultures in the dark showed very rarely a protonema production, and in neither light nor dark was any bud formation noted from the stem protonemata. In several cases where the receptacles with the perichaetial leaves were placed in culture an abundant protonema production was noted from the end cells of the receptacle. A dissection showed these protonemata to originate from the cells lying between the base of the antheridia, archegonia, and paraphyses, and also from the basal cells of the paraphyses as shown in *figs. 10, 11*. All attempts to obtain protonemata from the paraphyses when separated from the stem were without effect. The material for growth was evidently drawn from the stem, and when this supply was cut off the cells were not capable of independent growth.

In order to determine whether the production of new shoots and protonemata was called forth by defoliation or not, whole plants were placed in exactly the same conditions as the defoliated stems. Regeneration by means of new shoots occurred, but not in the abundance that was noted in the defoliated stems, while no production of protonemata occurred and only occasionally rhizoids. The production of protonemata was then called forth by defoliation; the formation of new shoots was only accelerated by the defoliation.

A fact which must be of importance to Funaria was shown in the experiments in which whole plants and defoliated stems were placed under earth at a depth of 3^{mm}. The stems in both cases formed lateral branches which grew erect from the stems which had been buried in a horizontal position. After a lapse of two weeks these new shoots first made their appearance above the soil. Considering the habitat of Funaria the power of regeneration in this manner is of considerable importance in nature, since the plants often become covered with soil and would otherwise perish.

The new shoots from the stem as grown in dark were about twice as long as in the light cultures, and the leaves were much reduced in size. The cultures in the light showed the new shoots to be strongly positively heliotropic. In the dark the new shoots grew erect from the prostrate stems. Stems were placed in a Petri dish in the ordinary horizontal position, and the dish then inverted. The new shoots curved around so as to grow upwards, showing them to be distinctly negatively geotropic.

3. BRYUM CAPILLARE.

The leaves of this plant show a very remarkable power of regeneration. Cultures of the leaves were made the same as for Mnium, and part placed in the light and part in the dark chamber. At the end of a week the majority of the leaves used had produced new growths, and these mostly from the basal portion of the leaf. The first growth from the leaf cells was of neither a pronounced rhizoidal or protonemal nature; the walls were colorless, the cross walls occasionally perpendicular, but more generally slightly oblique. With exposure to light the filaments tended to a growth of a more decided protonemal nature, the cross walls were predominantly perpendicular in the abundant lateral branches, and quite often in the main axes also, and the cells soon developed an abundant chlorophyll content. With time the walls of the main axes turned brown, and the chlorophyll content disappeared, so that eventually the main axes, even though exposed to the light, came to resemble rhizoids. With the continued exposure to darkness the filaments soon became brown; no chlorophyll was formed, and the lateral branching was very generally suppressed. In the cultures in the dark no buds were formed, while in the light cultures the first buds were noticed at the end of seven days, with the more abundant production as growth continued. The buds originated as side branches of the main axis soon after the filament had grown from the leaf cell. In the further growth the buds appeared at different points along the main axis and were homologous with the lateral protonemal branches. The lateral branches might also in their turn give rise to buds as lateral branches, and after six weeks an enormous number of new plants were produced in this way.

The protonema production occurred generally from the cells of the leaf base, either from the marginal cells or from those of the lacerated base, more generally than from the cells in the interior of the leaf. Although protonemata originated from the cells removed from the periphery, no distinct tendency to production from a certain side of a leaf was noted. Part of the protonemata would originate from the contact surface and part from the free surface, sometimes more from the contact surface, sometimes more from the opposed surface, so that no constant effect of contact was demonstrated. Leaves which had remained in the dark for two weeks had produced long, sparsely branched rhizoids without any signs of buds. They were then placed in the light, and after the lapse of ten days abundant protonemal branches were produced from the distal portions of the rhizoids, and also an abundance of buds, thus showing that light was necessary for the formation of buds. Luxuriantly growing protonemata without any buds were placed in the dark and allowed to remain for two weeks. The specimens were grown upon pieces of flowerpots, and at the end of the two weeks no buds had been formed, although the protonema from its previous exposure to light must have contained a considerable supply of plastic material, which was used in continued growth rather than in the formation of leafy shoots. No structures at all resembling rhizoids were produced, and at the end of the experiment the protonemal filaments were beginning to die from lack of food material. From these results it will be seen that in the case of *Bryum capillare* a continued exposure to light is necessary for the production of buds.

In order to determine whether the cells removed from the basal region of the leaf were able to produce protonemata as readily as those of the base, a series of cultures was made in which the leaves were cut transversely through the middle, and both basal and apical portions retained in culture. The basal half of the leaf produced protonemata from both the proximal and distal ends, but only rarely from the cells occupying the interior. The apical half of the leaf also produced protonemata from the cells next the cut base. (*Figs. 17, 18, 19.*) Another series of cultures was made in which the leaves were cut lengthwise, and these showed protonema production from the base and also from the cut margins. These experiments then show that almost any cell of the leaf may grow out into a protonema, but that in the cells with one side next the margin, the tendency to form protonemata is greater than in those cells which are surrounded on all four sides by others.

The experiments with whole plants placed under like conditions as the separated leaves, showed no protonema production whatever from the leaves, and when the tips of the leaves in whole plants were cut away, even then the leaves formed no protonemata. Thus nothing more or less than a complete separation of the leaves from the stem would suffice to call forth the power of the leaf cells to grow out into protonema filaments.

Experiments with leaves grown in blue and red light brought a different result from that found in the case of the Mnium leaves. The leaves in the red light produced buds, apparently with as great readiness as in normal illumination, while in the blue light no buds whatever were formed. When we reflect that it is only in the red light that photosyntax takes place to any extent, the importance of this process as furnishing material for the formation of buds is at once made evident. That the products of photosyntax are necessary for the formation of buds is shown by the fact that leaves grown in a CO_2-free chamber also produced no buds. The results of these experiments with Bryum leaves accord with those of Schostakowitsch[24] for the foliose Jungermannieæ, and those with Mnium agree partially with the results for thalloid liverworts. Experiments with Marchantia and other thalloid liverworts showed that regeneration occurred in the dark as well as in the light. I have also confirmed these results in the case of Marchantia, but in the case of *Lophocolea bidentata* my results were different from those obtained by Schostakowitsch for the same species. I found that the detached leaves produced buds from the marginal cells of the leaf, and that this production occurs quite abundantly in the dark, as well as when the leaves are exposed to light. This result is more in accordance with the observation of Klebs.[25] According to Klebs the leaves of *Lophocolea bidentata* produced buds in a weak light at an intensity which was not sufficient to produce the germ disk in the case of spore-protonemata. Mention may be made here of the cultures of *Plagiochila asplenioides* leaves. Greenhouse specimens showing every appearance of vigor were used, and the cultures were kept for over two months, but although the leaves remained green and vigorous, no sign of any bud or rhizoid production was observed. This was one of the species which Schostakowitsch grew successfully, and it is apparent from these results that there are conditions of the plant, when although apparently vigorous, the power of regeneration may be suppressed.

The defoliated stems of Bryum produced some protonemata direct from the region of the leaf axil, but in the case of specimens grown in the dark no distinct protonema growths were noted. The abundance of production was much less than in the case of *Funaria hygrometrica*. The paraphyses here also were

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[24] Flora, Ergänzungsband 1894: 380–384.

[25] Biol. Centralblatt 13: 649. 1893.

able to grow out into rhizo-protonemata by the continued growth of the distal cell. This occurred, however, only when they remained in connection with the stem, all attempts at cultivating the detached paraphyses being to no avail. The stems produced rhizoids quite abundantly, both in light and darkness, and the production was not confined to any particular portion of the stem. From the rhizoids an abundance of buds was formed as lateral branches, and in a light intensity which was not sufficient to produce vigorous protonemata. New shoots were produced by the stems as lateral branches the same as in Funaria. These appeared without any distinct localization of the point of origin, coming now from near the tip and now near the base of the stem. The production of protonemata was due mostly to defoliation of the stem, since only in rare cases was a protonema production noted from the whole plants which were kept in the same conditions as the defoliated stems. Rhizoid production was quite abundant from the whole plants, but the growth in general was more abundant from the defoliated stems. The production of new shoots was not called forth by the defoliation of the stems, but was only accelerated thereby, since whole plants also formed lateral axillary branches, a mode of growth which is often resorted to in nature, the new branches afterwards becoming separated from the parent plant. The whole and defoliated stems, when buried under 3^{mm} of earth and kept moist, also gave rise to lateral branches, which grew in the normal way, and by rapid growth soon appeared above the soil, the same as in Funaria. The importance of this power of regeneration in nature has already been emphasized in the case of Funaria.

The statements in regard to the elongated growth of the new shoots in the dark, with the development of reduced leaves, and the well-marked negative geotropism and positive heliotropism, hold good here as well as for Funaria.

4. BRYUM ARGENTEUM.

The manner of regeneration from the leaves of *B. argenteum* is so similar to that already described for *B. capillare*, that a detailed account will not be necessary. The whole leaves produced protonemata from the basal portion, and the cut leaves from all of the cut edges. The character of the growth from the leaf cells was practically the same. The formation of buds occurred in abundance in the light cultures, but none in the dark. The formation of protonemata was due to the separation of the leaf from the stem, and not to the mere cutting.

An abundant protonema production occurred from the defoliated stems, the growth taking place from the region of the leaf axil. The protonemal nature was generally suppressed in the dark cultures, only in a few cases long, unbranched, protonema-like growths being noted. The protonemata in the light produced buds in great abundance, and often as lateral branches of the first cell of the protonemal filament. No buds whatever were formed in the dark. The protonema production was called forth by defoliation, since whole plants only produced rhizoids, and not in the abundance which was noted in defoliated stems. As opposed to the other species studied, the defoliated stems did not produce new shoots as lateral branches, while whole plants under exactly the same conditions did. This is presumably explained by the small weak stem, which when robbed of its leaves is not able in itself to afford material for the growth of new shoots, in addition to what is used to produce the abundant growth of rhizoids and protonemata.

5. BARBULA MURALIS.

The leaves of Barbula produce protonemata with great readiness. Cultures of the detached leaves were made for both light and dark, and the best results were obtained from those upon pieces of flowerpot. After a lapse of about a week an abundant growth had appeared in the cultures in the dark as well as in the light. The first growth was colorless, with slightly oblique cross-walls, and no chlorophyll except what was derived from the leaf cell. Those which remained in the light for the entire period soon showed a very vigorous growth, with luxuriant branching and the absence of any bud formation. The walls of the main axes after a time turned brown and had more of a rhizoid nature. The side branches, although at times slender and tapering and now with oblique cross-walls, now with perpendicular walls, were decidedly protonemal in character and possessed an abundant chlorophyll content. A thick net of interlacing protonemal filaments was obtained from the culture in the light. At the end of ten weeks the network was several centimeters in extent, and notwithstanding the fact that it had been exposed to the light in the laboratory window, no bud formation had resulted. The suppression of bud formation could not have been due to the lack of sufficient light, since as exposed in the window the illumination was quite intense. Up to this time the culture had produced no growths which I could call rhizoids. The cultures which remained in the dark produced only long, very sparsely branched filaments which in their further growth tended more to rhizoidal nature, with no chlorophyll, brown walls, and always oblique cross-walls.

At the end of about eleven weeks the protonemata had given rise to distinct rhizoid branches, and an abundance of buds had been formed. Soon after this the old protonemata began to turn brown and die. During this period of growth, the extensive network of protonemal filaments had not been entirely produced by the direct growth of the originally formed main axes, but a multiplication of the protonemata had occurred. Certain side branches seemed to be specialized for this purpose, since the cells increased in size, developed a very abundant chlorophyll content, rounded themselves somewhat until they were about barrel-shaped, and then separated from the branches either singly or several together. These separated cells then gave rise to new protonemata. Goebel[26] mentions the power of a protonema, species not known, to separate in this way when the culture was allowed to dry. In the case of Barbula, however, the splitting away of the cells was not due to drying out, since the culture was supplied with nutritive solution for the entire period of growth.

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[26] Sitz.-Ber. d. mat.-phys. Classe d. k. Bayer. Akad. d. Wiss. **36**: 641. 1896.

The protonemata originated only from the basal cells of the leaf, generally either from the very end cells or from those next the margin. The cells of the basal portion are much longer than those occupying the apical portion, and the question now presented itself as to whether the small cells of the apical half of the leaf were capable of growing out into protonemata. In order to determine this the basal portions were cut away from a series of leaves, and both apical and basal portions retained in culture. The result was that no protonemata were produced from the apical portions of the leaves, while the basal portions only produced protonemata from the cells of the proximal end. The protonemal growth was generally from cells occupying the periphery, but occasionally one originated from a cell a little removed from the margin. These experiments then show the power of regeneration to be confined to the larger cells of the leaf base.

In the material which was accessible to me, most of the stems were bearing young sporophytes and had produced in their normal growth an abundance of rhizoids. The defoliated stems when placed in culture did not give rise to any new shoots and no appreciable production of rhizoids was to be noted.

6. ATRICHUM UNDULATUM.

So far as my knowledge goes, no moss leaves with a structure similar to that of Atrichum leaves have been known to give rise to protonemata.[27] Hence the successful growth of protonemata from these leaves is of the more interest. Four cultures of leaves were made: a series of leaves with the dorsal surface uppermost, and another series with the ventral surface uppermost, both to be placed in the light; two similar series were placed in the dark chamber. At the end of a month the first signs of protonemata were observed and in the course of a week they had grown to a considerable length. An examination of all the cultures showed that the protonemata in every case origi-

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[27] Since this was written an article has appeared by Correns (Ber. deutsch. bot. Gesell. **16**: 22–27. 1898) describing the production of protonemata from Polytrichum leaves.

nated from the ventral surface of the leaf without regard to the position which it had occupied in the culture. And further, the examination of the whole leaves showed that the protonemata originated from the cells lying at each side of the lamellæ. The protonema production from this region was quite general throughout the entire length of the leaf.

In order to determine more closely the origin of the protonemata, cross sections of the leaf were made. The sections showed that they originated from the large cells of the costal region lying at the base of the outer lamellæ (*fig. 32*). The first growth from the leaf, although the cross-walls were predominantly oblique, were decidedly protonemal in character and remained so whether the specimens were grown in the light or dark. The branching was often aggregated in a manner altogether unique, as is shown in *fig. 30*, which may be taken as a typical example. In other cases it was more as in ordinary protonemata, but the only difference between the protonemata grown in the dark and those grown in the light, was that in the dark cultures the cells were generally more elongated and devoid of chlorophyll, and the branching less. The cell walls in both cases were colorless.

After about five weeks, buds made their appearance, and always as modifications of lateral protonemal branches. Contrary to what has been described for all of the preceding species the buds were formed in as great abundance in the dark cultures as in the light. In the dark the buds did not attain any considerable size on account of the lack of food material, rarely reaching a length of 1^{mm}. The production of buds in the dark is evidently explained from the nature of the leaf. The lamellæ and the lateral portions of the leaf, since they give rise to no protonemata are able to furnish considerable food material which can be applied to the growth of leafy shoots. These experiments show that in one case, at least, light is not necessary for developing and unfolding the slumbering "Anlage" of which Klebs[28] surmises the existence.

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[28] Biolog. Centralblatt **13**:647. 1893.

In order to determine whether a correlation existed between the lateral halves of the leaf and the costal region in the production of protonemata, the lateral halves of a series of leaves were separated from the costal regions, and both retained in culture. Under no conditions were the cells or the lamina able to grow out into protonemata, the cultures being kept several months without any sign of growth. The costal portions after the usual length of time showed a growth of protonemata in the ordinary way, only the number was greatly reduced. The cells of the lamellæ are not able to grow out into protonemata, neither when in connection with the leaf nor when separated. The power of regeneration is thus distinctly localized in the large cells of the costa lying at the base of the outer lamellæ.

Whole plants which were kept under exactly the same conditions as the detached leaves gave rise to no protonemata from the leaves. That the production of protonemata was not called forth by cutting was shown by the experiments in which half of the leaf tip was cut away while the outer half was left in connection with the stem. Under these conditions the portion of the leaf remaining in connection with the stem showed no growth. A complete separation of the leaf from the stem is then necessary to call forth the power of the leaves to produce protonemata and buds.

The defoliated stems of Atrichum when placed under conditions favorable to growth gave rise to new shoots as axillary branches. This regeneration by means of new side branches occurred as readily in darkness as in light. In the dark the shoots grew more rapidly, producing more slender stems with reduced leaves. The tendency to apical production of shoots was not well marked, the shoots appearing at various points along the stem from base to apex. No new production of rhizoids or protonemata was obtained from the stems under any conditions, although the cultures were kept for several months. Whole plants under exactly the same conditions as the defoliated stems produced new shoots as axillary branches but not in as great abundance as the defoliated stems, showing that the production is accelerated by defoliation.

7. POLYTRICHUM COMMUNE.

Cultures of leaves were made the same as for Atrichum, but it was not till the end of about six weeks that the growth of protonemata was observed. The protonemata were similar in nature to those already described for Atrichum, with colorless walls and oblique cross-walls in both light and dark. A peculiar aggregation of branches occurred quite frequently, an example of which is shown in *fig. 36*, thus forming an assimilating organ, while the production of buds came later. In the protonemata grown in the dark the cells were longer, without chlorophyll, and the branching was more or less suppressed.

The protonemata originated exclusively from the ventral surface of the leaf, that is the lamellate side, without reference to the position which the leaves occupied in culture. An examination of the leaves showed that they came apparently from between the lamellæ, but the exact origin could only be determined by means of cross sections. The sections showed that the protonemata originated from the large cells lying just at the base of the lamellæ (*fig. 34*). The protonema production did not seem to be confined to any particular portion of the leaf, but was quite generally distributed over the leaf cells occupying the position above named. The portion of the lamina not covered by lamellæ is small, but the cells from that portion of the leaf as well as the cells of the lamellæ were not able to grow out into protonemata.

The first production of buds was noted at the end of about seven weeks, and, just as in Atrichum, in as great abundance in darkness as in light. The buds originated either as modifications of lateral protonemal branches or in a few cases by the divisions of the end cell of a main protonemal axis. The explanation for the production of buds in darkness, here as in Atrichum, is to be sought presumably in the nature of the leaf, the accessible supply of nutritive material being considerable.

The complete separation of the leaf from the stem was necessary to call forth the protonema formation. The experiments with defoliated stems gave the same results as have already been described for Atrichum.

Mention may be made here of the cultures of *Pogonatum nanum* leaves. Cultures of these leaves were kept for two months without any appearance of protonemata, although the leaves were apparently vigorous.

8. BRACHYTHECIUM RUTABULUM.

The leaves of Brachythecium did not produce protonemata with very great readiness, only about one out of every eight giving rise to protonemata. The first production of protonemata was noted at the end of nearly three weeks. As in the case of Bryum the first growth was neither distinctly protonemal nor rhizoidal. Even in the cultures in the light the main axis soon changed its cell walls to a well-marked brown, while the side branches continued as distinctly protonemal, with generally perpendicular cross-walls, and an abundant chlorophyll content. Buds were formed very soon and consequently the protonemata did not attain any considerable size. In the cultures in the dark the filaments remained long and occasionally branched, with brown cell walls, oblique cross-walls and no chlorophyll. Buds were found after about three weeks, but these were confined to the cultures which had been exposed to the light. The buds originated in all cases as side branches of the main protonemal axes.

The first experiments with the leaves showed that the protonemata originated exclusively from the larger cells lying next the very base. None of the cells removed from the periphery gave rise to a growth, but only those one side of which was next the free lacerated base of the leaf. Leaves were cut transversely, and also longitudinally and all portions placed in conditions favorable for growth. The apical half of the leaf gave rise to no protonemata whatever, while the basal half only produced protonemata from the proximal end, with an origin the same as in the cases of the whole leaves. The portions of the leaves which had been split longitudinally also gave rise to protonemata but only from the base and not from the cells lying along the cut margin. The power of regeneration is then located in the basal cells of the leaf the same as in *Barbula muralis.* The production is due to the separation of the leaves from the stem, since whole plants under exactly the same conditions as the detached leaves produced no protonemata, and since when the leaves were cut and still allowed to remain in connection with the stem no growth was called forth.

Essentially the same results were obtained with leaves from a variety of this species, except that the protonemata originated exclusively from the cells of the base which occupied the position next the costa.

The defoliated stems gave rise to new branches as axillary shoots, both from the main axes and from the side branches. These appeared without any apparent regularity with reference to base or apex of the stems, and also as well in the dark as in the light. In the dark the growth was more rapid, producing longer and slenderer shoots with very reduced leaves. Although the stems were cultivated for about two months no protonema production direct from the stems was observed. The production of rhizoids was not general, only here and there a few being produced. Whole plants brought into the same conditions as the defoliated stems, produced new plants in apparently as great abundance. The rhizoid production was about the same, so it was impossible to say that either rhizoid or shoot production was accelerated by defoliation.

9. LEPTOBRYUM PYRIFORME.

The leaves of Leptobryum compare very favorably with those of *Brachythecium rutabulum* in the extent to which they produce protonemata, perhaps not more than one in ten of the leaves used showing the formation of a new growth. The first appearance of protonemata was noted after the leaves had been in culture for nearly three weeks. As in Bryum and Brachythecium, the first growth was semi-protonemal in character. With continued exposure to light and increase in length, it assumed more and more the protonemal character. Towards the distal end the cells were much shorter, abundantly filled with chlorophyll, and with perpendicular cross-walls. Even in the light the branching remained suppressed and only long, unbranched filaments about 1^{cm} long were produced. In the cultures in the dark the filaments remained distinctly rhizoidal in nature and reached the length of about 1^{cm} after four weeks of growth. When leaves which had remained in the dark for about four weeks were placed in the light, the continued growth of the rhizoids soon became of a more protonemal character, so that a direct transformation of the main rhizoid axes to protonemata was called forth. Even in this case no branching resulted and no buds were produced, either in the light cultures or in the dark.

The protonemata originated from the basal portion of the leaf and generally from some of the cells a little removed from the end. There was no inherent tendency to the production of protonemata from a particular side of the leaf. And, moreover, the growth occurred now from the contact side, now from the free side. In order to determine whether the cells removed from the base had the power of producing protonemata, the leaves were cut transversely and kept in condition favorable to growth for about two months. No growth resulted from the apical portion, and from the basal portion the growth was the same as in the whole leaf. These experiments showed the power of growth to be localized in the cells of the basal half of the leaf. It was also shown that the production of protonemata was only called forth by the complete separation of the leaf from the stem.

Defoliated stems when kept in culture a short time produced an abundance of rhizoids and protonemata from the region of the leaf axils, the protonemata generally being the more abundant. In the dark all of the growths from the stem retained the nature of rhizoids, but when exposed to light the further growth was of a decided protonemal character. The protonema production was not local but occurred in as great abundance from one portion of the stem as another. Defoliated stems generally produced one or two new plants as lateral branches. The origin of these was not definite, since they appeared now at the base, now at the apex, and at intervening points. Whole plants placed under the same condition as defoliated ones also produced an abundance of protonemata direct from the leaf axil, the same as in defoliated stems. The production of new shoots was also as abundant in the whole plants as in the case of the defoliated stems. Hence, Leptobryum differs from the other species already described in that the protonema production is not called forth by defoliation.

The form of branching of the protonemata of Leptobryum is worthy of note, since it very frequently differs from the ordinary mode. In the normal branching of protonemata each cell is able to form a branch just behind the cross septum. In this case, however, two branches are formed opposite each other and immediately behind the septum (*fig. 48*). The plants which I used for experiments were grown in the greenhouse, and an examination of sterile plants showed that the production of protonemata from the leaf axils was quite general. The side branches of these protonemata often gave rise to strings of conidia-like cells, which broke away from the branch bearing them. The cells generally had assumed an oval form, were abundantly filled with chlorophyll bodies and quite often large oil drops, and possessed besides slightly thicker walls (*figs. 43, 44*). The striking similarity of this growth to conidia formation in fungi will at once be noted from the diagram. Some of these conidia-like cells were placed in conditions favorable for growth and after a lapse of about eight days germination or growth had occurred as shown in *fig. 45*. A great many of the leaf axils, instead of giving rise to protonemata or rhizoids, had produced dark brown, oval, multicellular brood-bodies borne upon a stalk several cells long (*figs. 46, 47*). The rhizoids also gave rise to similar brood-bodies. The conditions for this conidia production cannot be stated. In the artificial cultures when kept moist, this manner of breaking up of the protonemal branches into single cells did not occur. The plants in the greenhouse were not, however, especially dry.

10. PHASCUM CUSPIDATUM.

The leaves of Phascum produced protonemata with great readiness and in less time than any other species investigated. Cultures were made for both light and dark, part of the leaves in each case being dorsal side and part being ventral side up. At the end of five days both protonemata and buds had been produced in the light, and a careful examination showed that the majority of the growths originated from the ventral side of the leaf in the region of the costa, without reference to the position which the leaves had occupied in the culture. Occasionally a protonema originated from the leaf cells removed from the region of the costa, and now from the contact side and now from the free side of the leaf. Occasionally some of the cells from the region of the base gave rise to distinct rhizoids which showed no tendency to produce protonemal branches, but remained distinctly rhizoidal in nature even in the light. The branching of the protonemata in the light was not very profuse. while in those which remained in the dark all the time, the branching was suppressed to a considerable extent, and the walls very soon turned brown. No buds were formed in the dark cultures, while the cultures in the light had plenty of buds at the end of five days.

When the lateral halves of the leaves were separated from the costa, they also gave rise to numerous protonemata, showing that in the whole leaf the ability of regeneration was present, but that the supply of food material was contributed to the cells of the costal region, which produced protonemata with greater ease. It has already been stated that the majority of protonema production in the whole leaves was from the ventral leaf surface in the region of the costa. Cross sections of the leaves showed that the cells occupying the costal region on the ventral side were thinner walled than the remainder of the leaf cells, hence they produced protonema more readily.

The dorsal side of the costa was made up entirely of thick-walled cells, hence no protonema production from the dorsal side occurred (*fig. 51*).

Whole plants and plants with the tips of the leaves cut away produced no protonemata from the leaves, nothing but a complete separation of the leaves from the stems being sufficient to call forth the formation of protonemata. The protonema production from the costal region occurred throughout the entire extent of the leaf, but that from the apical portion was greater than that from the basal portion.

The defoliated stems produced protonemata directly throughout their entire length, and they were not confined entirely to the leaf axil, any of the surface cells being capable of growth. The defoliated stem generally produced at least one new shoot, and sometimes this originated from the very base of the stem, sometimes from nearer the apex. Whole plants placed in exactly the same conditions produced protonemata directly from the stem, and also new shoots.

II. CERATODON PURPUREUS.

All attempts to obtain protonemata from the leaves of Ceratodon were without effect. The leaves were kept for several months in apparently vigorous condition without any sign of protonema formation. The defoliated stems are however able to give rise to an abundant protonema growth, which originated direct from the region of the leaf axils. Rhizoids were also produced, but they very soon became protonemal in nature in the cultures which are exposed to light. In the dark the growths were of a more rhizoidal nature, and generally remained almost devoid of branches. The protonema production was not local but was general throughout the entire length of the stem. The defoliated stems also produced new shoots as lateral branches. The point of origin was not definite, since they might come at any point between the base and apex of the stem. The production of new shoots occurred as well in darkness as in light. Whole plants placed in the same conditions as the defoliated stems, produced new lateral shoots and quite a number of protonemata, hence the protonema and shoot production was not called forth by defoliation.

12. FISSIDENS BRYOIDES.

As in Ceratodon, all attempts to grow protonemata from the leaves of Fissidens were ineffectual. The leaves were kept for three months, and at the end of that time, although in apparent vigor, no protonemata had been produced. The stems, when stripped of leaves, produced rhizoids directly from the region of the leaf axils in both light and darkness. In the light, however, the rhizoids soon grew to possess a distinct protonemal character, but no protonemata originated directly from the stem. The stems grown in the dark produced long, sparsely branched rhizoids, which attained a length of about 1^{cm} after a month of growth. When first examined they possessed only oblique cross-walls, but at this time nearly all showed alternately oblique and perpendicular walls. The oblique walls were the ones first formed and the perpendicular walls were produced later by intercalary division. The great regularity of the alternately oblique and perpendicular cross-walls was due to the fact that each cell had become divided by a perpendicular wall. This fact is mentioned since intercalary division is an exception to the usual mode of protonema and rhizoid growth, and since it affords another example of perpendicular cross-walls being produced in darkness.

No buds were produced from the protonemata grown from the stem, but the stem gave rise to buds, and that in a peculiar way. After one month of culture the stems grown in the light were found to have produced buds directly from the region of the leaf axils, without the intervention of any protonemata. A bud grown in this way is shown in *fig. 53*. A surface cell from the region of the leaf axil produces a protuberance, which instead of growing out into a rhizoid or protonema divides directly to form a bud. This manner of bud formation was observed only in light cultures. Plants with the leaves still intact also produced buds in the same way, although not in as great abundance as in the defoliated stems. The buds were in the course of time detached from the stem. This manner of bud formation is of interest as affording another example of the production of buds without the intervention of protonemata. It is very probable that buds are produced this way in nature, and the presence of young plants coming from the region of the leaf axil confirms the supposition. The direct growth in nature was not followed however.

Mention may be made here of the attempts to obtain protonemata from *Fontinalis antipyretica*. The leaves and stems were cultivated in a variety of ways: in water, on earth, and with varying amounts of moisture, but no protonemata were obtained from either leaves or stem.

13. GENERAL EXPERIMENTS.

As shown by the foregoing experiments, the production of buds with reference to light and darkness seems to have been in a great measure dependent upon the supply of food material which the leaf could afford. The question which naturally suggests itself at this point is: Can bud production be called forth in the dark by the use of some such carbohydrate food as grape sugar, in the case of leaves which in themselves are unable to produce buds with the absence of illumination? This is a question difficult to solve, because the majority of leaves require a considerable length of time for bud production, and because it is impossible to make perfectly sterile cultures. Repeated attempts were made with various leaves, with every care possible to keep the cultures sterile, but the inroads of bacteria and molds usually destroyed the experiments and thus shut out all chance of success.

In one instance, however, my efforts were successful and that in the case of *Phascum cuspidatum*. The leaves of this moss under ordinary conditions produced protonemata and buds after five days. The rapidity of growth made it favorable for experimentation, and the cultures to which grape sugar was supplied formed buds after two days, both in light and darkness, but in greater abundance in the light cultures. With further growth in the dark, the buds grew to produce shoots, two, three, and in one case five millimeters in length.

Experiments were performed with several of the species which produced protonemata the most readily, to see what effect KNO_3 would have upon the regeneration and manner of growth. *Barbula muralis* and *Phascum cuspidatum* leaves were grown in 1 per cent. KNO_3 without any apparent retardation or change in the manner of growth. *Bryum capillare* leaves produced protonemata, but there was a marked retardation of growth and the filaments did not reach any considerable size. In 2 per cent. KNO_3 *Barbula muralis* still produced a vigorous growth without any marked retardation. The cells were, however, generally shorter, and the branching more aggregated. *Bryum capillare* and *Phascum cuspidatum* produced no growth whatever. In 3 per cent. KNO_3 *Barbula muralis* produced a slight growth, but the filaments did not reach any considerable length.

A series of experiments was also carried out in order to determine the temperature at which protonema formation would occur. For these experiments *Barbula muralis*, *Bryum capillare*, and *Phascum cuspidatum* were used, with the results given in the following table:

	19–21°	24°	27°	29.5°	32°	36°
Barbula muralis	×	×	×	×	×	
Phascum cuspidatum	×	×	×	×	×	
Bryum capillare	×	×	×			

Barbula and Phascum produced protonemata with as great vigor at 32° C. as at 19–21°, the temperature of the ordinary experiments; but at 36° no growth resulted. At 29.5° the Bryum leaves produced no growth but were not killed, since when exposed to the ordinary temperature, protonemata were produced. At 32°, however, the leaves were killed. At 27° a slight growth resulted but with a very marked retardation. At 24° the growth was to all appearance quite normal.

That moss plants are able to be dried completely for some length of time and still retain their power of regeneration has been demonstrated by Schröder.[29] By way of confirmation *Bryum capillare* was dried thoroughly for three weeks, then moistened and the leaves stripped from the stems and placed in conditions favorable for development. In the same time as usual protonemata made their appearance. *Barbula muralis* was dried for two weeks without the loss of protonema production.

The foregoing experiments have shown that in nearly all conditions, the only requisite for the development of protonemata from rhizoids has been the exposure to light. Either the main rhizoid axis has given rise to side branches which were distinctly protonemal in nature, or the continuation of the main axis has become decidedly protonema-like. There may, however, be conditions in which the rhizoids, even though exposed to light, do not produce protonemal branches. The rhizoids from Mnium leaves, in case the normal development of buds is allowed to be carried out, produce no protonemal branches. In the same way the rhizoids from the stem did not give rise to protonemal branches, but if the growth of the stem is interrupted the rhizoids undertake the regeneration of the plant and produce new leafy shoots and protonemal branches. This manner of growth is quite common when tufts of various plants are inverted so that the rhizoids are exposed to the light and the shoots killed by being covered with soil.

The experiments which I have carried out show that the protonemata do not produce rhizoids with as great readiness as the rhizoids do protonemata. This is in opposition to the view expressed by Frank,[30] since he says in regard to the protonemata: "Eben so leicht kann der Faden wieder in ein Rhizoid sich umwandeln." A protonema of *Bryum capillare* was grown on a

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[29] Untersuch. aus d. bot. Inst. zu Tübingen **2**: 15–21. 1886.

[30] Lehrbuch der Botanik **2**: 9. 1893.

piece of flowerpot until a considerable size and vigor was attained, and then placed in the dark. At the end of two weeks no sign of rhizoids was detected. The growth had, however, been considerable from the supply of food material which had been produced in the light.

In another case a luxuriantly growing protonema of the same species as above mentioned was placed upon a piece of flowerpot and one half covered with earth, the other allowed to remain free. Only in one or two cases was a growth of rhizoids noted from the part covered with earth. The same result was obtained with protonemata of *Bryum capillare* and *Barbula muralis* in which one half was covered with a screen of black paper. The protonemata lost their chlorophyll content, but did not develop any distinct rhizoids. From these results it is seen that although exposed to darkness and also grown on earth, a rhizoid production only rarely occurred. A culture of protonema of *Barbula muralis* which was grown in the light produced distinct rhizoids after about eleven weeks of growth. Here then is a case of the production of rhizoids in direct illumination. *Bryum capillare* and *Barbula muralis* leaves were grown under water and a luxuriant protonema growth obtained. It might be thought that growing under these conditions, the protonemata would retain their more algal nature and not produce new leafy shoots, but in the case of Bryum, buds made their appearance after the usual length of culture. There was, however, a difference in the form of growth. In Bryum and Barbula the lateral branches grew quite slender and tapering, while in the cultures on flowerpot they were more robust and of equal diameter throughout. In Barbula these side branches frequently possessed oblique cross-walls, while Bryum generally had perpendicular cross-walls. This manner of growth has been mentioned by Goebel[31] for a protonema of *Physcomitrium pyriforme* when grown in water. He compares these side branches to rhizoids and makes the statement that they evidently correspond to rhizoids. It might be inferred that the lack of rhizoid production in these

[31] Flora **72**: 8. 1889.

cultures was due to the medium of growth, either upon flowerpot pieces or in water. Cultures, which from the beginning were made upon earth, showed essentially the same manner of growth, except that the side branches were robust instead of slender, of equal diameter instead of tapering, and were distinctly positively heliotropic. It was only very rarely that a protonemal branch was found penetrating the soil and becoming rhizoidal. The same result was obtained with protonemata, which were grown either in water or upon flowerpot pieces and then placed upon the soil, the further growth still being without rhizoid development. Luxuriantly growing protonemata from the stem of Funaria were half covered with earth without any appearance of rhizoids. Schimper[32] grew Funaria protonema from the spores which did not show any rhizoid production.

V. SUMMARY.

Considering the various species of moss plants used in the foregoing experiments, there are, notwithstanding the variety of results, many striking similarities in the manner of regeneration, a brief summary of which will be brought together in the following conclusions:

1. The majority of moss leaves used showed a remarkable power of regeneration, producing either rhizoids or protonemata, with the later appearance of new leafy shoots. The rhizoid or protonema production was carried out in both light and darkness.

2. The point of origin of the new growth from the leaf in some cases depended upon contact and illumination, and was independent of gravity (Mnium). In other cases the protonema had a definite origin which was independent of external factors, and depended solely on the leaf structure: from the ventral side of the leaf as in Atrichum, Polytrichum, and Phascum; or from marginal cells and thus independent of contact, gravity, illumination, or position of the leaf.

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[32] Rech. anat. et morph. sur les mousses, *plate 1.* 1848.

3. The power of regeneration may be distinctly localized: *a*. In special cells of the leaf base as in Barbula, Brachythecium, and Funaria. *b*. In special cells of the ventral leaf surface as in Atrichum and Polytrichum. In other cases the power of regeneration was quite generally shared by all the leaf cells as in Mnium, Bryum, and Phascum.

4. The structures produced might be all rhizoids in both light and dark as in Mnium and occasionally so in Phascum. They were protonemata in light and rhizoids in the dark as in Bryum, Barbula, Brachythecium, and Phascum, or they were all protonemata in both light and dark as in Atrichum and Polytrichum.

5. Buds were produced under ordinary conditions of cultivation only in light in the following: Mnium, Funaria, Bryum, Barbula, and Brachythecium. In both light and dark by Atrichum and Polytrichum under ordinary conditions, and by Phascum when supplied with grape sugar. The production of buds seemed to be in a measure dependent upon the food supply.

6. Regeneration was called forth in all cases by the separation of the leaf from the stem. Mere cutting of the leaves while in connection with the stem did not call forth the production of protonemata or rhizoids.

7. The majority of moss stems, as well as the leaves, showed regeneration, and that in two ways: *a*. By axillary shoots. *b*. By protonemata directly or by rhizoids, which in the light very soon gave rise to protonemal branches. The stems in two cases had the power of regeneration, while this power was not shared by the leaves (Fissidens and Ceratodon).

8. Production of axillary shoots was not called forth by defoliation of the stem, but was generally accelerated thereby. In some cases the protonema production was called forth by defoliation, in other cases only accelerated.

9. Protonema production was quite general throughout the entire extent of the stem. In some cases the protonemata orig-

inated only from the axillary cells, in other cases from the various surface cells of the internode. The axillary shoots in one case showed a tendency to marked apical origin (Mnium). In the other cases the distribution was quite general.

10. The buds originated from Mnium leaves and Fissidens stems without the intervention of a protonema. When of protonemal origin, they were either modifications of lateral protonemal or rhizoidal branches, or direct modifications of the main axes. The tendency of protonemata to produce rhizoids was not as great as the tendency of rhizoids to produce protonemata.

11. The upper temperature limit for regeneration from the leaves investigated varied from 24 to 32° C. Protonemata were grown in 1 and 2 per cent. solutions of KNO_3. Drying for a considerable length of time did not alter the power of the leaf to produce protonemata.

The investigations here recorded were carried out during the years 1896–7 in the laboratory of the Botanical Institute at Leipzig, under the direction of Herr Geh. Professor Dr. Pfeffer. I wish here to express my thanks to him for aid and many valuable suggestions.

PARSONS COLLEGE,
Fairfield, Ia.

EXPLANATION OF PLATES XIX–XX.

PLATE XIX.

Mnium rostratum.

FIG. 1. Diagram of a leaf to show origin of rhizoids and buds. × 12.

FIG. 2. Cross section of a portion of a leaf showing the origin of a bud from a leaf cell, together with the previously produced rhizoid. × 130.

FIG. 3. Cross section of a portion of a leaf showing a bud at a more advanced stage. × 130.

FIG. 4. Portion of a leaf with rhizoids and a bud produced as a lateral branch of a rhizoid. × 53.

FIG. 5. Rhizoid (*r*) with protonemal branches (*p*) which have been produced after exposure to light. × 130.

FIG. 6. Rhizoid (*r*) with protonemal branches (*p*) showing the origin of a bud from a cell of the main rhizoid axis, and homologous with the lateral protonemal branches. × 220.

FIG. 7. Same as 6, only the bud formation has occurred from one of the protonemal branches direct. × 220.

Funaria hygrometrica.

FIG. 8. Protonema and bud grown from the receptacle. × 130.

FIG. 9. Portion of a protonema as grown from a leaf in the dark. × 130.

FIG. 10. Paraphysis, showing the origin of a protonema from the basal cell. × 53.

FIG. 11. Proximal portion of the same on a larger scale. × 130.

FIG. 12. New shoot, rhizoids, and protonemata growing from a defoliated stem.

Bryum capillare.

FIG. 13. Several cells from the leaf base showing the origin of protonemata, with the formation of a bud. × 130.

FIG. 14. Protonema and bud grown from the leaf. × 130.

FIG. 15. Bud and protonema grown from the leaf. × 53.

FIG. 16. Leaf base showing origin of protonemata and the formation of a new leafy shoot. × 53.

FIG. 17. The basal half of a leaf, showing origin of protonemata from both the proximal and the distal ends. × 53.

FIG. 18. Tip of a leaf showing protonemata growing from the cut edge. × 53.

FIG. 19. Protonemata and leaf cells from the preceding on a larger scale. × 130.

FIG. 20. Protonemata originating directly from the defoliated stem. × 130.

FIG. 21. Paraphysis which has grown out into a protonemal filament.

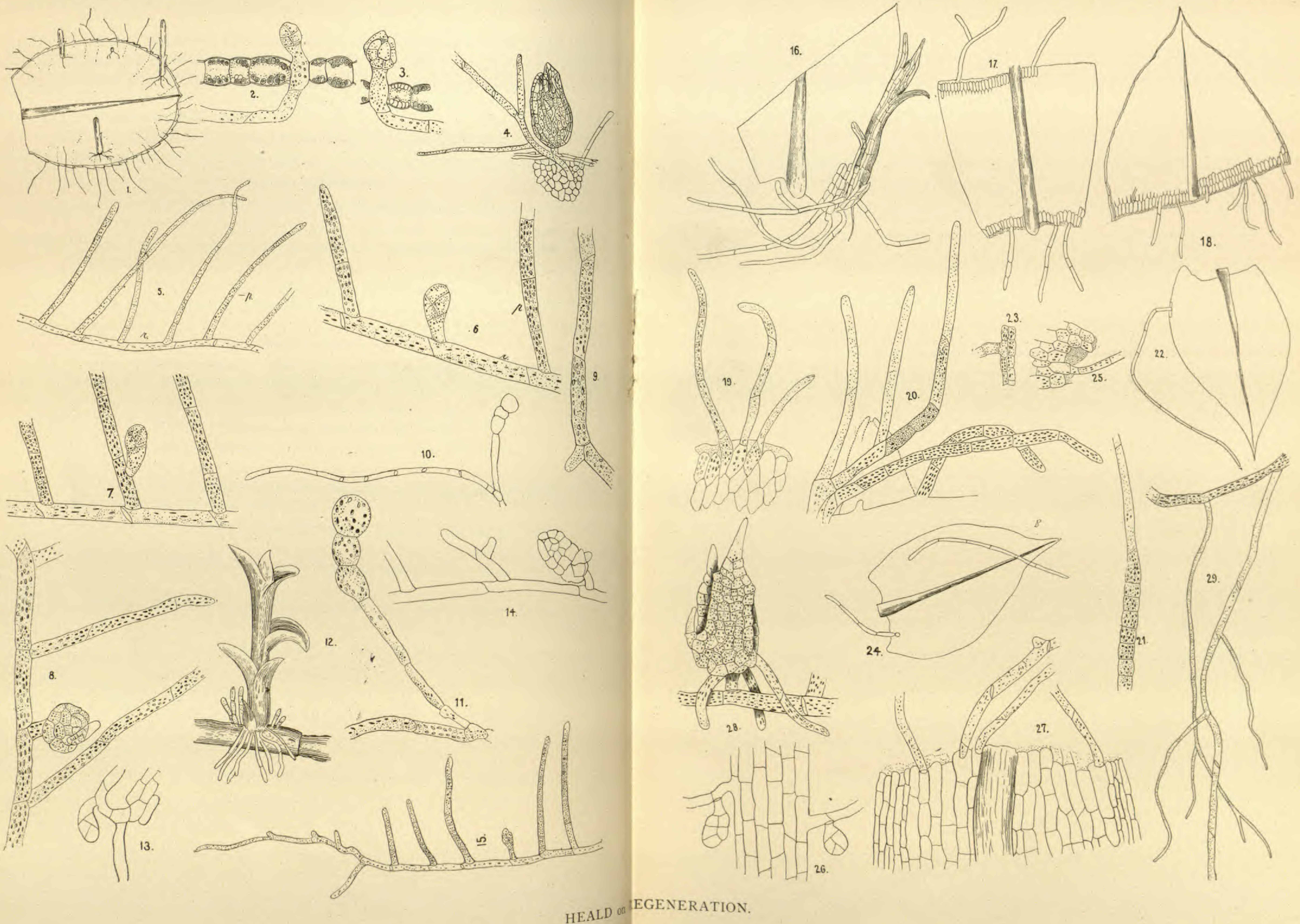
Bryum argenteum.

FIG. 22. Leaf with protonema. × 53.

FIG. 23. A few of the marginal leaf cells showing the origin of protonema. × 130.

FIG. 24. Leaf with protonemata. × 53.

FIG. 25. A few of the basal cells showing the origin of the protonema. × 130.



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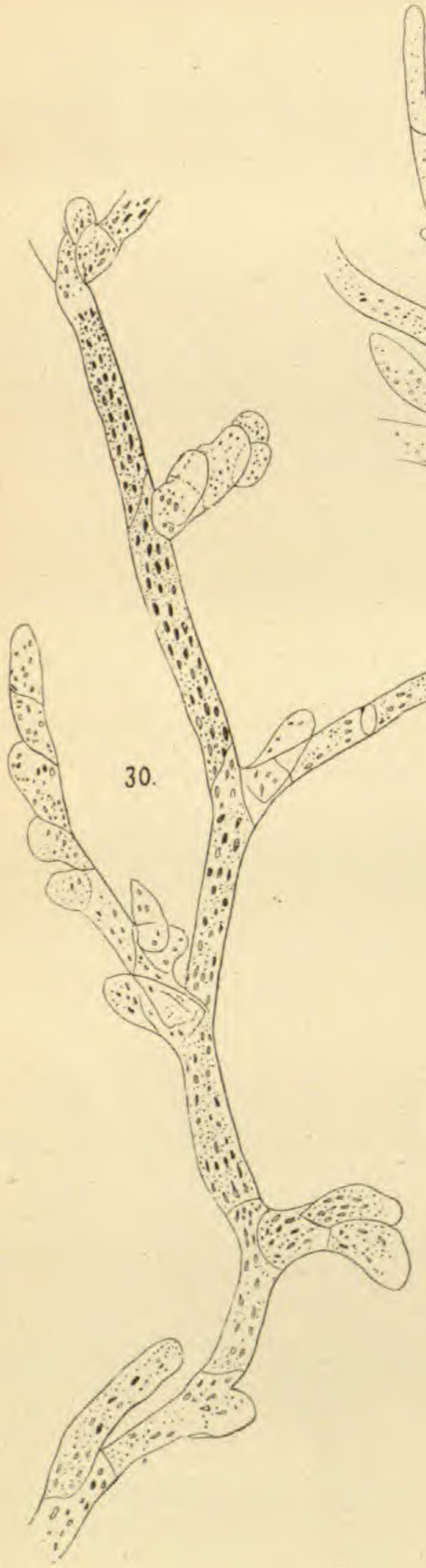
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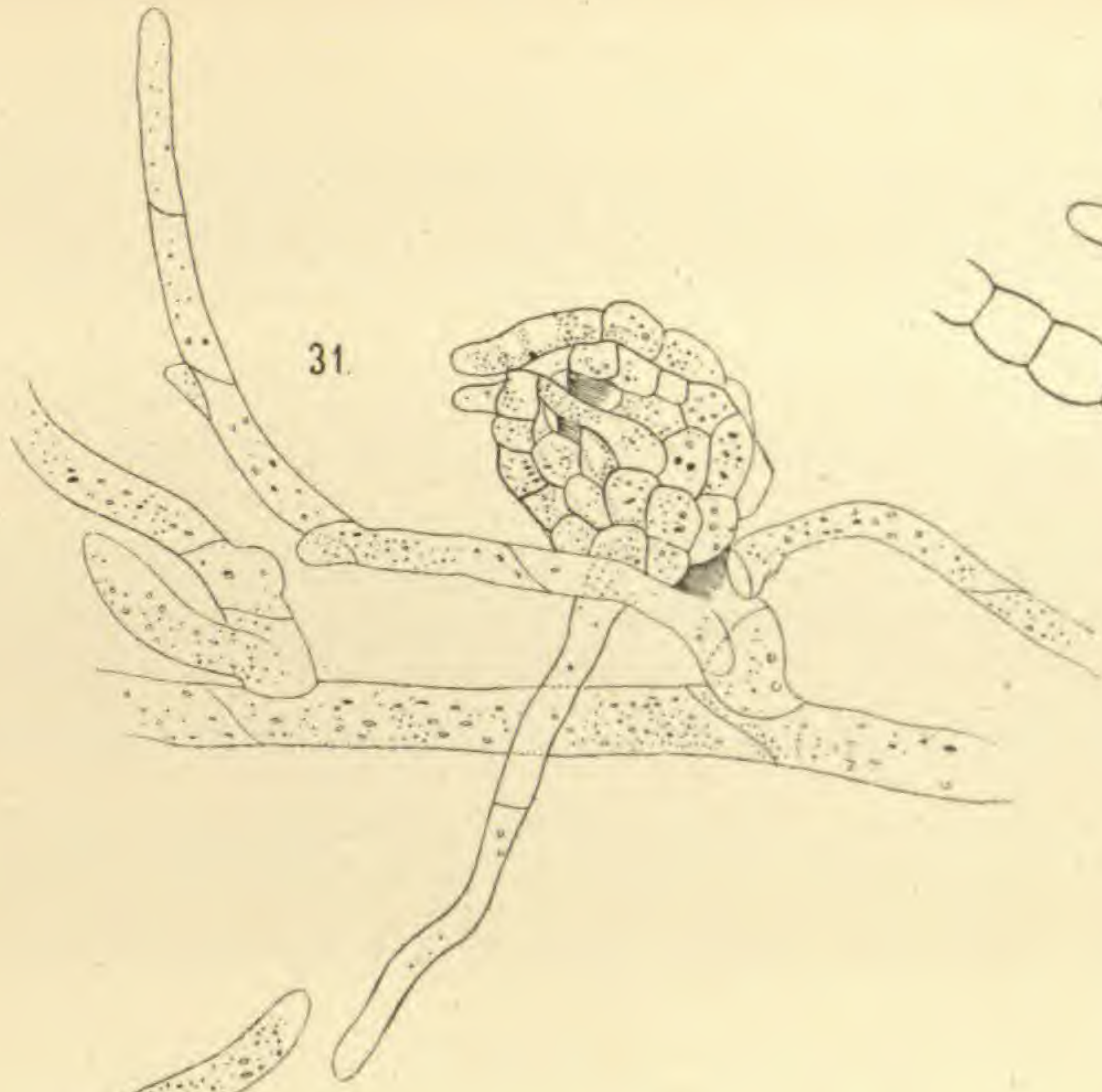
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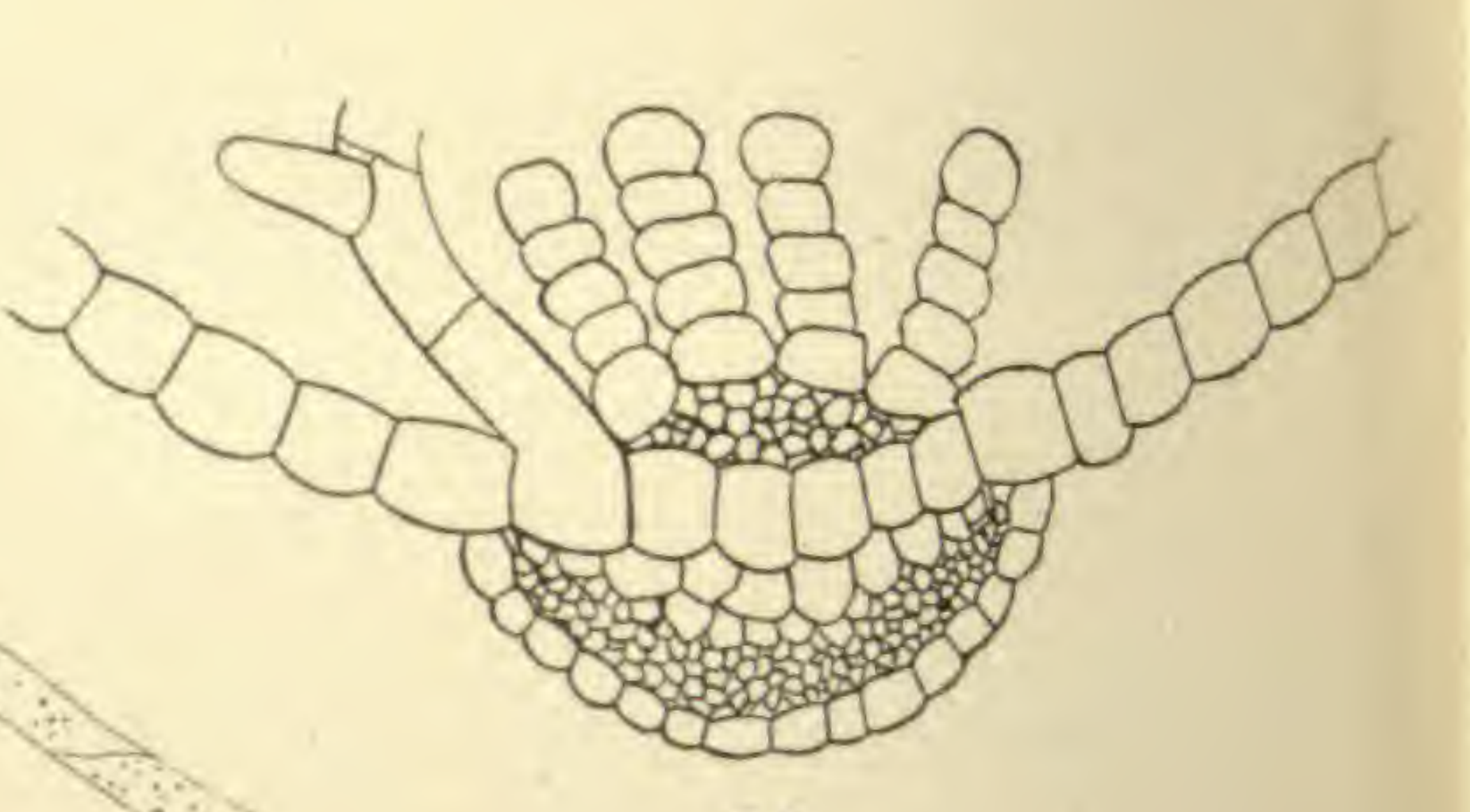
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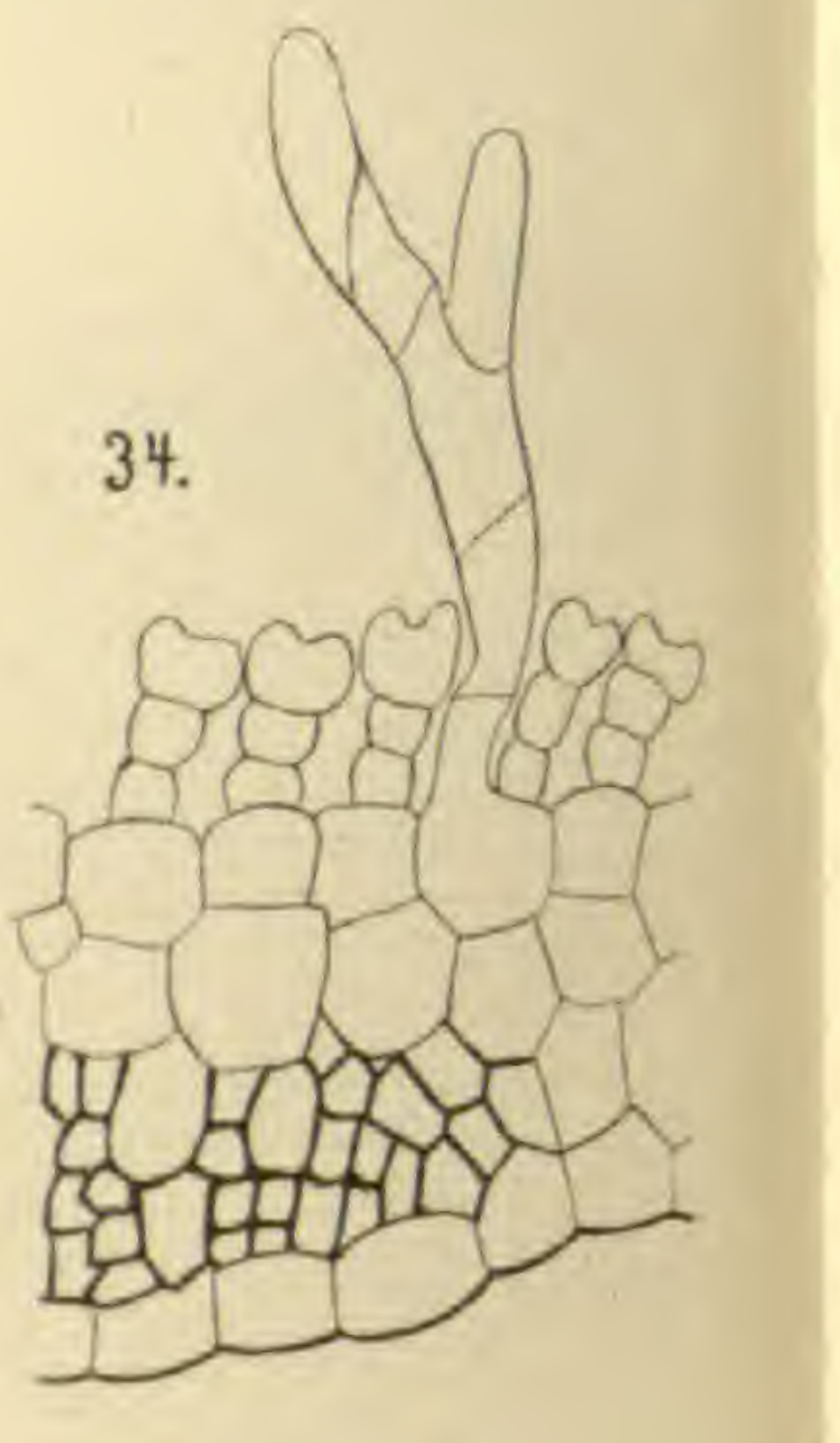
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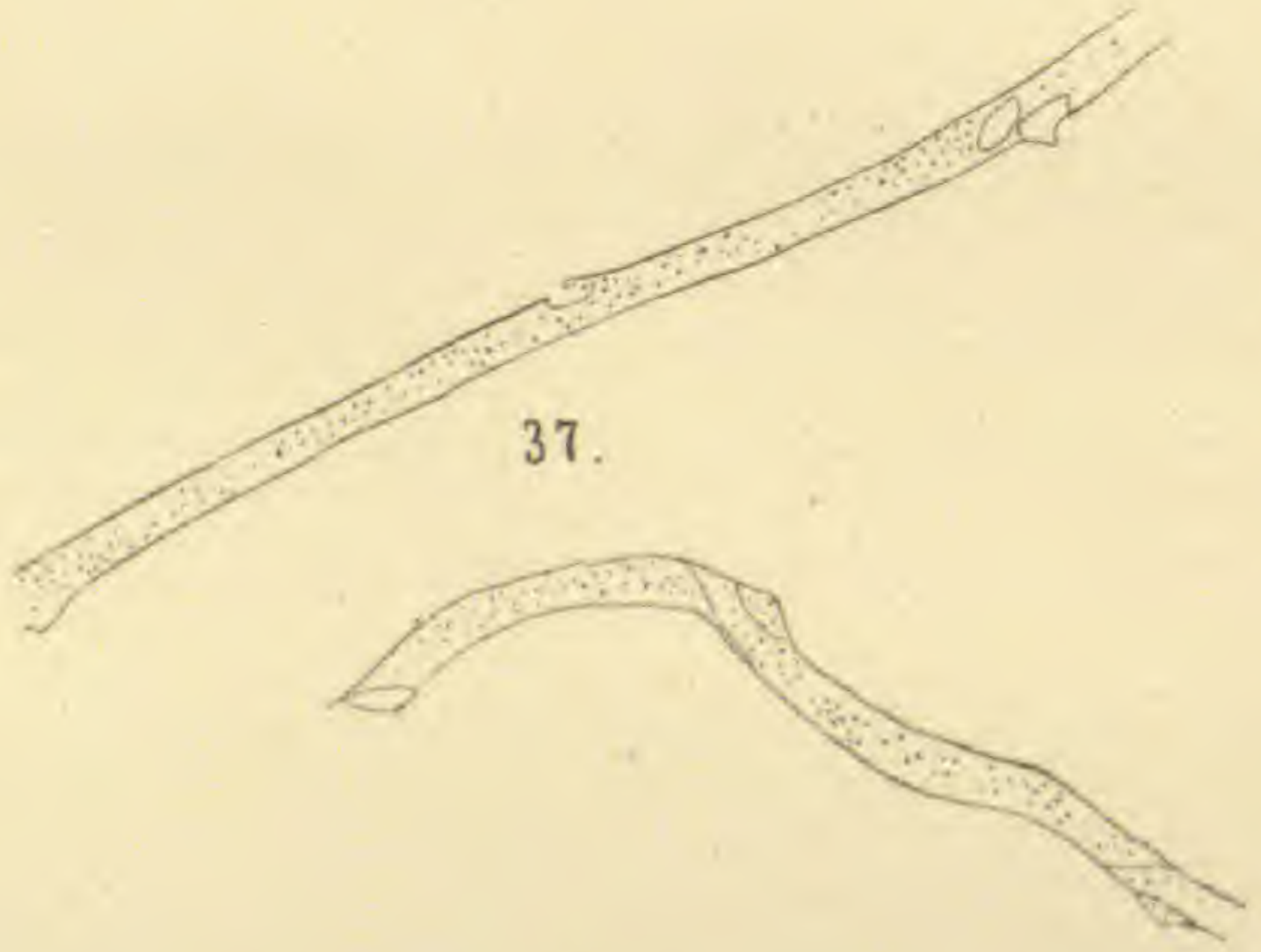
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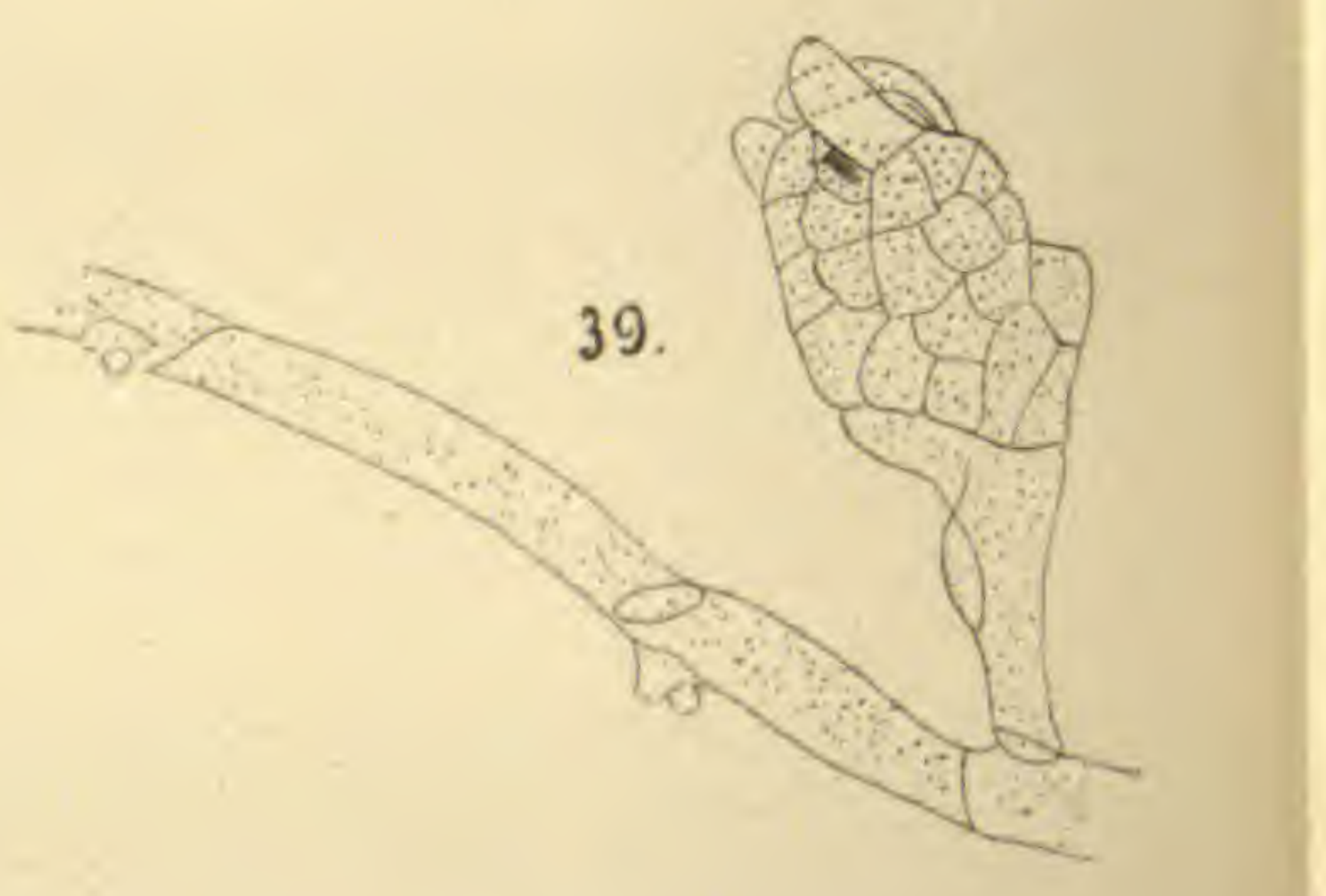
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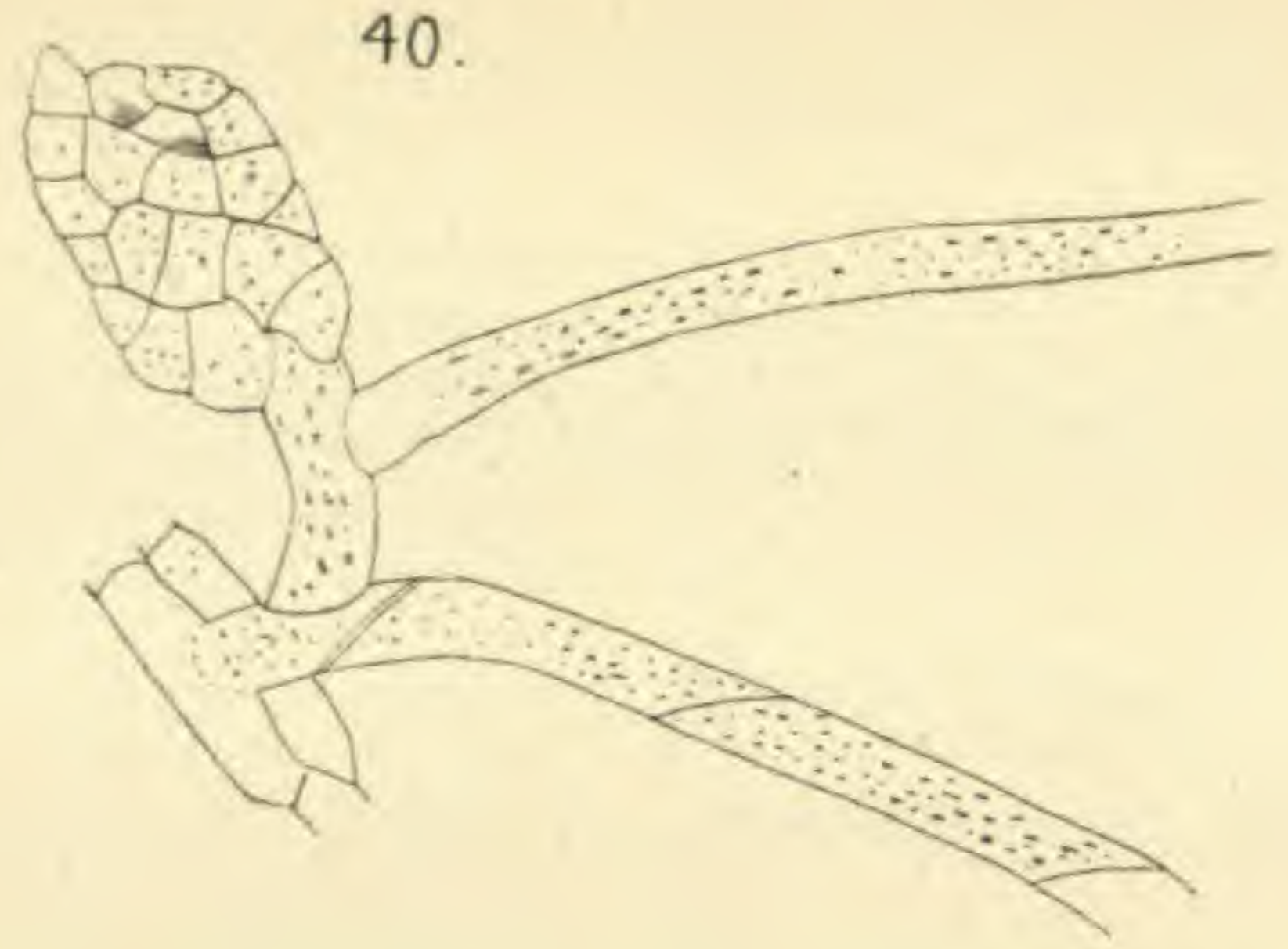
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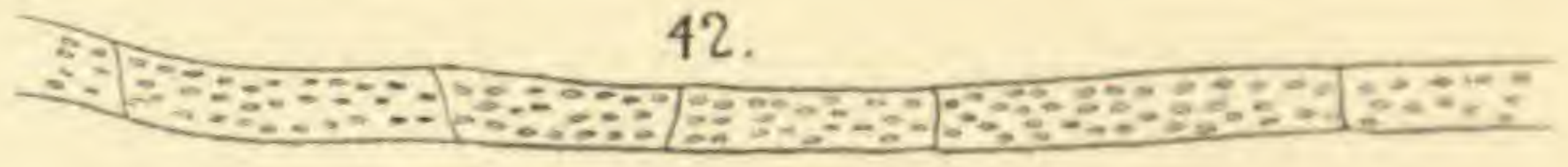
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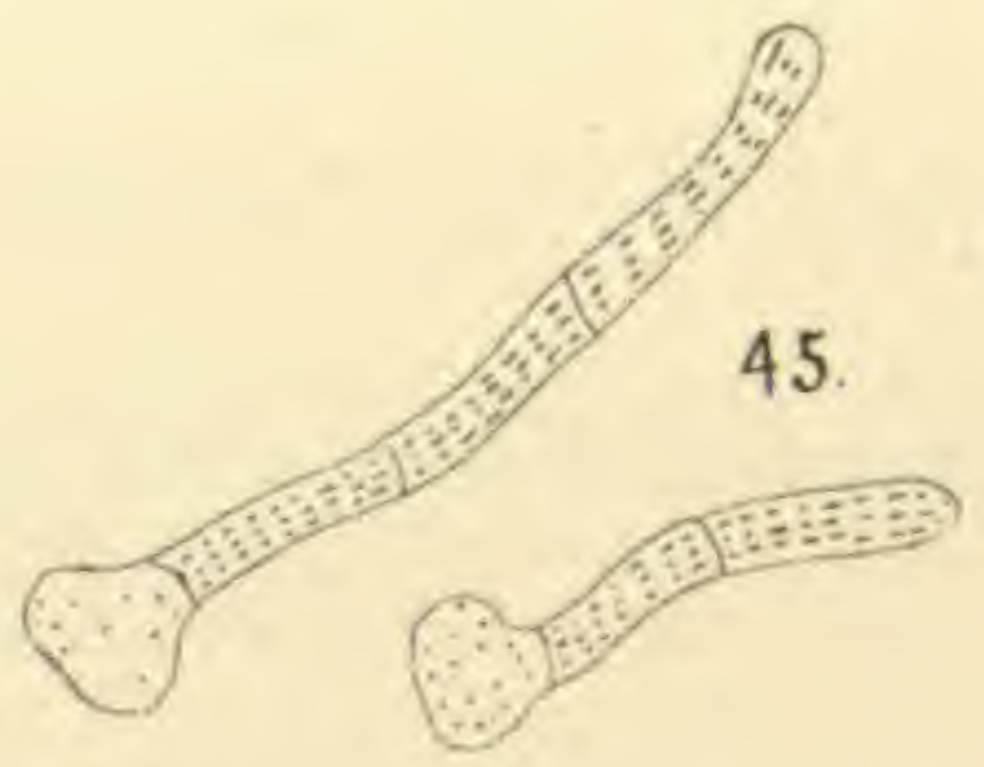
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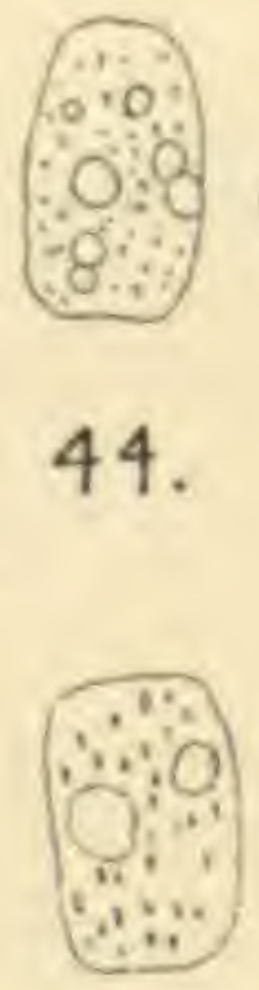
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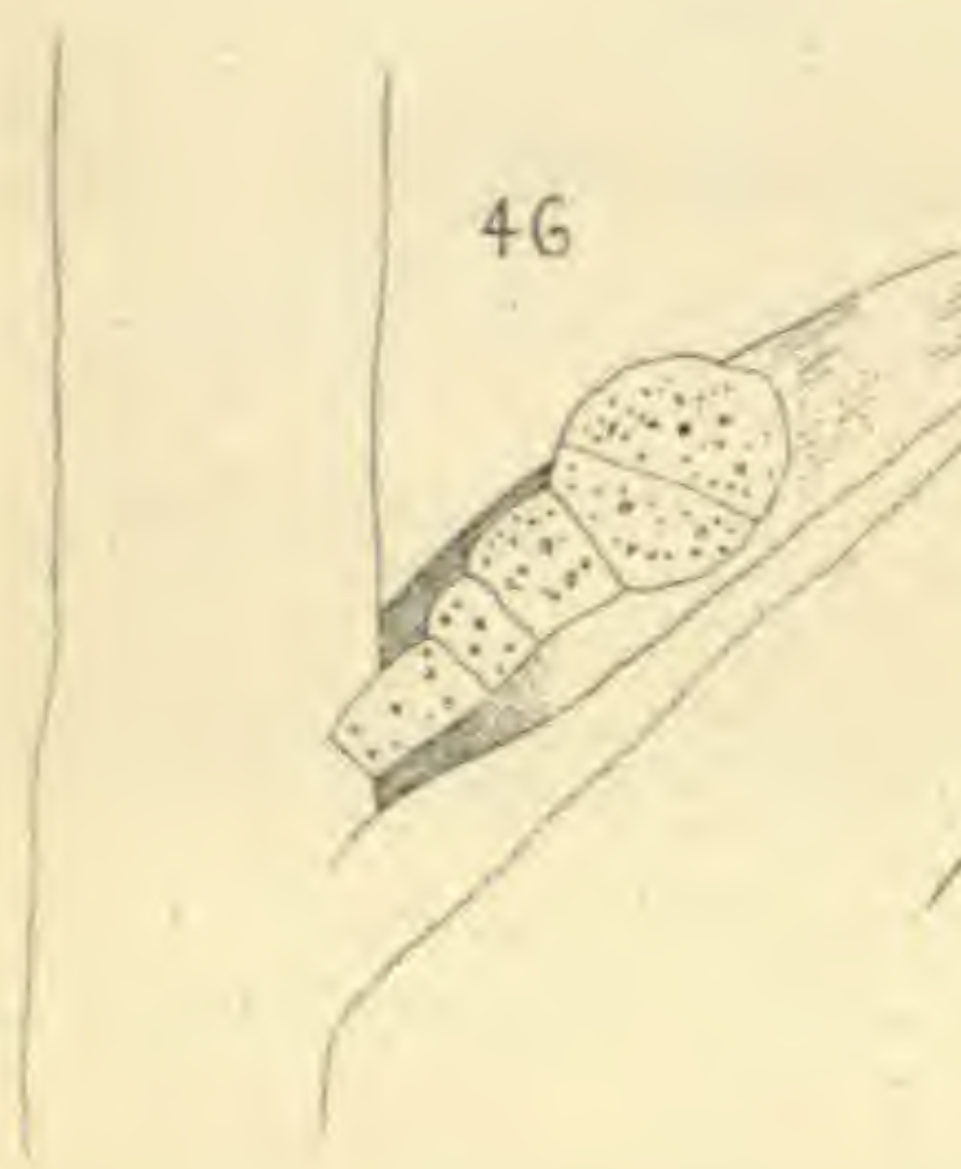
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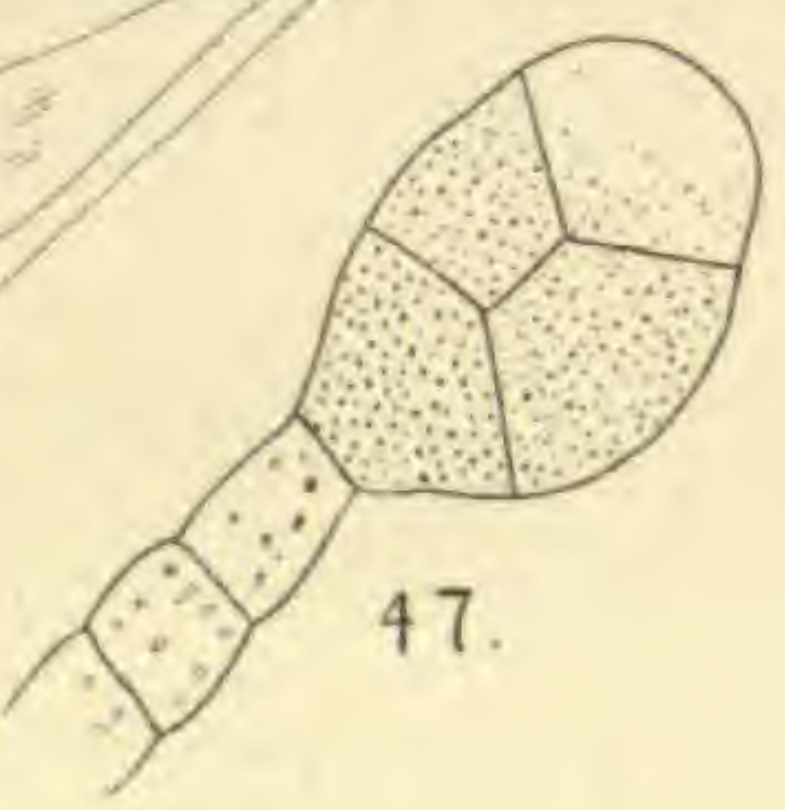
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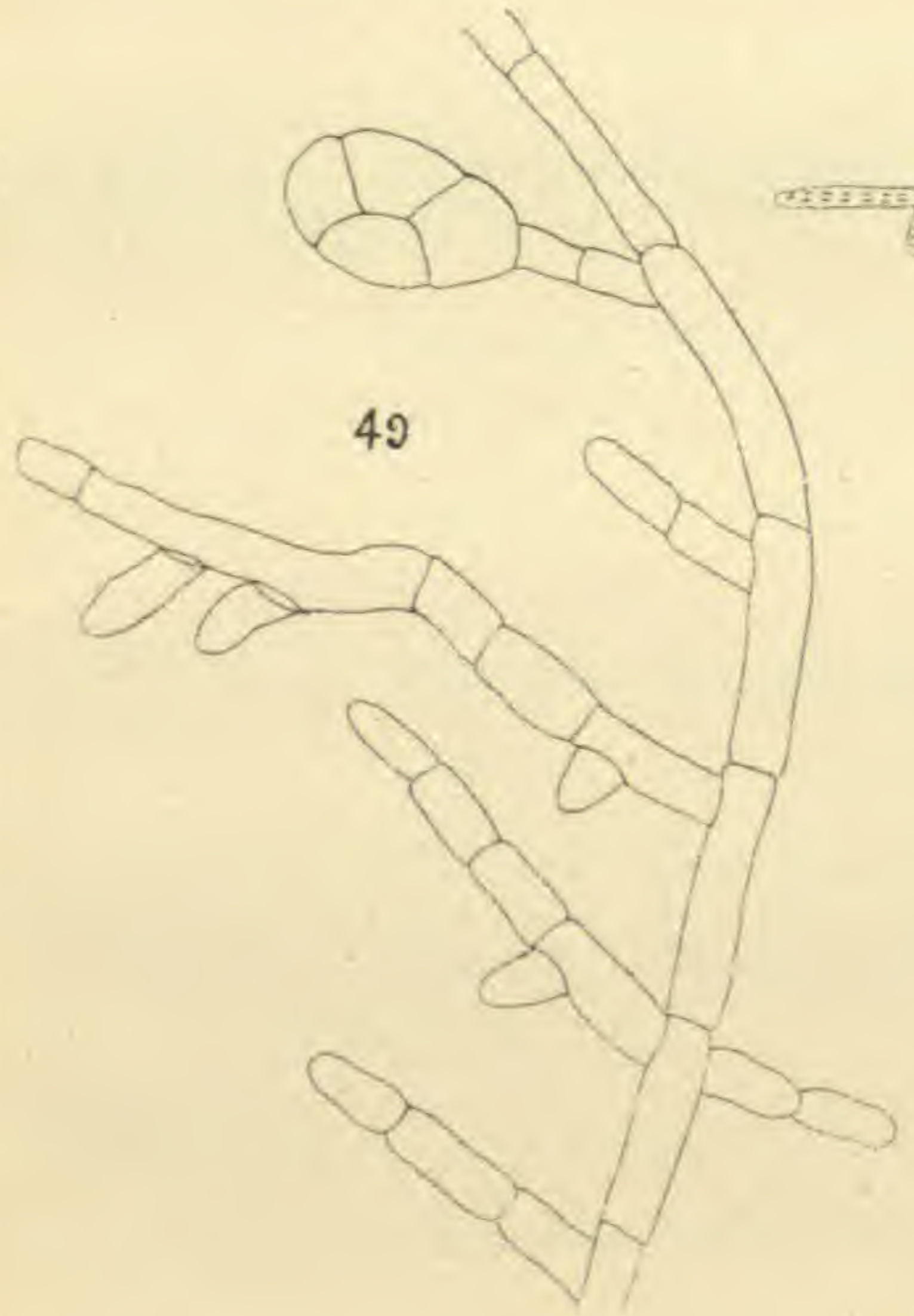
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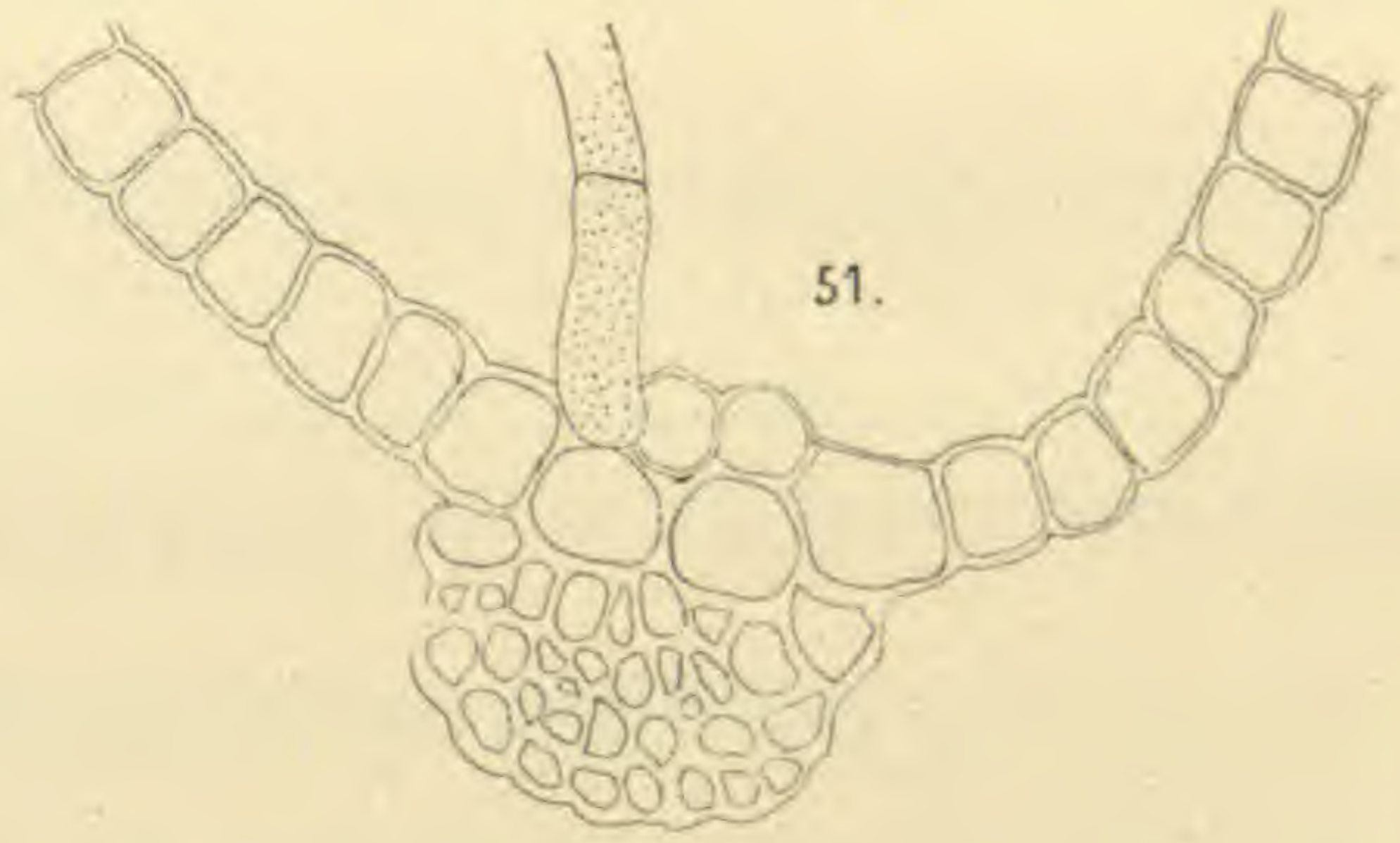
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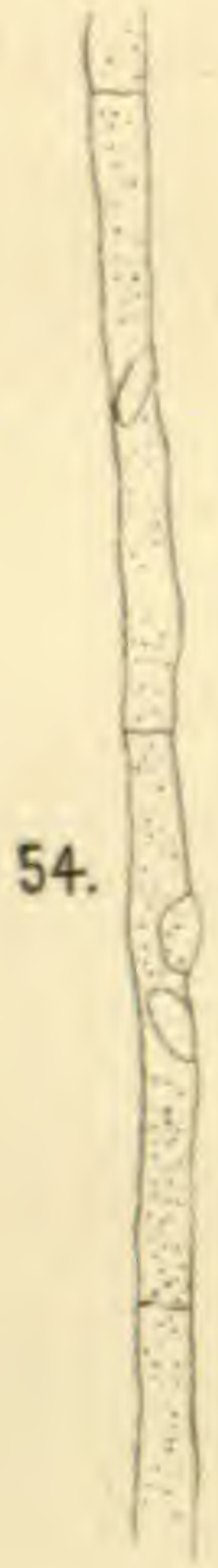
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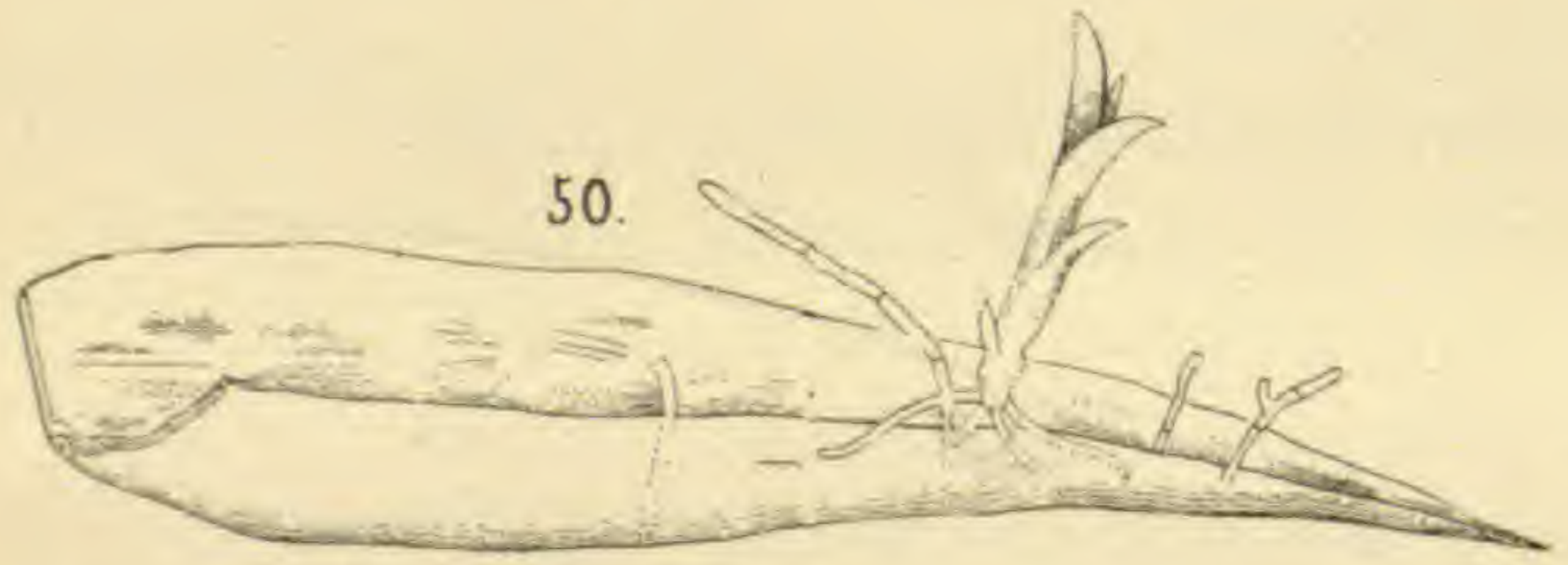
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53.

52.

HEALD on REGENERATION

FIG. 26. Portion of a defoliated stem showing the origin of protonemata and the formation of buds. × 130.

Barbula muralis.

FIG. 27. Basal portion of a leaf showing the origin of protonemata. × 130.

FIG. 28. Portion of a leaf protonema showing a bud with rudimentary leaves. × 130.

FIG. 29. Protonema with rhizoids which have been produced in light in a ten weeks old culture. × 130.

PLATE XX.

Atrichum undulatum.

FIG. 30. Protonema grown from the leaf and showing the aggregated branching so common in the leaf protonemata of Atrichum. × 130.

FIG. 31. Portion of a protonema with bud. × 130.

FIG. 32. Cross section of a leaf showing the manner in which the protonemata originate from the cells at the base of the outer lamellæ. × 130.

Polytrichum commune.

FIG. 33. Diagram of a leaf which has produced protonemata and a leafy shoot. × 6.

FIG. 34. Portion of a cross section of a leaf showing the origin of a protonema from a cell at the base of a lamella. × 220.

FIG. 35. A bud produced direct by the end cell of the main protonema axis. × 220.

FIG. 36. A portion of a leaf protonema with aggregated branching. × 220.

FIG. 37. Protonema grown from leaf in the dark. × 130.

FIG. 38. Protonema grown from leaf in the light. × 130.

FIG. 39. Portion of a protonema, and a bud grown from a leaf in the dark. × 220.

Brachythecium rutabulum.

FIG. 40. Cells from the leaf base, with bud and rhizo-protonema. × 220.

Leptobryum pyriforme.

FIG. 41. Cells of a rhizoid grown from a leaf in the dark. × 130.

FIG. 42. Continuation of the same filament after exposure to light showing a direct change to protonema. × 130.

FIG. 43. Protonema grown from a leaf axil, showing the formation of conidia-like cells by the lateral branches. × 130.

FIG. 44. Two of the separated protonema cells. × 220.

FIG. 45. Germination of two of these cells. × 130.

FIG. 46. Early stage in the formation of an axillary brood-body. × 130.

FIG. 47. Mature brood-body with its stalk. × 130.

FIG. 48. Protonema grown from the stem, and showing two lateral branches often coming from a single cell of the main axis. × 53.

FIG. 49. Protonema with a brood-body, similar to those produced in the leaf axil. × 130.

Phascum cuspidatum.

FIG. 50. Leaf showing origin of protonemata and the formation of a new leafy shoot. × 27.

FIG. 51. Cross section of a leaf showing the origin of a protonema from a cell of the ventral surface. × 220.

FIG. 52. Portion of a protonema with a bud. (*d*) Cells just above the costa. × 220.

Fissidens bryoides.

FIG. 53. Bud grown from the leaf axil of a defoliated stem without the intervention of a protonema. × 220.

FIG. 54. Rhizoid grown from a defoliated stem in the dark with perpendicular cross-walls produced by intercallary growth. × 130.

BRIEFER ARTICLES.

THE SOUTHERN MAIDENHAIR FERN IN THE BLACK HILLS OF SOUTH DAKOTA.

SPECIMENS of *Adiantum capillus-veneris* L., said to have grown wild at Cascade, in the Black Hills of South Dakota, were sent to me by Mrs. Alice M. Crary a couple of months ago. Yesterday, in company with Dr. Frederic E. Clements, I visited the locality and found the ferns growing in great abundance along the banks of a stream of warm water which issues from several very large springs. The banks of this stream, for nearly a mile, are lined with the ferns of all sizes and ages, from those just issuing from the gametophytes (which were abundant) to fruiting specimens 40 to 50^{cm} high. A thorough examination convinced us that it is indigenous along this warm stream, and that it has not been introduced by human agency.— CHARLES E. BESSEY, *The University of Nebraska, August 25, 1898.*

BACTERIAL CONTENT OF HAILSTONES.

BUJWID[1] seems to have been the first investigator to make a bacteriological examination of hailstones. The stones examined by him fell during a storm at Warschau, on May 4, 1888. He washed them carefully in sterilized water, then broke them into small pieces, put them into a sterilized test tube, and made plates from the water obtained from melting. In 1^{cc} of this water he found 21,000 bacteria, and from these he isolated the following species: *B. fluorescens liquefaciens, B. fluorescens putridus*, and *B. janthinus* (Zopf). He was of the opinion that surface water had been carried into the air by the storm and frozen, and that this fact accounted for the large number of germs found in the hail.

Foutin[2] also examined hail by bacteriological methods in 1888. The storm occurred at St. Petersburg, and the stones were about the

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[1] BUJWID, O.: Die Bakterien in Hagelkörner. Centralbl. für Bakt. 3 : 1. 1888.

[2] FOUTIN, W. M.: Die Bakteriologische Untersuchungen von Hagel. Wratsch. 1889, nos. 49, 50. Quoted from an abstract in the Centralbl. für Bakt. 7 : 372. 1890.

size of a walnut, and fell with sufficient force to break windows. The stones were carefully washed, melted, and plates made from the water. The number found was 628 to 729 bacteria per 1^{cc}. Only bacteria were discovered, and neither fungi nor yeasts were noticed. He described the morphology and cultural characteristics of two cocci, and two bacilli; of these one coccus was pathogenic in large doses to rats.

On July 15, 1897, a violent hailstorm swept over Guelph, and hail fell heavily for about fifteen minutes, with such force as to break many panes of glass in the greenhouses. The stones averaged 20^{mm} in diameter, and looked like round bullets made in a badly fitting mould, with a projecting rim around the center. A number of these were taken to the laboratory, washed in mercuric chloride (1 to 500), rinsed several times in sterilized cold water, and each stone thus treated was dropped into a tube of melted nutrient gelatine, thoroughly shaken, and plates then poured in the usual manner. Four days after the plates were counted by the aid of Pakes' apparatus; the quantitative results were as follows:

12	per	hailstone,	all bacteria.
35	"	"	" "
52	"	"	a few molds present.
53	"	"	" " "
352	"	"	nearly all molds.
368	"	"	a few molds.
608	"	"	mostly molds.
704	"	"	a few molds.
1280	"	"	" "
1440	"	"	" "
2880	"	"	" "
3680	"	"	" "

11464 : an average of 955 per hailstone.

These numbers err on the small side, as a portion of the hailstone was lost in the cleansing process. All the bacteria and a number of the moulds were isolated, and their cultural characteristics noted. Among those present were *Penicillum glaucum*, *Mucor* sp., *Aspergillus* sp., *B. fluorescens liquefaciens*, *B. fluorescens non-liquefaciens*, a protean form similar to *Proteus vulgaris* (Hauser), and one other germ subsequently described. No micrococci were found.

On July 30 another hailstorm occurred more violent than the former, but of shorter duration. Twenty hailstones were accurately measured, the largest being 25^{mm} in diameter and 18^{mm} thick, the smallest 15^{mm} by 7^{mm}. The average of the twenty was 19^{mm} by 15^{mm}. They were more spherical than those examined on the previous occasion. They were treated as previously outlined, but all were placed in a sterilized test tube, and slowly melted. Fifteen plates were made from gelatine, containing varying amounts of the hailstone water. The average number of bacteria and spores of moulds counted was 1125 per c.c. The number of moulds present was far smaller than before. Three bacilli and two cocci were isolated. *B. fluorescens liquefaciens*, and *B. fluorescens non-liquefaciens* were again present.

It is worthy of note that these fluorescing germs were present on both occasions, and, further, Bujwid also found two of this class present. The repeated presence of these micro-organisms lends additional support to Bujwid's surmise that surface water is carried up by the storm and congealed. The presence of so many moulds in the hail was probably due to contamination from the air, which at that time (July) contained numerous species.

Of the remaining germs found, one closely resembles *Sarcina alba* Zimmermann, but does not liquefy gelatine even after two weeks growth. Another appears to be closely allied to *Bacillus candicans* Frankland, but differs in its growth on potato and in milk. Two micro-organisms found do not conform to any published description in the literature at my disposal, and unless any other worker recognizes them as already described species, I would suggest that the bacillus be called *B. flavus grandinis*, and the coccus *M. melleus grandinis*.

BACILLUS FLAVUS **grandinis**.—Found in hailstones : a large bacillus, with rounded ends, occurring singly and in pairs; $1 \times 3\mu$, varying according to the media, longer when growing in bouillon ; non-motile : no spore formation observed : grows readily at 20°C., sparingly at 37°C. : aerobic, will not grow in hydrogen (Novy's method) : does not liquefy gelatine : yellow (flavus)[3] : stains readily with all the anilines : in gelatine plate culture the surface colony is about 3^{mm} in diameter, waxy, bright yellow, and appears coarsely granular with a low power ; the submerged colony is perfectly round with sharp edges, and very coarsely granular : in gelatine stick culture, after four days' growth, the line of puncture appears cloudy, and a pale lemon growth spreads

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[3] SACCARDO, P. A.: Chromotaxia seu nomenclator colorum. 1894.

over the entire surface: in agar streak culture there is abundant massive growth, glistening and faintly tinged with yellow: milk is coagulated on the fifth day, the curd solid with a yellowish cast, and per cent. of acidity 0.8: on potato a dry, beady, raised and dirty yellow growth: in fermentation tube no gas is produced in glucose bouillon, growth only in the open arm of the tube: grows well in Uschinsky's media, a ring of yellow color being deposited around the upper part of the tube: bouillon becomes slightly turbid, with thick zooglœa.

MICROCOCCUS MELLEUS **grandinis.**—Found in hailstones: a coccus, occurring singly, about 1μ in diameter: non-motile: no spore formation observed: grows well at 20°C., feebly at 37°C.: aerobic: will not grow in hydrogen (Novy's method): does not liquefy gelatine: yellow (melleus)[3]: stains readily with all the anilines: in gelatine plate cultures the surface colony small, about 1^{mm} in diameter, with an irregular margin, the outer portion a darker yellow than the center, granular; the submerged colony round, edges irregularly indented, contents granular: in gelatine stick culture a thin feather-like growth along the line of puncture, growth spreading irregularly on the surface, amber colored: in agar streak culture grows abundantly as a raised, glistening, and amber yellow-colored growth: when touched with a needle the growth adheres and can be drawn out in a long string: milk is not coagulated, and there is no acidity: on potato a dry raised growth, bright amber color, growth slow: in fermentation tube no gas is produced, and growth is only in the open arm of the tube: grows slowly in Uschinsky's media, a zooglœa of a pale yellow color being formed: in bouillon a slimy mass is formed that settles to the bottom of the tube.—F. C. HARRISON, *Guelph, Ontario.*

CURRENT LITERATURE.

BOOK REVIEWS.

Experimental physiology.

THE study of plant physiology is becoming more common, and is destined to occupy an important place in instruction both in colleges and secondary schools. One of the factors in the increasing attention given to this subject, was the publication a little more than ten years ago of the first edition of Detmer's *Pflanzenphysiologisches Praktikum*. Many teachers have relied upon this as the basis of a course of experiments. Darwin and Acton's book followed and gave many useful suggestions. When, a few years ago, MacDougal translated Oels's little book and later published a similar one as an independent guide for the simpler laboratory experiments, the secondary schools began to feel the impetus to this sort of instruction.

In 1895 a second edition of Detmer's *Praktikum* appeared, almost completely rewritten and much improved. This second edition has now been translated into English by Principal S. A. Moor, of Girasia College, India, formerly lecturer on botany in the University College of Wales.[1] The book in its German form is so well known to teachers that there is nothing to say of it in its new form, except that the translation is unusually faithful and smooth, and that the publishers have given it a worthy dress but for the flimsy binding. To announce the appearance of the English edition will be enough to put it into the hands of every teacher of plant physiology who is conducting laboratory courses. The chief regret is that the translation has been so slow in making its appearance that it is somewhat out of date. Nevertheless, it will be very useful for students in those classes which make a serious study of the subject as a preparation for research. Of course it must be used with judicious omissions, and it will need to be supplemented by such new light as has been obtained since the middle of 1894. The book is conspicuously weak in the section on the molecular forces in plants, which was by no means up to date at the time of the revision. But this and other weaknesses belong to the original, which has been before the public long enough to be thoroughly judged. It would have been, therefore, an acceptable service had the translator improved it, instead of giving us an exact reproduction.— C. R. B.

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[1] DETMER, W.— Practical plant physiology: an introduction to original research for students and teachers of natural science, medicine, agriculture, and forestry. Translated from the second German edition by S. A. Moor. 8vo. pp. xx + 555. figs. 184. London: Swan Sonnenschein & Co. New York: The Macmillan Co. $3.

The Bonn text-book.

WE have scarcely noticed the appearance of the translation of the second German edition of the Bonn text-book before the third edition is received.[2] Few books have won for themselves such instantaneous and universal approbation. This welcome, the authors feel, has put them under obligation to maintain the work abreast of the progress of botanical science. Yielding to the frequently expressed wish for references to the most important literature, they have included such in this edition. The references are brought together at the close of the volume, exceeding a thousand in number, as we estimate. This is a valuable addition.

The other improvements, besides some changes in the text of minor importance, consist in the replacing of many of the older illustrations by new ones, and the increase in the number of the colored figures to more than double that in previous editions. They now include illustrations not only of the poisonous plants but also the most important official plants of the pharmacopœia. The utility of these figures to foreigners is small, and doubtful, we think, even for medical and pharmacy students of Germany.—C. R. B.

Van Tieghem's "Elements de Botanique."

THE appearance of a third edition[3] of this work is sufficient evidence of its usefulness. The first volume (pp. 559, with 235 illustrations) deals with general botany; the second (pp. 612, with 345 illustrations) with special botany. The first volume follows practically the same outline as in the preceding edition, merely making such additions and corrections as were necessitated by recent research. No acknowledgments are made either for the figures or results of other investigators. While this might escape criticism in the case of familiar figures and statements which have been in common use for twenty years, it would seem no more than just to give credit for recent discoveries. For example, at least an "after Webber" might have been put under Webber's figures of the development of spermatozoids in Zamia. Anatomical questions, as in all of Van Tieghem's works are treated in a masterly manner. Morphology and physiology are intimately associated; for instance, the physiology of the root, stem, or leaf immediately follows the morphology of the organ.

The second volume, dealing with special botany, has undergone a decided revision. Instead of recognizing six orders of fungi, the Uredineæ and

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[2] STRASBURGER, NOLL, SCHENCK and SCHIMPER.—Lehrbuch der Botanik für Hochschulen. Dritte verbesserte Auflage. 8vo. pp. viii + 570. figs. 617, in part colored. Jena: Gustav Fischer. 1898. *M.* 8.50.

[3] VAN TIEGHEM, PH.: Éléments de Botanique. Troisiéme Édition, revue et augmentée. Paris: Masson et C^ie^. 1898.

Ustilagineæ have been included under the Basidiomycetes. In the algæ, bryophytes, and pteridophytes the classification remains unchanged, so far as orders and arrangement are concerned. The name *Astigmatées* appears as a synonym for gymnosperms, and *Stigmatées* for angiosperms. Sweeping changes have been made in the classification of angiosperms. The monocotyls have been divided into four orders, Cyperinées, Joncinées, Liliinées, and Iridinées ; but the Graminées, which previously headed the list of monocotyls, are put with the Nymphéinées in a class intermediate between monocotyls and dicotyls, and of equal rank. The Graminées seem to have been taken from the monocotyls on the ground that they have two cotyledons.

The previous classification of dicotyls was into Apetalæ, Dialypetalæ, and Gamopetalæ, each being subdivided into hypogynous and epigynous forms. The present classification is radically different, and here, too, many will hardly admit that there has been an improvement. The dicotyls are divided into two subclasses, the *Inseminées* and *Seminées*. The Inseminées include five orders : Inovulées or Loranthinées, Innucellées or Santalinées, Integminées or Anthobolinées, Unitegminées or Icacinées, and Bitegminées or Heistérinées. The second subclass contains two orders : Unitegminées, a series beginning with the Salicinées and ending with the Compositales; and Bitegminées, a series beginning with the Piperinées and ending with the Cucurbitinées. The book closes with a chapter on plant distribution.—CHAS. J. CHAMBERLAIN.

Medical botany.

STUDENTS of medicine and especially of pharmacy are required to have knowledge of a very large number of plants, widely distributed both in a taxonomic and in a geographic sense. In no other field of botany, perhaps, is the existing condition of things less satisfactory as regards really good text-books than in pharmacy. The reason for this state of affairs seems to lie in the nature of the subject. To a degree probably nowhere else observed, the subject-matter to be presented consists of unrelated facts, and the student, without aid from any guiding thread of reasonableness, is expected to make himself master of these facts. As a result the work easily becomes tedious and mechanical. In order that as many details as possible may be retained in memory, a frequent repetition of the most important things becomes well-nigh a necessity. For these reasons a book which presents these facts in a brief, pithy style must find large appreciation and use. M. L. Trabut has made an attempt to condense into a small volume[4] not only the necessary

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[4] TRABUT, L.—Précis de botanique médicale. Deuxième edition. 12mo. pp. 739. figs. 954. Paris : Masson & Cie. 1898.

information concerning plants furnishing drugs, but has extended the scope of the work to plants useful in furnishing food ; to those having poisonous properties ; and to those causing diseases. In order to make a place for one hundred and twenty-five pages dealing with the bacteriology of pathogenic forms, condensation has been carried to a great length. The interpretation by which the author has been led to this method of balancing his subjects seems rather extreme. An abundance of text-cuts, good in the main, adds value to the substance presented.—RODNEY H. TRUE.

MINOR NOTICES.

PROFESSOR A. S. HITCHCOCK has a paper in the *Monde des Plantes* on the Onagraceæ of Kansas. The geographical distribution is illustrated by states in the United States and by counties in Kansas, by the use of diagrammatic maps. His *Flora of Kansas* is in course of publication in the *Industrialist.* It consists entirely of these diagrams, sixty-five to a page. It is remarkable how thoroughly these present the facts of distribution. Kansas, on account of the great regularity of its outline and the equality of its almost rectangular counties is unusually well adapted to the use of such maps.—C. R. B.

A LIST OF MOSSES of New Brunswick, compiled by John Moser and edited by G. U. Hay, is reprinted from *Bulletin 16,* 1898, of the Natural History Society of New Brunswick, pp. 23–31. The editor has allowed an unfortunate designation of *n. sp.* to stand after those species recently described by Kindberg, which may mislead some. It is customary to use such a sign only in the original place of publication.— C. R. B.

CHICORY GROWING, as an addition to the resources of the American farmer, is advocated, guardedly, by Maurice Kains in bulletin 19 of the Division of Botany, U. S. Department of Agriculture. Last year more than 17,000,000 pounds of this root were imported.— C. R. B.

DR. J. C. ARTHUR read a paper before the last meeting of the American Carnation Society, showing the important relations of moisture to the plant and advocating the sole use of the subirrigation method of watering carnations indoors.— C. R. B.

IN A RECENT bulletin[5] of the North Carolina Geological Survey Mr. Pinchot gives brief descriptions of the trees of North Carolina, with particular attention to the local distribution of the economic species. Excellent maps, showing botanical and commercial distribution within the state and good illustrations enhance the value of the descriptions.

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[5] PINCHOT, GIFFORD, and ASHE, W.W.—The timber trees and forests of North Carolina. Bulletin no. 6, North Carolina Geological Survey, Raleigh.

Mr. Ashe's share of the bulletin is a careful description of the forest regions of the state, in which he makes the reader familiar with the practical aspects of his subject, dealing especially with the present condition of the great pine region, and the results of injudicious cutting, turpentine orcharding, pasturing, and fires.

The bulletin is not only of permanent value for the facts it contains, but is rich in suggestion, for the reader can hardly fail to approach a study of the forest problem in a more rational way after he has read these notable articles. —CHARLES A. KEFFER.

NOTES FOR STUDENTS.

MR. WALTER HOUGH[6] discusses "The environmental interrelations in Arizona" from the standpoint of an ethno-botanist. From this point of view, of course, the "interrelations" are chiefly those existing between the Arizona flora and the tribes of Arizona Indians, such as the Hopi, the Moki, and the Tuñi Indians. But Mr. Hough discusses in some detail the extremely xerophytic nature of the Arizona flora, analyzing, not very technically, its ecological features, showing that the flora of which the Indians could make use was a meager one, of extreme type and embracing some 160 indigenous species, nearly every one of which has been brought into use as a food or forage plant, as medicinal, in folk lore and religion, in domestic or other usage. Probably no other flora is so rich in descriptive folk names, and this fact bespeaks the very close "interrelations" existing. Among the Hopi Indians over 35 per cent. of the species of plants is made use of in medicine, folk lore, and religion, and it seems that the use of plants for food, house-building, and such practical purposes is of less importance. In this arid region tribe and flora are brought into very close relation, both being dependent upon the same meager water supply; and the very characters selected by plants as protective against the rigors of environment are often those most useful to the tribes in furnishing medicines or charms of real or inferential value.

A valuable part of Mr. Hough's contribution is the complete list of species, including about 173 species, with the descriptive names given by the Hopi Indians, and the part each species plays in relation to the tribe.—W. L. BRAY.

THREE CASES of abnormal development of the inferior ovary in species of Opuntia are described and illustrated with colored plates by Dr. Ramírez, of Mexico.[7] In the first a fruit, otherwise normal, appears as the terminal

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[6] Amer. Anthropologist 11: 133–155. 1898.

[7] Tres monstruosidades en ovarios ínferos. Annales del Instituto Medico Nacional 3: 223–227. [Lám. V–VII] Ja., F. 1898.

third of a cladodium, the one being a direct continuation of the other without constriction or articulation. The second case is of a fruit formed within the upper portion of a cladodium and swelling the otherwise flat branch as if the ovary had been forced into it from above. The third anomaly is of a fruit bearing on its sides thirteen smaller fruits, all apparently normal. Dr. Ramírez discusses their morphological significance and concludes that all three cases strongly support the view that the inferior ovary of the Cactaceæ is axile in nature.—FREDERICK LEROY SARGENT.

BELAJEFF'S recent paper[8] on the reduction division of the plant nucleus is quite a surprise. Haecker intimated in 1895 that the figures of Strasburger and Guignard might indicate a reduction division in plants, but the efforts of botanists, especially of Miss Sargant, have given only negative evidence. The zoologist Ishikawa, who studied pollen mother cells of *Allium fistulosum*, gives the only report of a reduction division in plants. Strasburger and Mottier described such a division in pollen mother cells of Lilium and Podophyllum, but almost immediately acknowledged that the work needed reinvestigation. Belajeff now comes forward with a genuine reduction division (in the sense of the Freiburg school) in the second division of the pollen mother cells of Iris. For evidence he relies upon the shape of the chromosomes, and gives figures illustrating the shape taken by chromosomes in vegetative division, heterotype division, and his reduction division. He claims that previous investigators have not been able to interpret properly this division on account of vague conceptions of division in vegetative cells. Following Haecker's scheme his formulæ are as follows. For the vegetative division:

$$\frac{a \quad b \quad c \quad d \quad e \quad f \quad \text{etc.}}{a \quad b \quad c \quad d \quad e \quad f \quad \text{etc.}}$$

In the heterotype division the chromosomes are united in pairs with the following formula:

$$a + b \quad c + d \quad e + f \quad \text{etc.}$$

Their division leads to the formation of daughter nuclei with the segments:

$$\frac{a + b \quad c + d \quad e + f \quad \text{etc.}}{a + b \quad c + d \quad e + f \quad \text{etc.}}$$

The second division in the pollen mother cells leads to the separation of the halves of the segments:

$$\frac{a \quad c \quad e \quad \text{etc.}}{b \quad d \quad f \quad \text{etc.}}$$

Whether the grouping of the segments is accidental or determined must remain unanswered. At any rate, the chromosomes of the nuclei resulting

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[8] Ber. der deutsch. Bot. Gesells. 16:27–34. 1898.

from the reducing division are not identical, a fact which may help explain the difference between descendants of the same parents. — CHAS. J. CHAMBERLAIN.

ONE OF THE MOST common requests made of a botanist is to give some simple rule by which edible and poisonous fungi may be distinguished. The Department of Agriculture has done great service in publishing a bulletin upon the subject, to which botanists may refer their correspondents, and it could not have done a wiser thing than to secure Dr. W. G. Farlow to prepare it. The account is very simple and effective and is designed to be a sort of primer for the beginner who does not know fungi, but who wants to eat them. The following rules are given for the beginner:

1. Avoid fungi when in the button or unexpanded stage; also those in which the flesh has begun to decay, even if only slightly.

2. Avoid all fungi which have stalks with a swollen base surrounded by a sac-like envelope, especially if the gills are white.

3. Avoid fungi having a milky juice, unless the milk is reddish.

4. Avoid fungi in which the cap, or pileus, is thin in proportion to the gills, and in which the gills are nearly all of equal length, especially if the pileus is bright colored.

5. Avoid all tube-bearing fungi in which the flesh changes color when cut or broken, or where the mouths of the tubes are reddish, and in the case of other tube-bearing forms experiment with caution.

6. Fungi which have a sort of spider web or flocculent ring around the upper part of the stalk should in general be avoided.—J. M. C.

FL. TASSI, of the University of Siena, has been investigating the anatomy and morphology of the Proteaceæ, using *Stenocarpus sinuatus* Endl. as a type. The results are published in a bulletin of the laboratory, with thirteen plates, more or less colored. The many interesting anatomical peculiarities of the group are plainly set forth in detail. The morphological features seem much as usual, at least so far as they relate to the development of the microspores and megaspores, and their germination.— J. M. C.

MARCUS HARTOG[9] has suggested recently that the function of chromatin in nuclear division may be a mechanical one, and that linin may be the important substance. "The splitting of a viscid thread is one of the most difficult mechanical feats to accomplish. Suppose, then, that there is a certain polarity about the granules of chromatin, through which, after their division, they tend to recede from their fellows as far as possible; through this they will determine a splitting of the filament on which they are strung. The close of nuclear division sees their task accomplished; and, as we should expect, the chromatic granules, having fulfilled this appointed task, now atrophy, and

[9] Natural Science **13**:*119*. 1898.

remain in this state till the approach of a new cell-division determines a fresh growth of their substance. According to this view the linin is the transmitter of inherited properties, and the chromatin has a purely mechanical function in karyokinesis."—J. M. C.

ITEMS OF TAXONOMIC INTEREST are as follows: In his treatment of the Umbelliferæ (Engler and Prantl *Nat. Pflanzenfam.*) Drude proposes the new genus *Tænidia,* based upon *Pimpinella integerrima* Gray (3^8 : 195), and reduces *Berula* to a subgenus under *Sium* (3^8 : 195).—W. P. Hiern has described (*Jour. Bot.* 36 : 289–291. 1898) two new genera of Compositæ from Welwitsch's African collection: *Pseudotrichia,* an asteroid form; and *Adenogonum,* a genus which does not accord with any of the recognized tribes, but is thought to be an aberrant senecioid form.—James Britten (*Jour. Bot.* 36 : 297–302) has been examining the types, mostly in the Banksian herbarium, of plants described in Smith's "History of the rarer lepidopterous insects of Georgia" (1797), and publishes his conclusions in reference to six species, which have considerable bearing upon their synonymy.—The *Bulletin of Miscellaneous Information,* issued by the Royal Botanic Gardens of Trinidad, continues its publication of the pteridophytes of the British West Indies and Guiana. The current one (no. 15) presents the genera Alsophila (14 spp.), Hemetelia (15 spp.), and Cyathea (25 spp.).—Thomas H. Kearney has published (Bulletin 11, Division of Agrostology) a revision of the North American species of Calamagrostis, recognizing thirty-eight species north of Mexico, eleven of which are new. The revision also contains a very interesting section upon the ecology of the group.—In the same bulletin F. Lamson-Scribner describes and illustrates, with seventeen plates, twenty-eight new species of grasses. New species are added to Elymus (5), Poa (5), Panicum (4), Sporobolus (3), Stipa (3), Agropyron (2), and six other genera.—George V. Nash has published (*Bull. Torr. Bot. Club* 25 : 432–450. 1898) a revision of *Chloris* and *Eustachys* in North America. Although often united as two sections of a single genus, the author regards them as worthy of generic separation. Ten species of Chloris are recognized, two of which are new, and four species of Eustachys.—E. O. Wooton continues (*Bull. Torr. Bot. Club* 25 : 451–459. 1898) his descriptions of miscellaneous new plants from New Mexico, the last fascicle adding species to ten genera.—J. M. C.

NEWS.

DR. GEORG KARSTEN, privatdocent in the University of Kiel, has been promoted to an associate professorship.

DR. GEORG KLEBS, professor of botany and director of the botanic gardens at the University of Basel, has been appointed to the same position in the University of Halle.

DR. HENRY C. COWLES, in charge of plant ecology at the University of Chicago, has had a field class of twelve at work for six weeks on North Manitou island, Lake Michigan.

THE FIRST number of the new volume of the *Minnesota Botanical Studies* appears in a new dress of very handsome type. This makes it one of the best printed of botanical publications.

MR. A. A. HELLER has resigned his position at the University of Minnesota, to give all his time to collecting. Correspondence in reference to the Exchange Bureau should be directed to Professor Conway Macmillan.

THE DEATH is announced of Dr. Anton Kerner, Ritter von Marilaun, professor of systematic botany and director of the botanical gardens and museum of the University of Vienna. He is best known as the author of *Pflanzenleben,* of which a second edition is now in course of publication. The first edition was recently translated into English and published as *The Natural History of Plants.*

PROFESSOR FERDINAND COHN, director of the institute for plant physiology of the University of Breslau, died on June 25 of heart disease, at the age of 70. He has been professor of botany at Breslau for almost forty years. His series of popular lectures, issued under the title *Die Pflanze,* went through several editions and were models of accurate and elegant presentation. He was editor of the series of monographs entitled *Beiträge zur Biologie der Pflanzen,* which came to a close a few years ago.

PROFESSOR DR. SIMON SCHWENDENER, director of the botanical institute of the University of Berlin, has been made a knight of the order *Pour le merite,* in the class of science and art. This order was founded by Frederick the Great, as a mark of distinction for military service, but the statutes were revised in 1842 by Frederick William IV to include scientific men and artists of distinction. The latter class is limited to thirty Germans and the same number of foreigners. The order is practically conferred by vote of the members. Schwendener is the only botanist thus honored.

DR. E. LEWIS STURTEVANT died at his home in Framingham, Mass., on the 30th of July, at the age of 56. While not a professional botanist, he was a special student of plant variation under cultivation, and was thoroughly informed of the bearing of botany upon agriculture. He accumulated one of the finest collections of prelinnean books in existence, and donated this, a few years ago, together with his notes on the genus Capsicum, to the Missouri Botanical Garden. The study of this genus, for which he stipulated, was published in the last report of the garden, shortly before his death.

HERBERT LYON JONES, professor of biology in Oberlin College, died at his father's home in Granville, Ohio, Saturday, August 27, 1898, after an illness lasting for two months. Professor Jones was born in Granville February 11, 1866. He graduated from Denison University in 1886, and followed this with a year of special study at his *alma mater*. His graduate work was taken at Harvard University, where he was highly esteemed in his department. He taught for several years in Radcliffe College, until about a year ago, when he was chosen to the chair in Oberlin. He was a man of sterling character, who worked diligently in his profession and gave promise of an exceedingly useful career.

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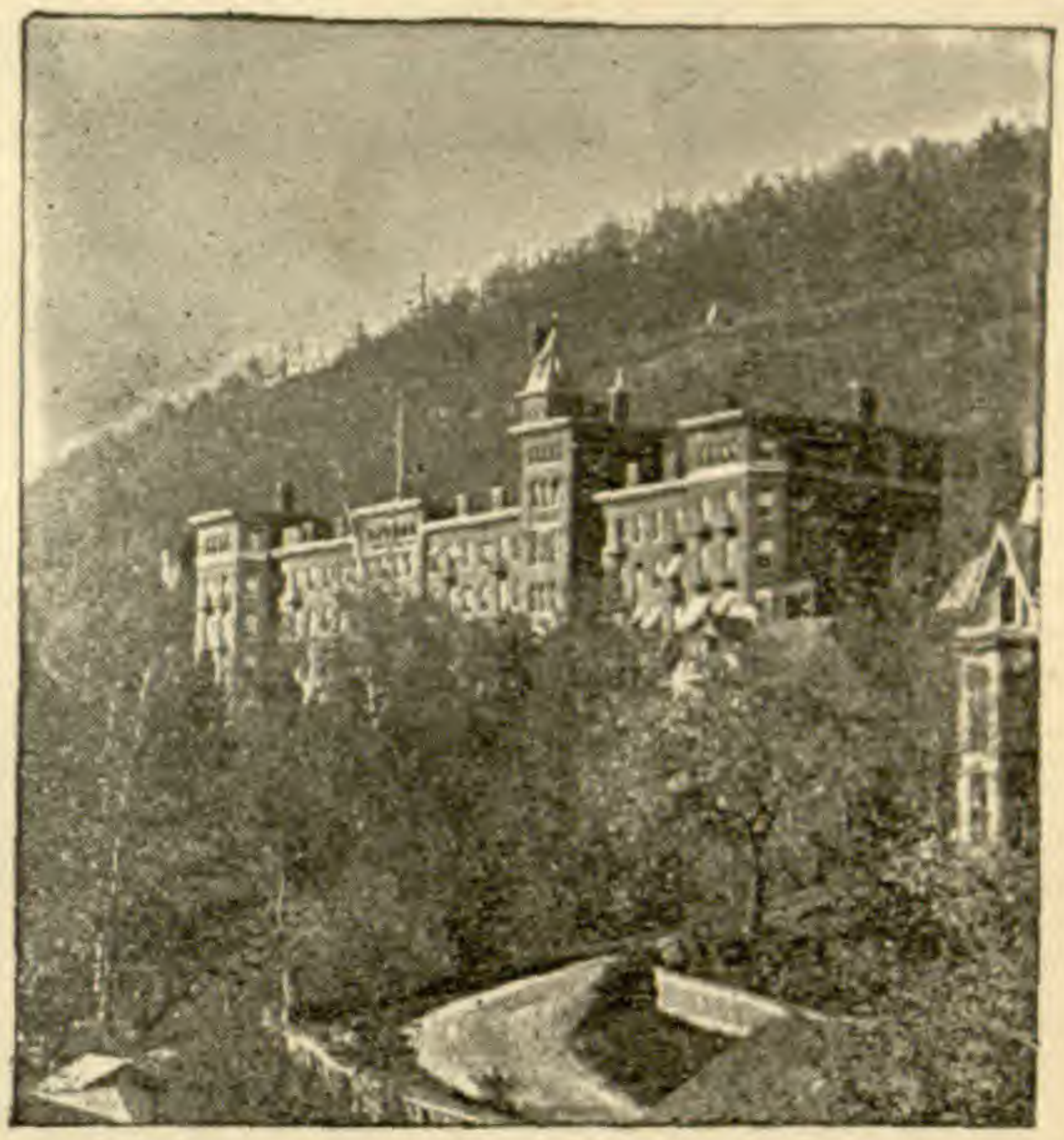

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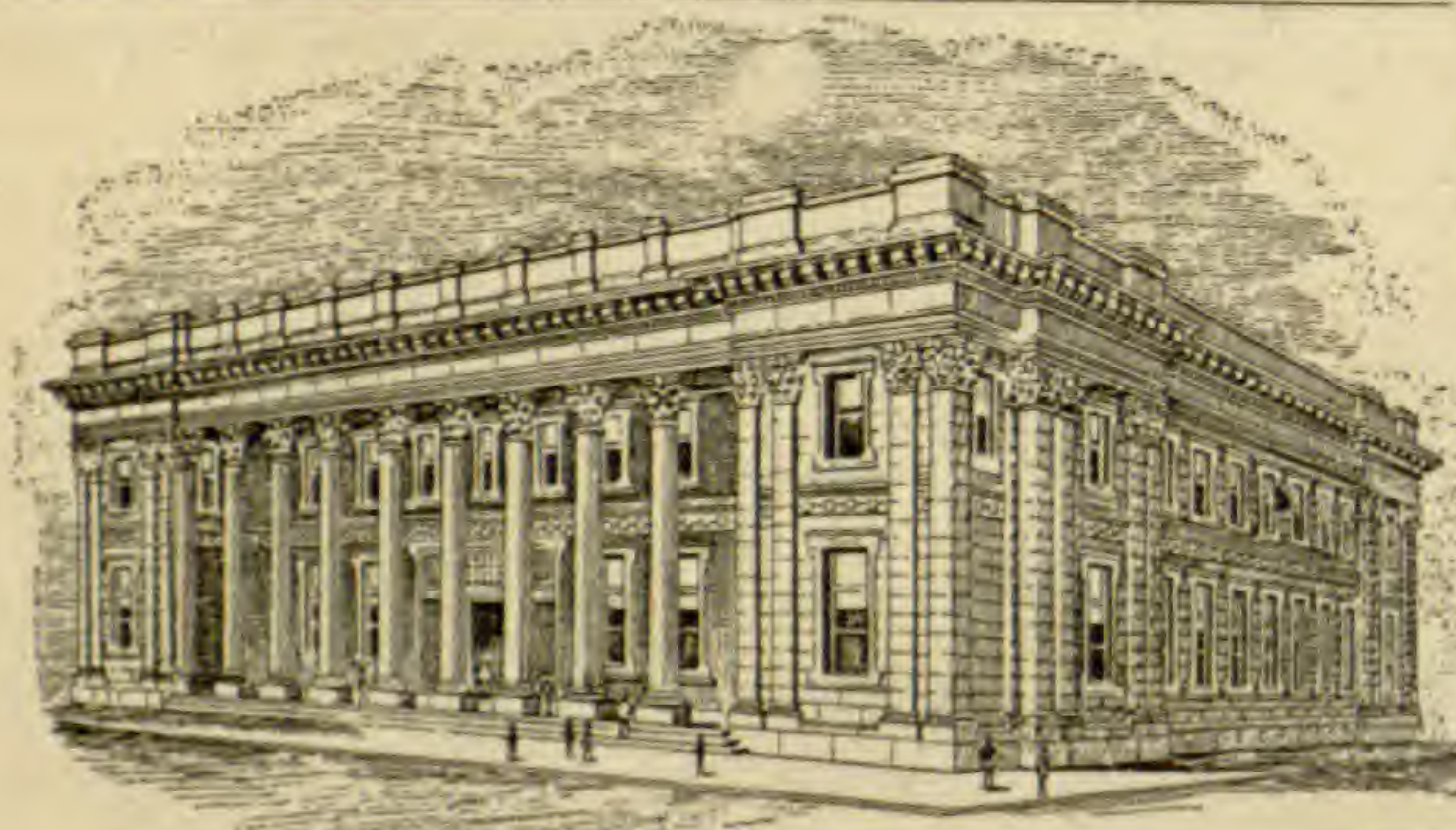

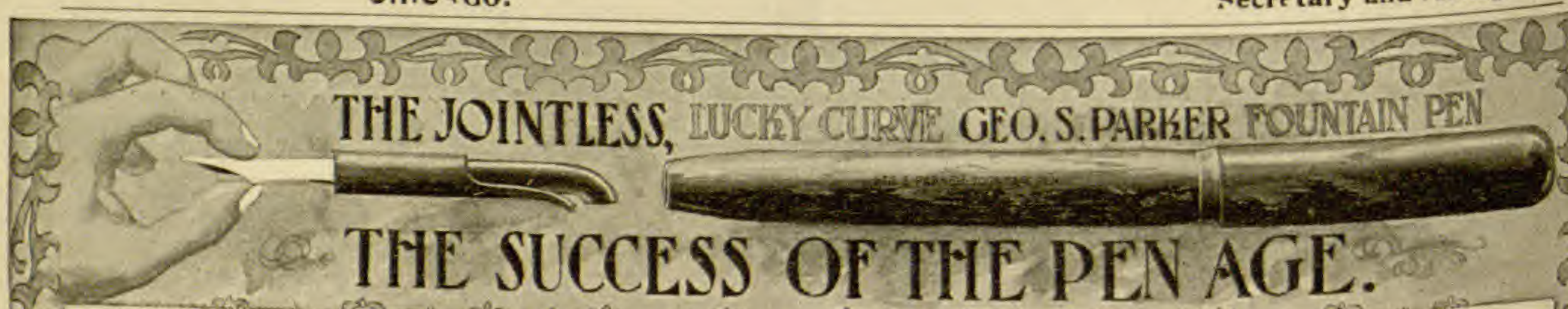


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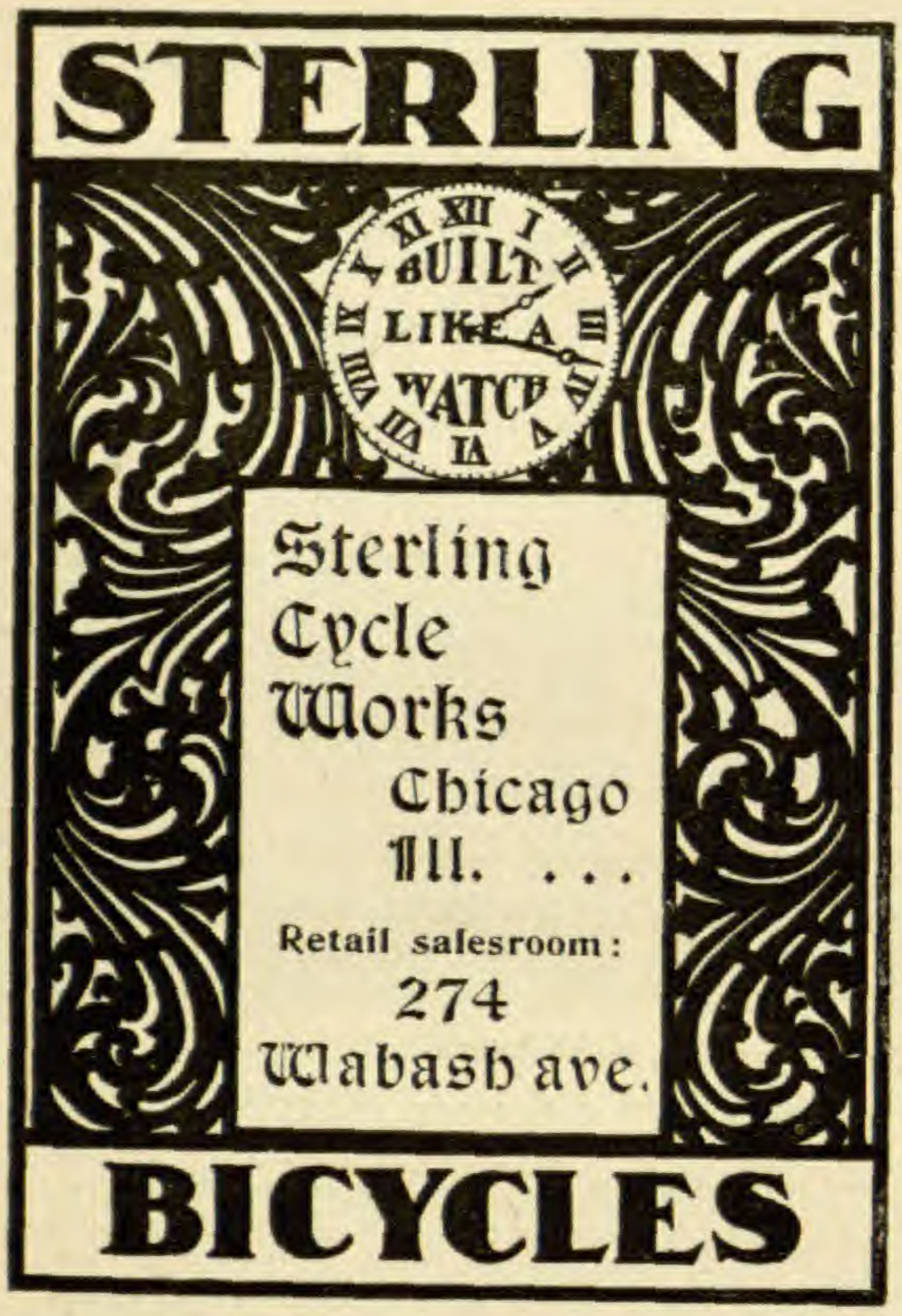

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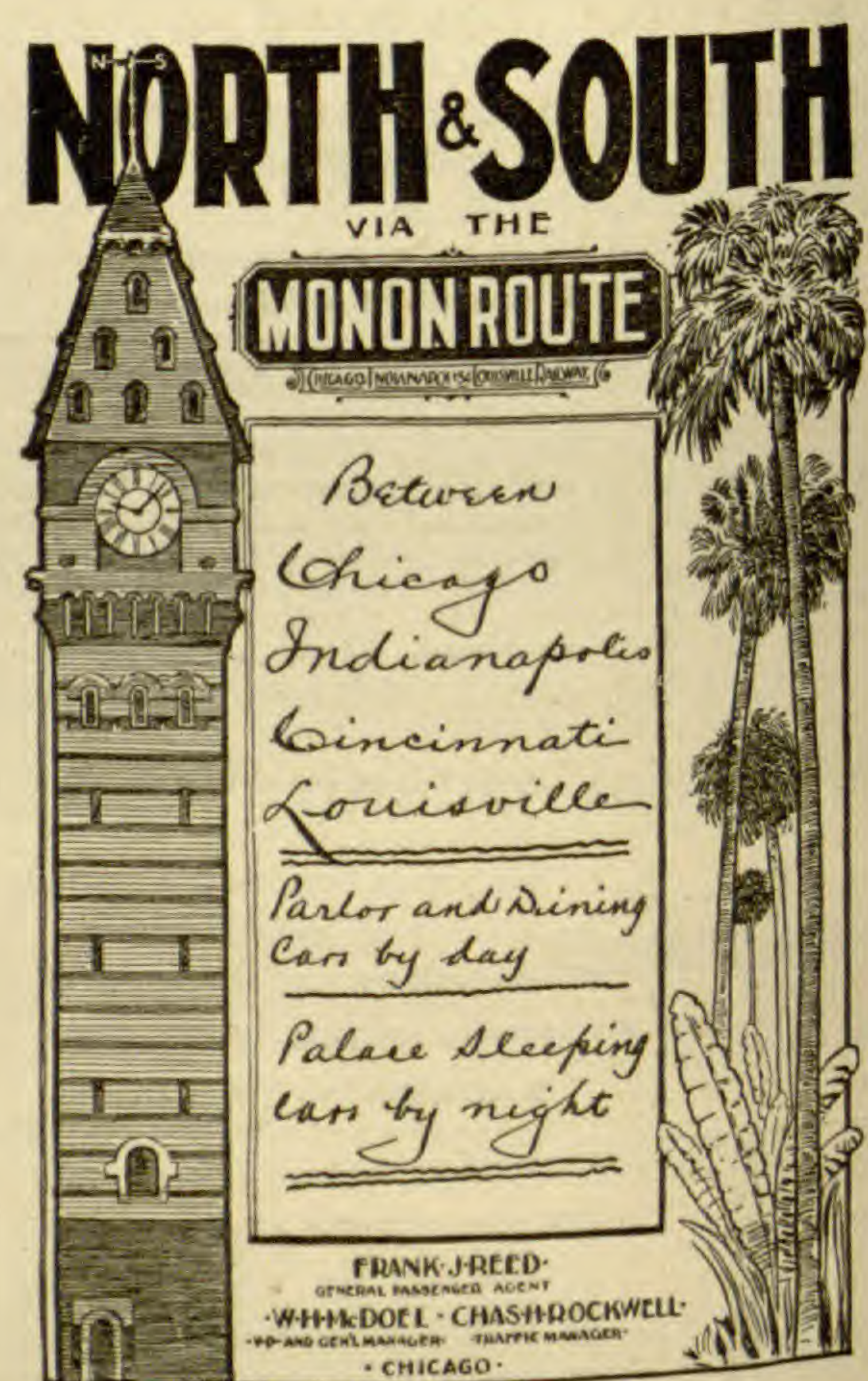

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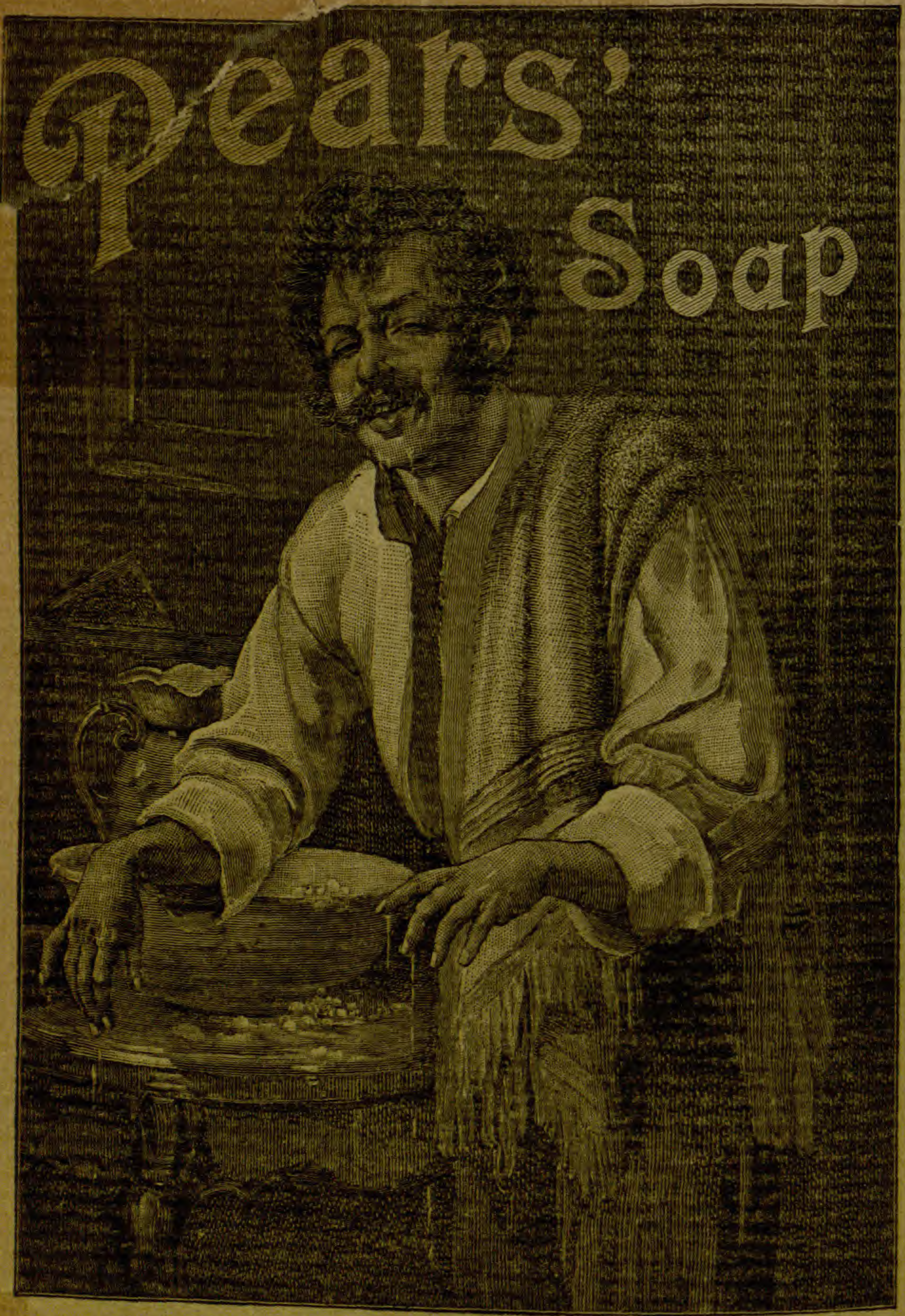
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THE LATER LIFE OF LINCOLN

Miss Tarbell's papers on the later life of Lincoln will begin in the November number. They tell the story of Lincoln's life from the time of his first nomination to the Presidency to his death. It is a short period, but it was tremendously eventful, and Miss Tarbell has collected a great deal of new material about it.

Reminiscences of Lincoln by Personal Friends,

Unpublished letters and unpublished documents have been placed at her disposal. Then she has derived from talks and correspondence with men prominent in the events of the time recollections of Lincoln that give new glimpses of his character. The papers will exhibit Lincoln at his home in Springfield between the time of his nomination and his inauguration, and in his daily life in the White House, giving a complete picture of the man throughout the last five years of his life, and also an account of such of the movements of the war as centered in him.

STORIES BY RUDYARD KIPLING

Short stories and poems by Mr. Kipling will continue to appear from time to time in the Magazine. Mr. Kipling has lately returned to England from a sojourn in South Africa, during which he has had some rare experiences, and which, it is safe to assume, will give a new and peculiar interest to his coming work.

TRUE INDIAN STORIES, by Hamlin Garland

Mr. Garland has spent many months among the Indians, gathering their reminiscences and traditions. In coming numbers of the Magazine will appear *Sitting Bull's Defiance*—a fine story of Sitting Bull's refusal to treat with a commissioner from the Government, and his insensibility to fine words and rich gifts; and *Rising Wolf, Ghost Dancer*—Rising Wolf's autobiography, giving strange instances of his power of magic and his own story of how he acquired the power.

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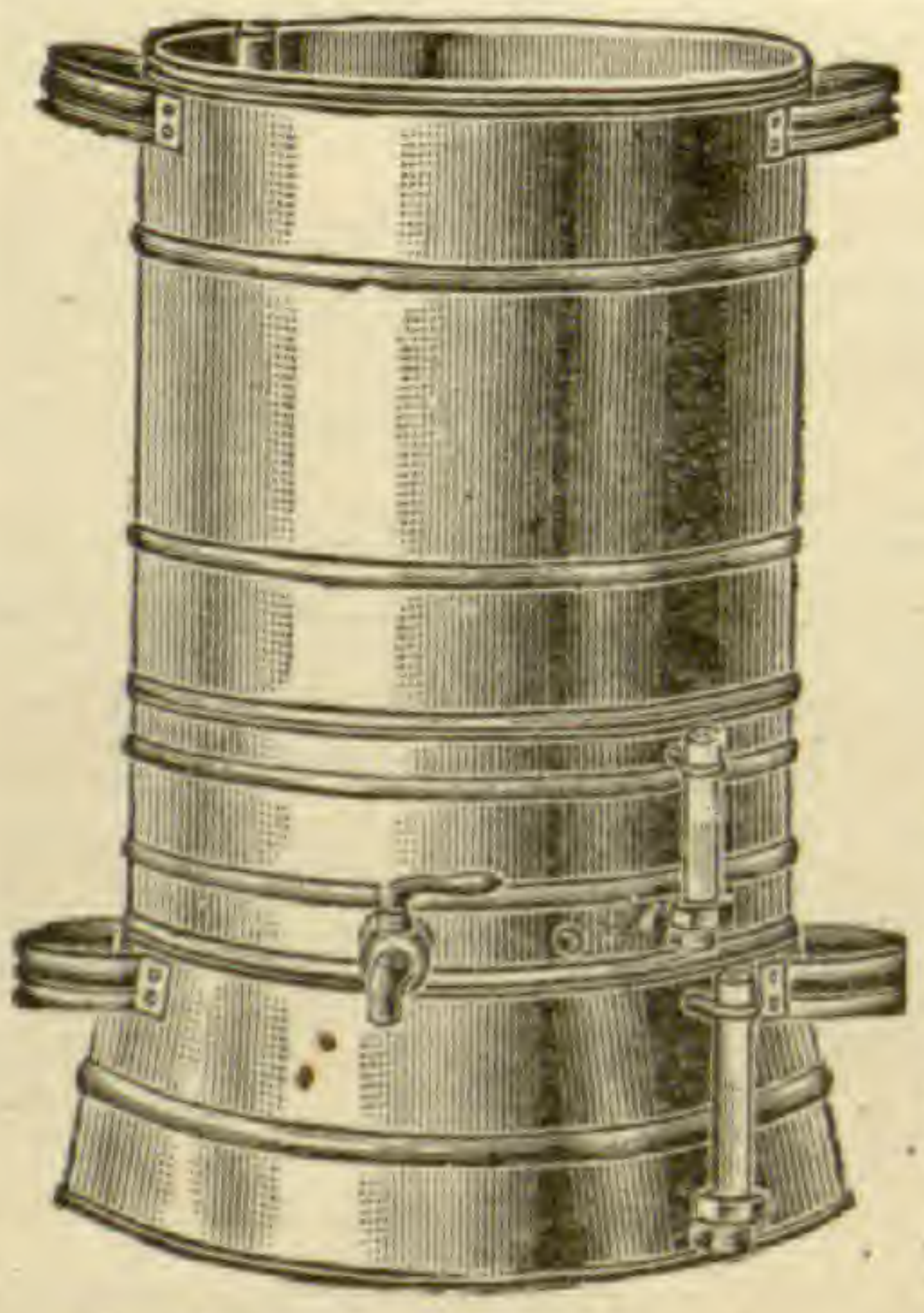

VOLUME XXVI NUMBER 4

BOTANICAL GAZETTE

OCTOBER 1898

KARYOKINESIS IN THE ROOT TIPS OF ALLIUM CEPA.[1]

JOHN H. SCHAFFNER.

(WITH PLATES XXI AND XXII)

FOR several years the writer has desired to study in detail the formation of the achromatic spindle in the root tips of *Allium Cepa*, having frequently seen interesting figures in the early stages of division while investigating the subject of centrospheres in this plant. Especially was the desire increased when the interesting series of papers appeared from the Bonn Botanical Institute[2] dealing especially with the origin of the nuclear spindle. Accordingly a set of preparations was made, the material being killed in several fixing fluids, and stained in various ways, so that any irregularity due to technique might be eliminated. Flemming's weaker and stronger fluid and chrom-acetic acid seemed to give the best results, although several others worked fairly well. So far as the appearance of the spindle was concerned there did not seem to be any great difference in the effect produced by the several fluids. Chrom-acetic acid is without doubt the best for general purposes, as it preserves the structures of the dividing nucleus just as faithfully as Flemming's, and does not interfere with the action of the stains used.

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[1] Contributions from the botanical laboratory of Ohio State University. III.

[2] Jahrbücher für wiss. Bot. 30: 159–422. 1897.

The proportions were as follows: Chromic acid, 0.8^{cc}; acetic acid, 0.5^{cc}; water, 99.0^{cc}. The combinations of stains giving the best results were anilin-safranin and gentian-violet; iron-alum-haematoxylin; and anilin-safranin and iron-alum-haematoxylin.

ANILIN-SAFRANIN, GENTIAN-VIOLET.

1. Anilin-safranin alcoholic (50 per cent.) solution prepared by combining equal parts of anilin water, and saturated alcoholic (95 per cent.) solution of safranin.

2. Gentian-violet 2 per cent. aqueous solution. Stain from two to four hours in the safranin, and from two to four minutes in the gentian-violet. The slides must be taken through the alcohols quite rapidly or the stain will be lost.

HEIDENHAIN'S IRON-ALUM-HAEMATOXYLIN.

1. Ammonio-sulphate of iron 2 per cent. aqueous solution.

2. Haematoxylin, a ½ per cent. solution obtained by dissolving in hot water.

Keep the sections from two to four hours in the iron-alum, and then from eight to twelve hours in the haematoxylin, afterwards taking out the excess of stain with the iron-alum until the sections are of the proper color.

ANILIN-SAFRANIN, IRON-ALUM-HAEMATOXYLIN.

This was by far the best combination used, bringing out with remarkable distinctness chromatin network, chromosomes, nucleoli, spindles and centrospheres. The centrosomes were especially distinct in some pollen mother cells of *Sagittaria variabilis*, showing as large, black, spherical granules at the poles of the spindle. The sections are stained in the usual way in the anilin-safranin for two or three hours, and then carried through the iron-alum-haematoxylin in the same manner as when this combination is used alone. This method, although tedious, will amply repay in results for the long time necessary for the staining. The combination is improved a little, perhaps, by staining for two minutes after the anilin-safranin in gentian-violet.

The material was imbedded in paraffin, sectioned from 10–18μ thick and stained on the slide.

The root tips of *Allium Cepa* L. are very favorable objects for the study of karyokinesis, and in making a critical investigation of the structures and activities of the cell during division it was thought best to take some such common object, which could be followed easily in the class room, and tested as to its accuracy. Accounts and figures of karyokinesis in plant cells are very scarce, and the so-called diagrammatic or schematic figures and descriptions given in most of the text-books are but a poor guide for the student and young investigator. For these reasons a rather complete account of the whole process has been given.

The most typical resting nuclei occur some distance back of the tip beyond the actively dividing region. Here, in good stained material, the nuclei usually have one or two large nucleoli and a very distinct chromatin network, with large irregular chromatin granules, which usually appear at the crossings of the meshes (*fig. 1*). In these cells there are large vacuoles, and it is rarely that the cytoplasmic contents or the centrospheres show to advantage. However, if one goes near the tip, in the actively dividing region, it is easy to find cells showing all the various cell organs usually present. The cells mostly divide in but one plane by transverse walls, and at the upper or lower side of the nucleus there is usually a depression in which two small bodies lie (*fig. 2*). The presence of this depression, and two characteristic bodies in it leave but little doubt as to their nature. They are to all intents and purposes centrospheres. Just at the time when the nucleus begins to divide it generally stains much deeper, and around it may be seen radiating streams of cytoplasm (*fig. 3*). While the nucleus is in this condition the finer chromatin threads disappear. Just how this disappearance takes place it is not easy to tell. The finer meshes seem to be drawn into the coarser threads, or if this is not the case the whole thread shortens and thickens, thus becoming more evident, and also giving the appearance that there are fewer threads present. While this process is going on the centrospheres separate and take up their positions on opposite sides of the nucleus, being closely applied to the nuclear membrane (*fig. 4*). As the chromatin thread continues to shorten and thicken the incept[3] of the

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[3] The word *incept* is used as the equivalent of the German *Anlage*.

achromatic spindle makes its appearance. This arises as two flattened, dome-shaped prominences on opposite sides of the nucleus. These seem to inclose the nucleus completely, and at their summits can usually be seen two spherical bodies, the centrospheres, each with a dark center, the centrosome, around which there is a series of cytoplasmic radiations (*figs. 5, 8, 11*). Sometimes there is an outer granular zone near the limit of the radiations (*figs. 8, 24*). Thus it seems that the spindle originates from the two opposite centrospheres. The spindle usually arises on the two flattened sides of the nucleus (*figs. 5, 10, 12*), but sometimes it originates on the ends of the long axis of the nucleus. It is nearly always very much rounded and flattened at first, except in cases of long narrow cells, in which it seems to be pointed from the very first. In the younger stages the radiations are often not very marked, in other cases they are very distinct and very thick but few in number. In case the spindle is formed on the ends of the long axis of the nucleus it cannot be seen as early as usual, since it then lies very close to the nucleus (*fig. 7*). Although the centrospheres generally separate quite early and take their position on opposite sides of the nucleus, they may sometimes be considerably delayed. *Fig. 9* seems to be such a case, where the chromatin band is well formed but the two centrospheres are still close together and their centrosomes have begun to divide. This figure may be explained by supposing a late separation of the centrospheres and a precocious division of the centrosomes. There are beautiful, delicate radiations passing out into the cytoplasm. In some cells the incept of the spindle remains dome-shaped and very much flattened for a long time, and frequently no bodies can be seen which look like centrosomes. It need not be implied, however, that centrosomes are not present in such cases. In cells of about the same age the spindles are often becoming pointed and show a centrosphere in close contact with the spindle fibers, and having well developed radiations around the poles (*figs. 11, 13*). In *fig. 10* there is a system of streams of cytoplasm passing out from the young spindle to the cell wall. These are no doubt ordinary delicate streams of cytoplasm and are of the same nature as those shown in *fig. 3*. They have nothing to do directly with the formation of the spindle. The incept of the spindle is very sharply differentiated from the surrounding cytoplasm and the space between it and the nuclear membrane appears very clear and transparent, like the achromatin of the nucleus.

After the chromatin band has become considerably thickened it loops up into sixteen definite loops, the heads of which, in typical cases, point toward the two poles (*figs. 13, 14*). The loops, however, do not always seem to have this position in relation to the poles, as is shown by *figs. 15* and *16*. When one looks down from one pole nothing is seen of the nuclear spindle (*fig. 14*). The dome-shaped spindle gradually extends outward and becomes pointed, until the time of the breaking of the chromatin coil into a definite number of chromosomes, accompanied by the disappearance of the nuclear membrane (*figs. 15–20*). In these stages the centrospheres become more prominent, probably through expansion or growth previous to division. The fate of the nucleoli was not discovered. They have generally disappeared by the time the chromatin coil has segmented. In some cases they appear quite vacuolate (*fig. 11*), in others of the same consistency throughout (*figs. 15, 16*). It will be seen from an examination of the figures that the spindle is bipolar from the first. It arises as two closely applied caps on opposite sides of the nucleus at the summits of which are well defined centrospheres. These centrospheres gradually extend outwards, drawing the spindle into a sharp pointed bipolar structure. In the case of the onion, therefore, it is an impossibility for the spindle to arise by an aggregation of many cytoplasmic radiations which first form multipolar structures passing out on all sides of the nucleus, as has been described by Mottier, Osterhout, and others. The spindle is so sharply defined from the very first that it can be traced step by step in all its stages of development, its limits always appearing with proper staining very distinct and sharply differentiated from the cytoplasm. In some cases, where the cells are very flat in longitudinal diameter, the spindle also appears very much flattened (*fig. 21*). Were such a spindle sectioned it could easily give the appearance of a multipolar structure. No such cases, however, were found. If the spindle extended clear across the cell so that it touched the opposite walls it might give the appearance of the threads ending in the cell wall. Although the nature and origin of the spindles in *figs. 19*, *21* and *22* are exactly the same, there is a striking difference in their shape, and very suggestive of how the shape of the cell may influence the appearance of the karyokinetic figures. The same is evident from a comparison of *figs. 6* and *10*. Often the two poles of a spindle are not 180° apart. This is caused no doubt by the centrospheres not becoming exactly opposed (*fig. 19*). After the nuclear membrane has disappeared the V-shaped chromosomes are gradually drawn down into the equatorial plane, with their heads toward the center, until they form quite a symmetrical figure (*figs. 22–26*). The centrosome usually does not divide until after the formation of the mother star, but sometimes the division may occur earlier (*fig. 23*). The longitudinal splitting of the chromosomes takes place about or during the time of the formation of the mother star (*figs. 27, 28*). When the cell is very long and narrow there does not appear to be a typical mother star formed (*fig. 24*). In such cases the chromosomes do not appear to be drawn symmetrically into the equatorial plane. The chromosomes appeared quite homogeneous throughout, nothing being visible having the appearance of chromatin granules. It was not possible to tell exactly how the chromosomes are arranged on the achromatic spindle threads, but the threads seemed to be in bundles running continuously from one pole to another, ending in the hyaline area of the centrosphere and having the chromosomes attached by their heads (*figs. 28–30*).

When the chromosomes have been brought into the equatorial plane, and longitudinal splitting is complete, the daughter chromosomes are gradually pulled apart, and the central spindle begins to appear between them in the equatorial region. Sometimes the figures of the metakinesis stage are remarkable for their symmetrical development (*figs. 29, 30*). Such symmetry could not be present were the two ends of the spindle formed at haphazard from variable numbers of irregular smaller elements. The centrosomes usually divide during metakinesis (*figs. 31, 32*). By the time the daughter chromosomes have arranged themselves around the poles, the centrospheres, as a general rule, have divided and the radiations show more prominently than in the earlier stages (*fig. 23*). The chromosomes now begin to contract and the free ends turn inwards, while at the same time the threads of the central spindle become thickened and stain much deeper than before. The polar radiations also become more widely separated because of the outward pressure exerted by the chromosomes (*fig. 34*). At the time when the chromosomes are curving inward the central spindle threads begin to bulge outwards, and the cell plate is formed from the center, appearing at first as granular thickenings in the spindle threads. In this stage the centrospheres often appear still united but containing a double centrosome (*figs. 35, 36*). In *fig. 37* only one centrosphere is visible at the upper pole, the other one lying immediately beneath the one in view.

The central spindle continues to bulge outward and the cell plate becomes larger, until finally when it reaches the cell walls the spindle has a very flattened appearance (*figs. 38, 39*). The spindle threads continue to stain very dark at the center until the cell plate is complete. What the cause of this dark staining may be was not discovered. It was probably due to the presence of various materials in the thickened spindle threads which are used in the formation of the cell wall. It is not easy to understand how the threads of the central spindle extend outward until they are sometimes almost doubled on themselves. But whatever the direct cause, they are considerably longer than they were at first. The central spindle threads disappear as soon as the cell wall is well formed, being absent in the center while they are still prominent in the outer regions (*fig. 39*). As soon as the cell wall is complete the threads disappear entirely. Whether they remain in the cytoplasm, or are withdrawn into the nucleus, or furnish part of the material for the nuclear membrane, are all matters of mere conjecture. The nucleoli begin to appear a little before the time when the cell wall has been completely formed.

Fig. 41 is an interesting case in that it shows the centrosome not yet divided in a very late stage. This body appears as a long, black, rod-like body forming a slender dumb-bell. The chromatin bands seem to be distributed again or spread out in a fine network, and the nucleus continues to swell out and become more rounded until the complete resting stage is again attained. The depression formed at the pole, however, remains, and in this there can often be seen exceedingly distinct centrospheres. Although the cases in the resting condition are not numerous where these bodies appear very distinct, yet in such cases as *fig. 42* there can be no doubt of the continuance of the centrospheres into the resting stage of the nucleus. In the example given in *fig. 42* the whole cell is remarkably clear and free from granules, the two prominent bodies lying alone in the polar depression. To claim that these bodies are not centrospheres would be exceedingly dogmatic, and the only recourse left would be to name and describe two new organs of the cell which have the same appearance and occupy the same position as do real centrospheres.

The general process of karyokinesis for the onion root may be summarized as follows:

I. PROPHASE.

1. The division begins with the separation of the centrospheres, and when these have moved apart nearly 180° the incept of the achromatic spindle appears, forming two dome-shaped projections on opposite sides of the nucleus, at the summits of which the centrospheres are situated, forming the poles around which are cytoplasmic radiations. At the same time the chromatin network is transformed into a continuous ribbon or spirem producing the figure known as the *close mother skein* (*figs. 2–10*).

2. The continuous spirem shortens and thickens and is looped into a definite number of loops, the heads of which, in typical cases, point toward the two poles of the spindle. The nucleoli and nuclear membrane disappear and the dome-shaped spindle becomes more pointed by the outward extension of the poles. This stage ends with the breaking of the chromatin loops into separate chromosomes, and it may appropriately be called the *looped mother skein* (*figs. 11–19*).

II. METAPHASE.

3. After the nuclear membrane disappears, the separate chromosomes are drawn down, with their heads toward the center, into the equatorial plane, while the spindle continues to become more pointed (*figs. 20–25*). This constitutes the *loose mother skein* stage.

4. When the chromosomes have come into the equatorial plane, there is a pause resulting from the seeming pull of the spindle fibers in opposite directions, which holds the chromosomes rigidly until the longitudinal splitting of the chromosomes is complete, when separation of the daughter chromosomes begins (*figs. 26–28*). This constitutes the *mother star* stage.

III. ANAPHASE.

5. After the longitudinal segmentation of the chromosomes which, as a general rule, does not begin until the chromosomes are in the equatorial plane, the daughter chromosomes are gradually pulled apart, the separation beginning at the heads of the loops. The centrosomes usually divide during this stage, though in some cases the division may be considerably earlier. This stage is appropriately known as *metakinesis* (*figs. 29–31*).

6. The daughter chromosomes having been completely pulled apart, now travel to the poles and arrange themselves in star-shaped figures around the poles, while the central spindle appears between the two stars. The radiations around the centrospheres, which now contain two separate centrosomes, become more prominent (*figs. 32, 33*). This is the *daughter star* stage.

IV. TELOPHASE.

7. The chromosomes having oriented themselves around the poles, now begin to contract, becoming wavy in outline, and the free ends curve inward. The threads of the central spindle begin to thicken preparatory to the formation of the cell plate. In the center of each thickened thread a granule appears, these being formed first in the central strands, and as the spindle bulges outward the cell plate gradually enlarges until it reaches the surrounding cell wall. In the meantime the nucleoli begin to appear in the daughter nuclei. This stage may be called the *loose daughter skein*, and may be considered to end when the cell plate is complete (*figs. 34–39*).

8. After the daughter cells are completely separated by the new cell wall the threads of the central spindle disappear, and the daughter nuclei appear with complete nuclear membranes. The chromosomes begin to be transformed again into the chromatin network; the radiations disappear from around the centrospheres, which have now usually divided completely into two separate bodies; and the two daughter nuclei in the meantime expand and take on a more spherical form until they enter again into the resting stage (*figs. 40–42*). This stage may be known as the *close daughter skein.*

Fig. 1 may be taken as a typical nucleus in the tissue beyond the growing point, showing in detail the actual arrangement of the chromatin network, chromatin granules, and nucleolus. *Fig. 2* represents a typical cell in the active part of the meristematic region.

To illustrate the normal order of karyokinesis, the following figures may be taken as a complete series: *2, 4, 5, 8, 11, 13, 16, 17; 20, 22, 25; 26, 27, 29, 30, 32, 33; 34, 35, 36, 38; 39, 40, 42.* A briefer series may be represented by the following: *2, 5, 8, 13, 17, 20, 25, 26, 27, 30, 32, 33, 34, 36, 39, 40, 42.*

SAGITTARIA VARIABILIS.

The anilin-safranin, iron-alum-haematoxylin combination was also tried on dividing pollen mother cells of Sagittaria. The results were even more striking than in the onion. In the mother star stage the centrosomes at the poles look like large black spherical granules, but the attraction sphere is usually not very well differentiated. The poles usually lie very close to the wall of the cell, giving little or no room for polar radiations (*figs. 43, 44*). The figures drawn are not exceptional cases, but scores of similar figures can be seen in a single section across the flower bud. From a careful estimate, I have a single slide which will show several hundred figures of the same nature as those given. A careful search was again made for multipolar spindles, and in this material they are frequently seen. This is not at all surprising, however, and is exactly what must necessarily follow the sectioning of tissues where the spindles do not all lie in the same plane. Especially in thin sections is the pole often cut away, giving the appearance that the spindle does not end in a single point. Since the spindle threads in Sagittaria pollen mother cells are massed into definite bundles, any injury to the spindle will produce a multipolar spindle. Such a case is shown in *fig. 45*, where the cell has been crushed at one end, producing four apparently separate spindles on the lower side, while the upper end is practically intact. The centrospheres appear at the two original poles. At the present time, in all the material examined by the writer, multipolar spindles seem due entirely to two causes: first, to pathological conditions; and second, to injuries of the spindle produced by improper manipulation in preparing the sections. The latter may be due to a variety of causes. Among the more common of these may be mentioned improper killing and treatment of material, sectioning the cells into such thin slices that the poles are entirely lost or injured, cutting off the poles from the spindles which lie diagonally to the plane of the section, and finally, injury by crushing the cells in such a manner that the spindle is spread out and torn.

COLUMBUS, O.

EXPLANATION OF PLATES XXI, XXII.

The drawings have been reduced three-eighths of their original size. They were drawn with an Abbé camera, and except in one instance combinations of Zeiss and Bausch and Lomb oculars and objectives were used.

PLATE XXI.

FIG. 1. A resting nucleus from a cell beyond the growing point. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 18, B. and L. obj. $\frac{1}{12}$.

FIG. 2. Resting cell with centrospheres from the growing point. Anilin-safranin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 3. Cell just before division, stained very deeply. Iron-alum-haematoxylin. Zeiss. oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 4. Nucleus with centrospheres on opposite sides, in early stage of division. Iron-alum-haematoxylin. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

FIG. 5. Cell with incept of achromatic spindle and centrospheres at the poles. Iron-alum-haematoxylin. Zeiss. oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 6. Long cell with bipolar spindle having sharper ends than usual at this stage. Acid fuchsin, methyl-green. Zeiss. oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 7. Close mother skein with no spindle visible, but with radiations at the two ends of the nucleus. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 8. Cell with centrospheres and granular zones outside of the polar radiations. Iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 9. Cell with late separation of centrospheres and precocious division of the centrosomes. Delicate radiations around the centrospheres. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 10. Nucleus with very flat dome-shaped spindle and cytoplasmic radiations or streams. Acid fuchsin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 11. Cell with centrosomes and distinct coarse radiations. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 12. Early dome-shaped spindle with no centrosomes visible. Iron-alum-haematoxylin. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

FIG. 13. Looped mother skein showing radiations around the poles of the dome-shaped spindle. Acid fuchsin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

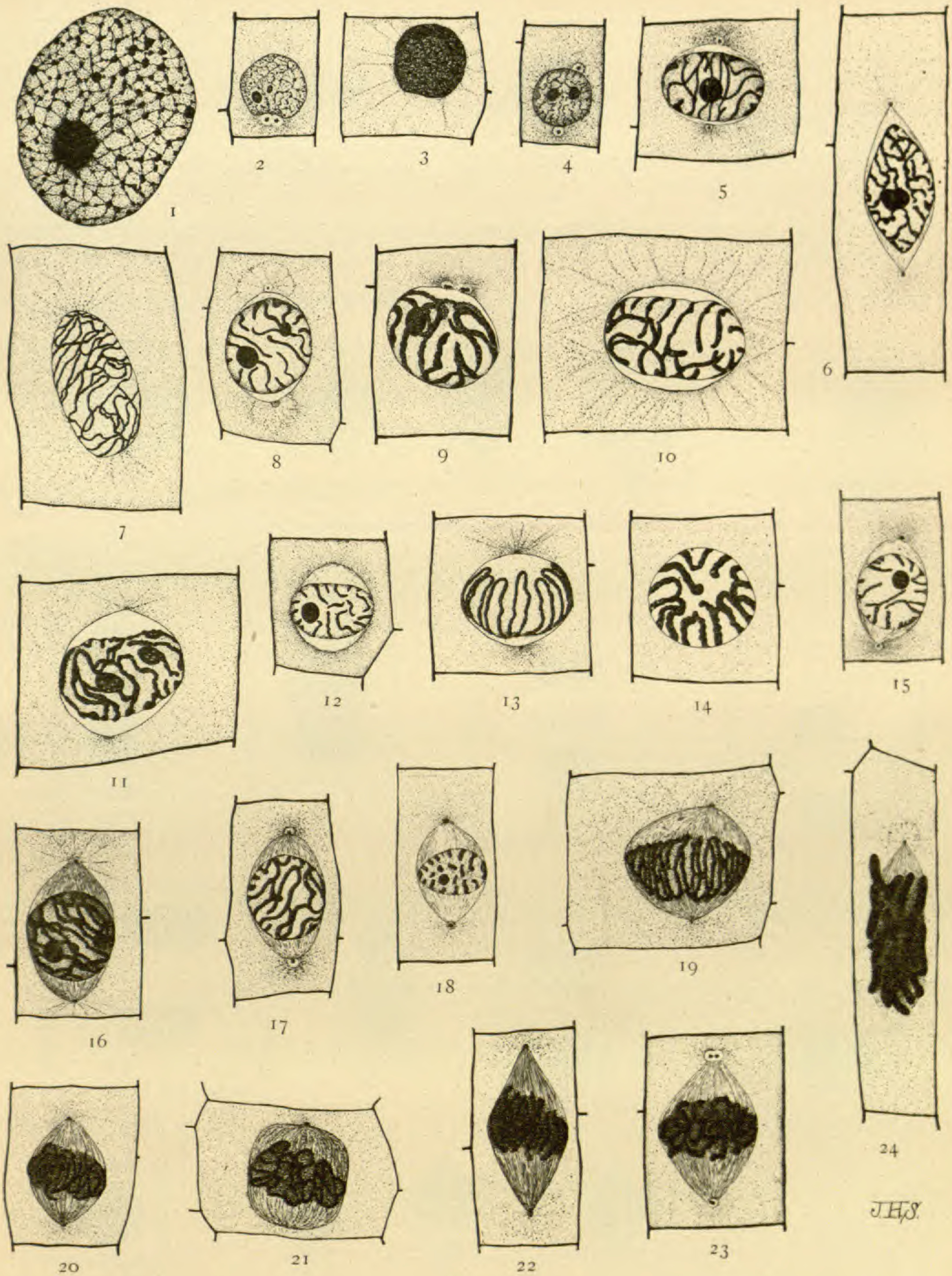
FIG. 14. End view of looped mother skein. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 15. Dome-shaped spindle with centrospheres. Anilin-safranin, gentian-violet. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

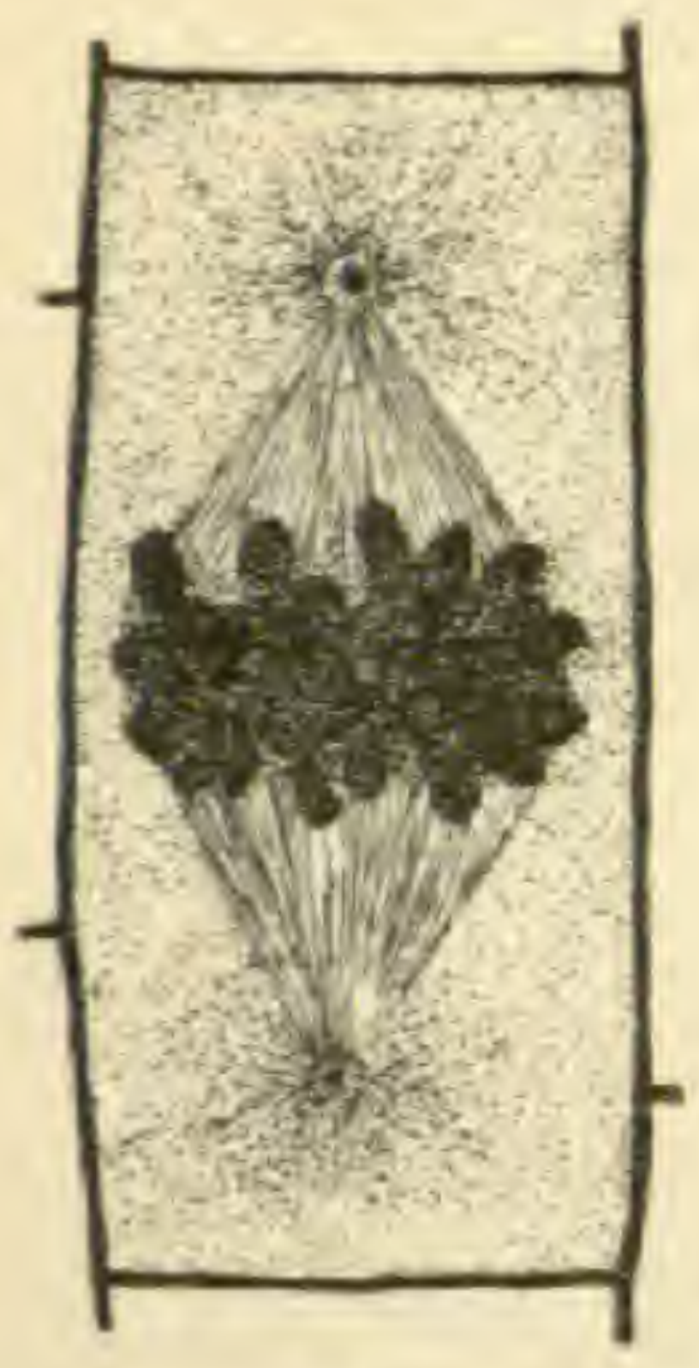
FIG. 16. Dome-shaped spindle becoming pointed, with prominent radiations around the poles. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 17. Dome-shaped spindle with prominent centrospheres. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 18. Spindle becoming pointed. Anilin-safranin, gentian-violet. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.



SCHAFFNER on KARYOKINESIS.



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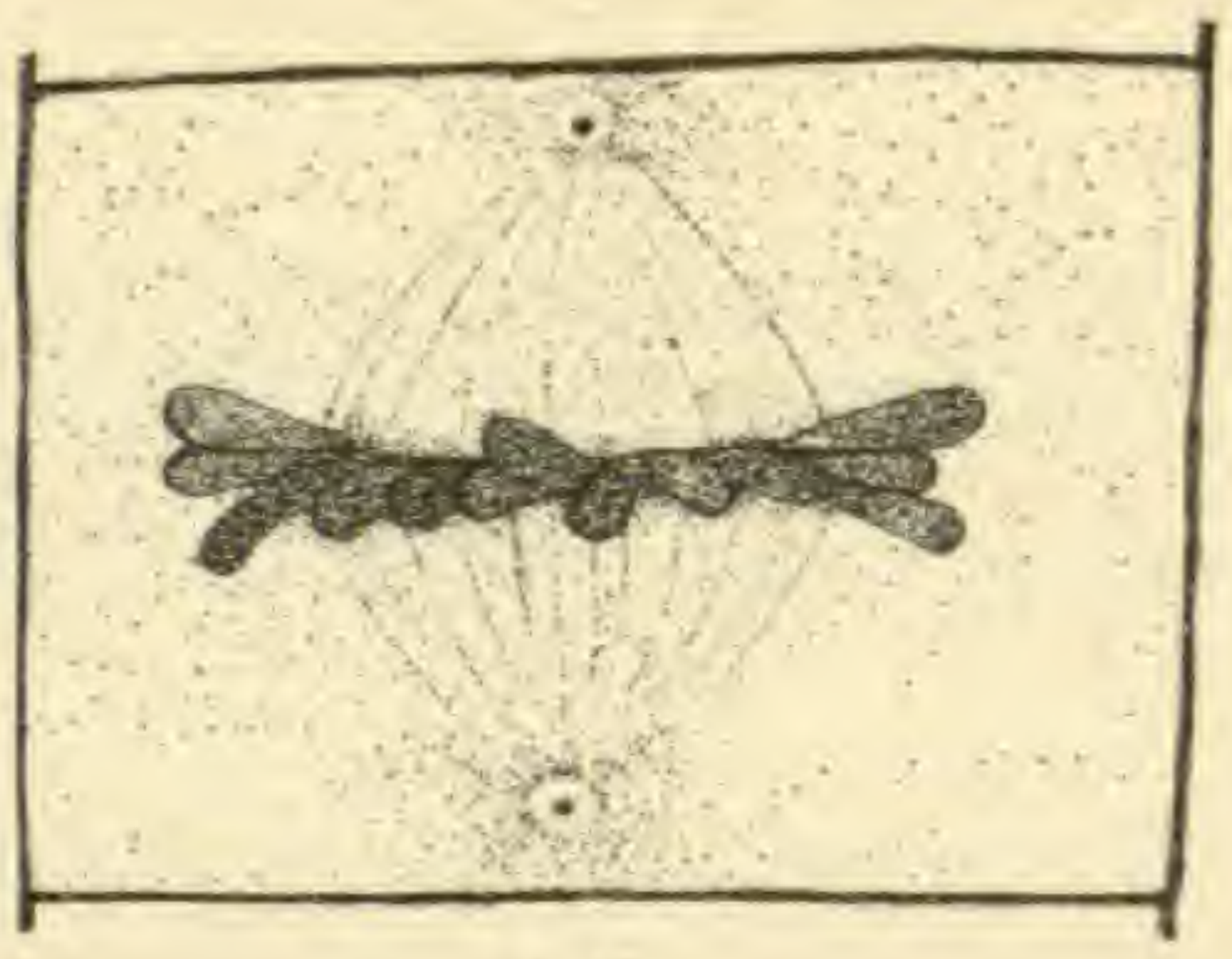

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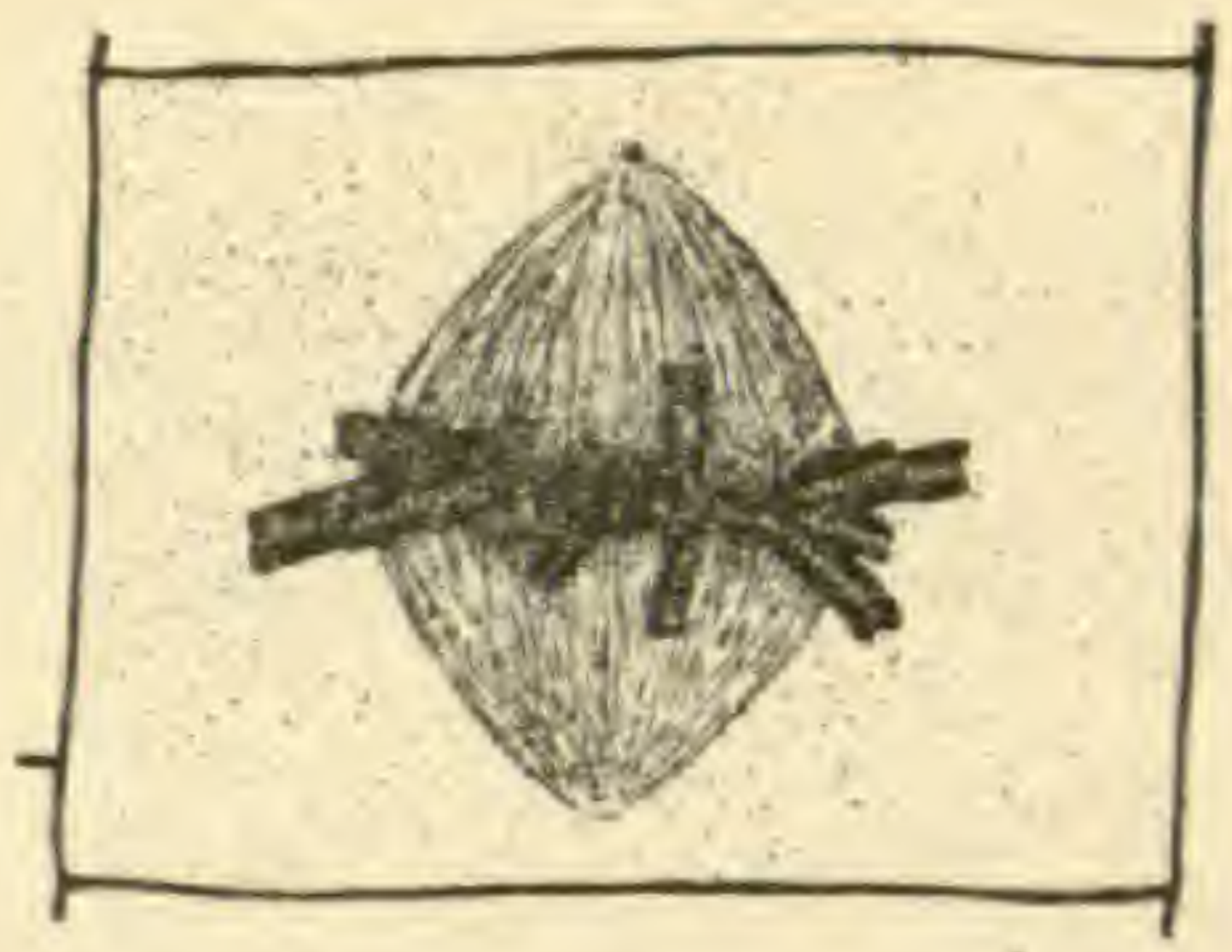

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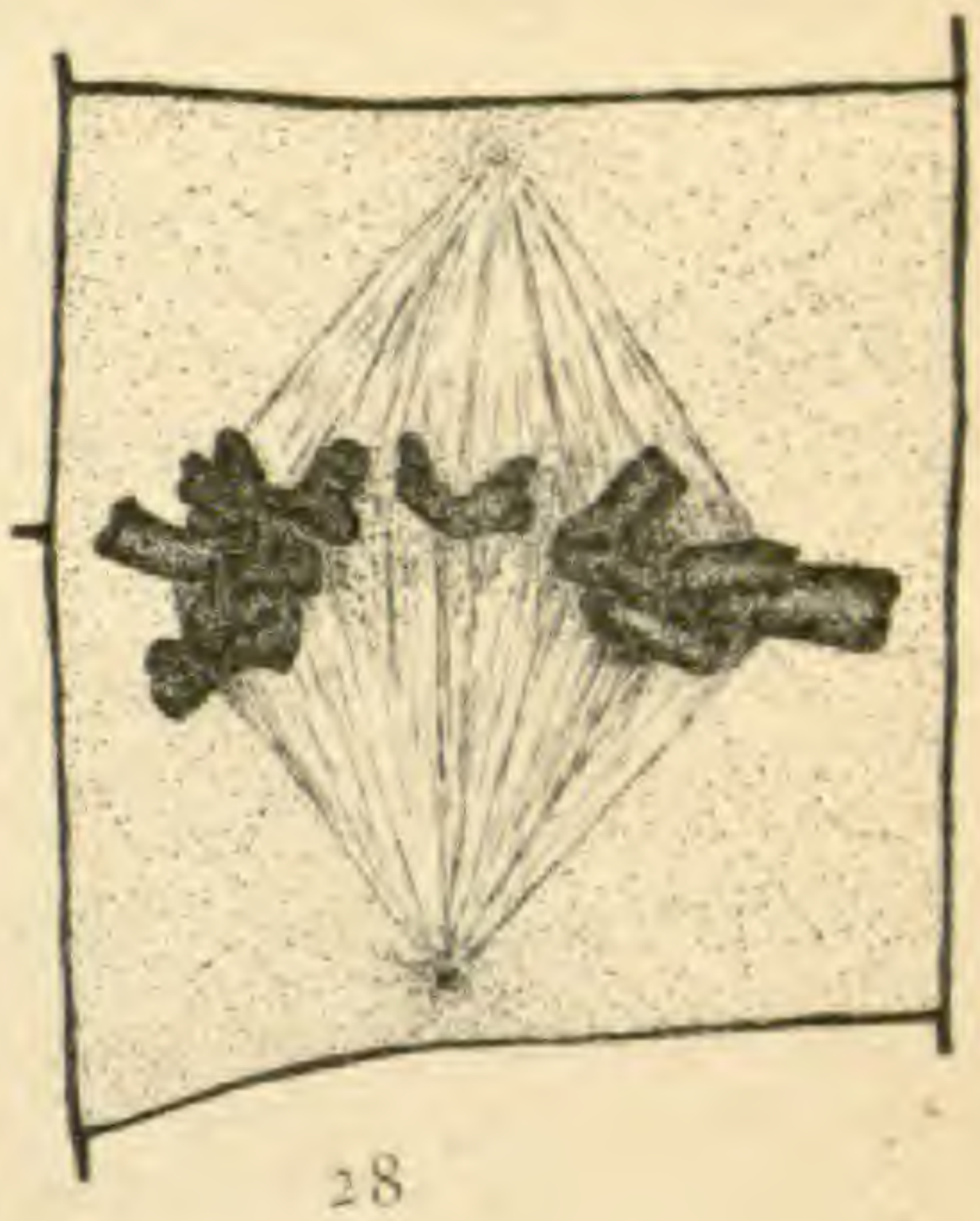

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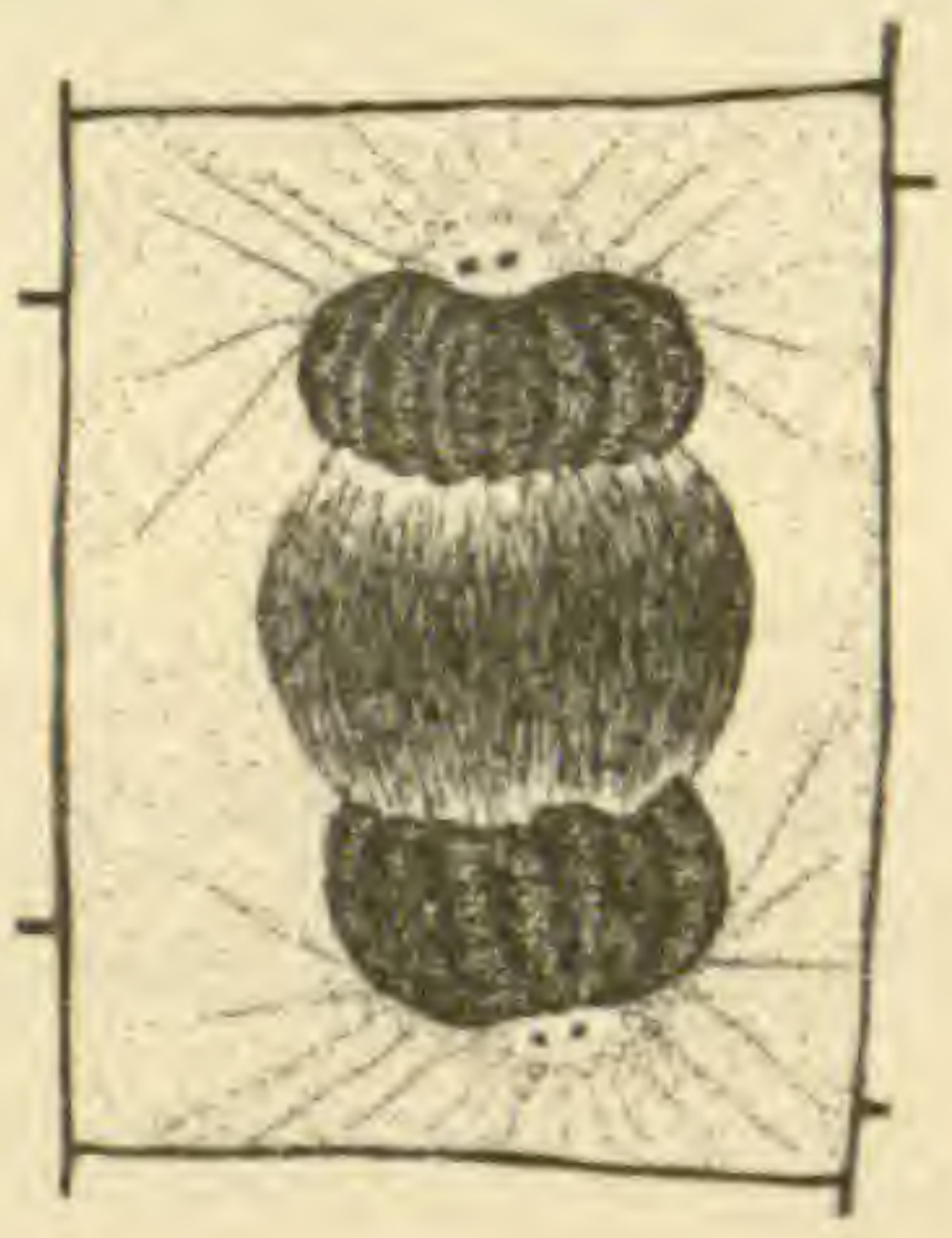

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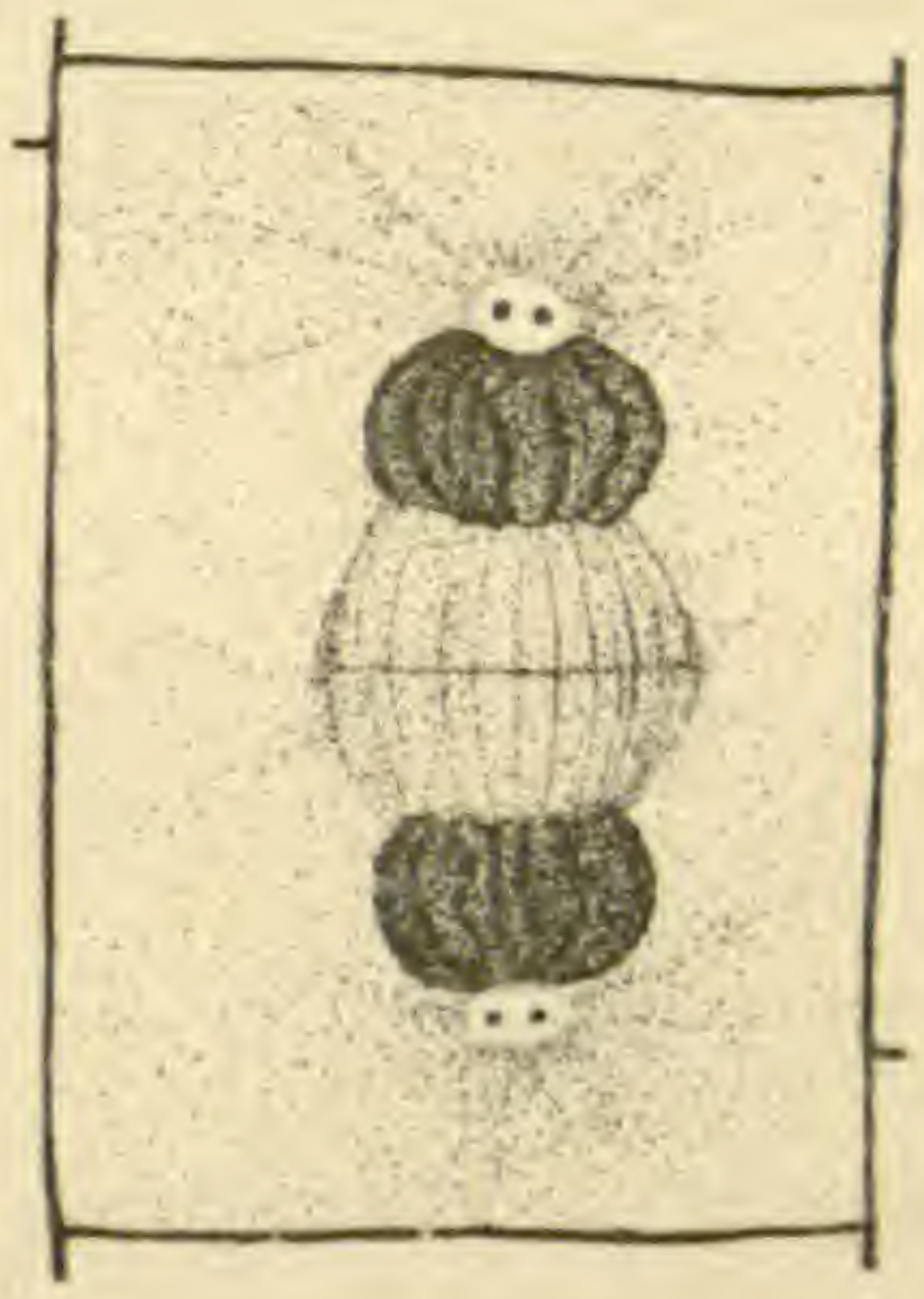

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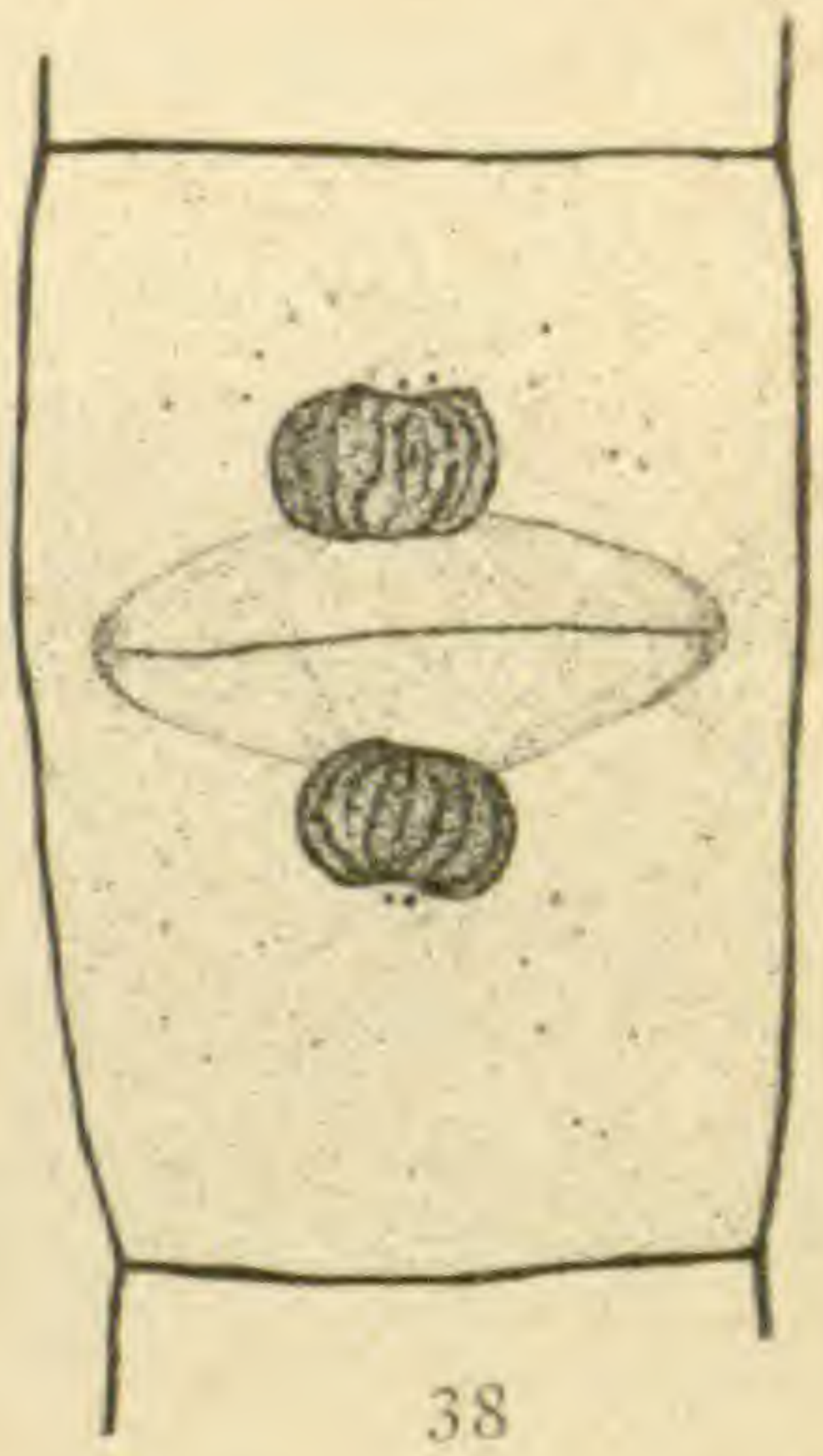

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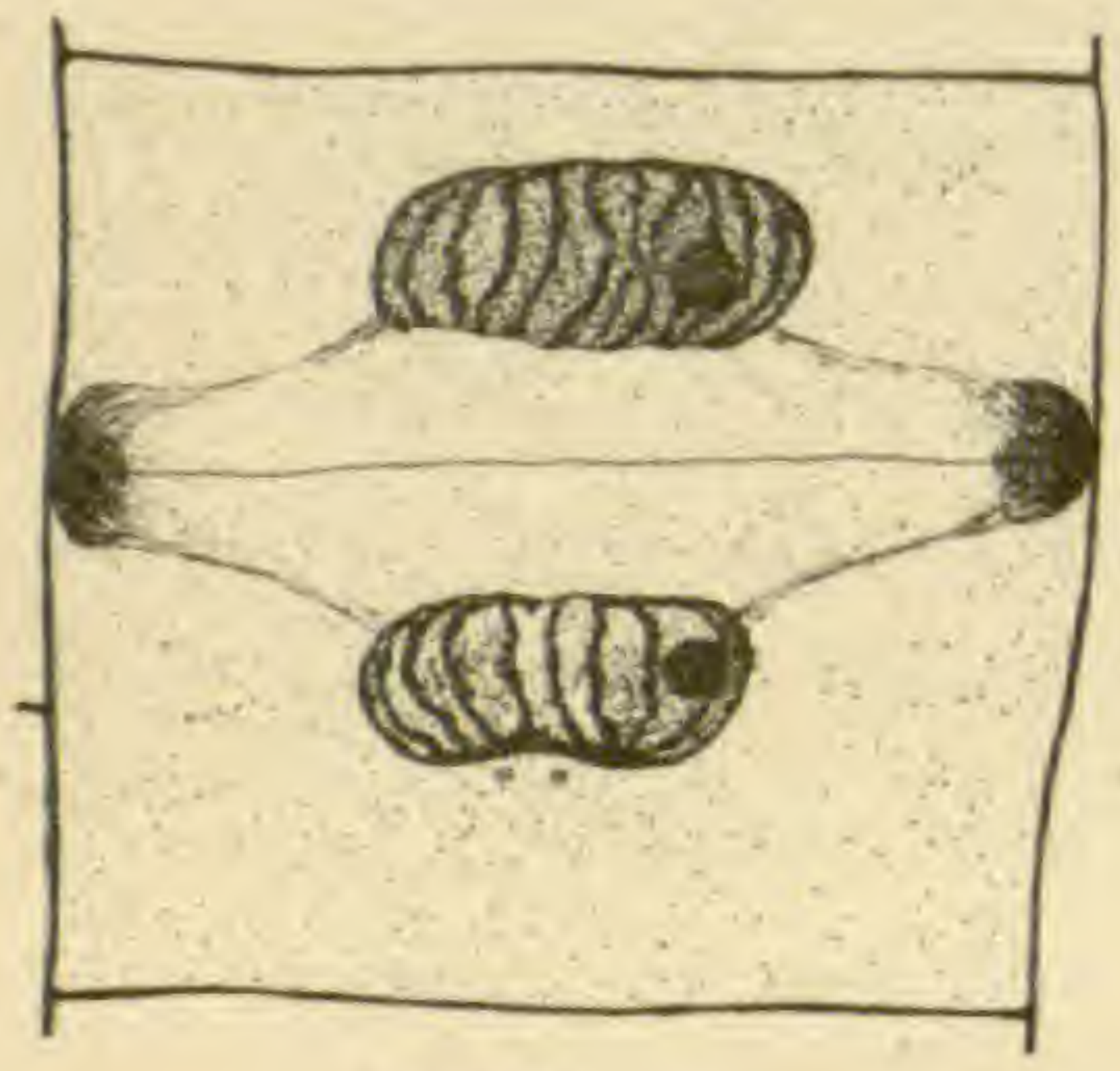

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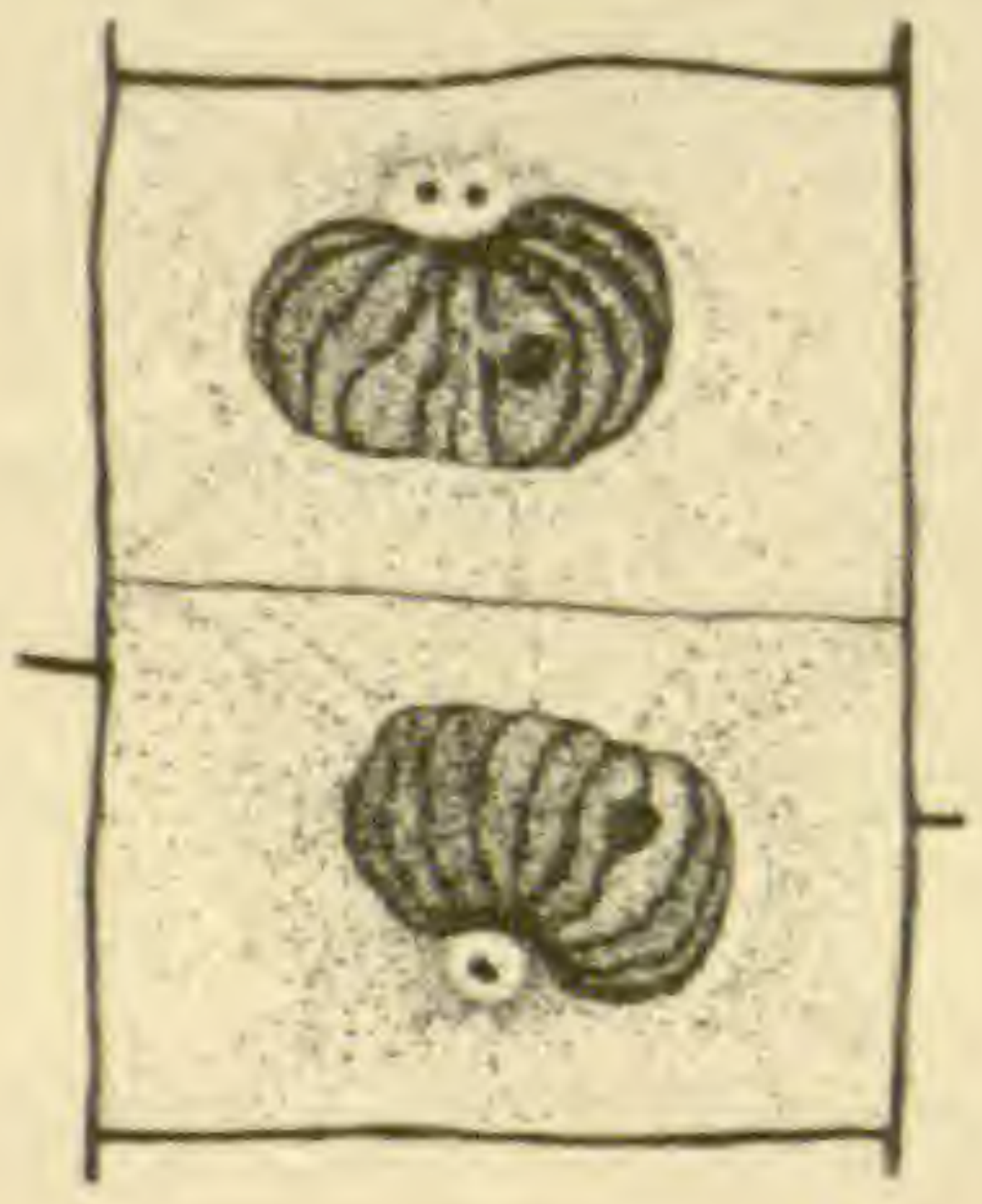

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J.H.S.

SCHAFFNER on KARYOKINESIS.

FIG. 19. One-sided spindle with looped spirem. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 20. Loose mother skein with centrosomes at the poles of the spindle. Iron-alum-haematoxylin. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

FIG. 21. A flat cell with a very flat spindle. One end shows a centrosome. Anilin-safranin, picric nigrosin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 22. Spindle much as in *fig. 20*, but more pointed. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 23. Loose mother skein with large centrospheres in which the centrosomes have divided earlier than usual. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 24. Long cell showing a sharp-pointed spindle with centrosphere and an outer granular zone in the radiations. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

PLATE XXII.

FIG. 25. Loose mother skein showing spindle with typical centrospheres and radiations. Iron-tannin, safranin. Zeiss oc 12, B. and L. obj. $\frac{1}{12}$.

FIG. 26. Typical mother star. Anilin-safranin, gentian-violet, Gram's iodin potassium iodid. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 27. Segmented mother star. Acid fuchsin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 28. Segmented mother star from large cells of central strand. One end shows a very marked centrosome, the other none. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 29. Early stage of metakinesis with spindle still somewhat dome-shaped because of the flatness of the cell. Centrosomes divided. Anilin-safranin, picric nigrosin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 30. Metakinesis stage showing radiations around the poles. Anilin-safranin, gentian-violet. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

FIG. 31. Last stage of metakinesis; centrosomes dividing. Anilin-safranin, gentian-violet. Zeiss oc. 12, obj. 2^{mm} ap. hom. im.

FIG. 32. Daughter star stage; centrosomes dividing. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 33. Daughter star. Prominent radiations around the poles. Anilin-safranin, gentian-violet. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 34. Beginning of loose daughter skein. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 35. Loose daughter skein with coarse radiations. Gentian-violet, eosin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 36. Loose daughter skein with early stage of cell plate and prominent centrospheres. Anilin-safranin, gentian-violet, Gram's iodin potassium iodid. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 37. Loose daughter skein with prominent centrospheres. At the upper pole one centrosphere is hidden. Iron-tannin, anilin-safranin. Reichert oc. 12, Leitz obj. $\frac{1}{12}$.

FIG. 38. Loose daughter skein with large cell plate. Anilin-safranin, picric nigrosin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 39. Close daughter skein with cell plate about complete. Acid fuchsin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 40. Close daughter skein with cell plate complete. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 41. Close daughter skein with dumb-bell-shaped centrosome delayed in division. Anilin-safranin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 42. Resting daughter cell with remarkably distinct centrospheres. Iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 43. *Sagittaria variabilis.* Microspore grandmother cell showing spindle with large centrosomes. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

FIG. 44. Same as *fig. 43.*

FIG. 45. *Sagittaria variabilis.* Microspore grandmother cell somewhat crushed, resulting in a distinct multipolar spindle. Centrosomes still visible. Anilin-safranin, iron-alum-haematoxylin. Zeiss oc. 12, B. and L. obj. $\frac{1}{12}$.

CELL DIVISION IN PINE SEEDLINGS.[1]

By EDWARD L. FULMER.

(WITH PLATES XXIII AND XXIV)

THE chief purpose of the following investigation was to determine the origin of the achromatic spindle, especially as to whether it originates as a bipolar or a multipolar structure. Along with this the subject of centrospheres was considered and also such other points of interest as might be observed in connection with karyokinesis.

The greater part of the work was done on *Pinus laricio* Poir., *P. silvestris* L. being used for comparison. The cell structures in the two species were found to be so nearly identical that it was not considered necessary to make any distinction between them in presenting the results of the investigation.

The material was obtained by sprouting the dry seeds, and when the embryos were from 0.5–3^{cm} long the root tips and cotyledons were cut off and killed in the usual manner. The fixing agents used were Flemming's stronger solution and chrom-acetic acid. The sections were imbedded in paraffin, and cut 10, 5, and 4 μ thick. Various combinations of stains were used ; but the best results were obtained with analin-safranin gentian-violet, and orange G; iron-alum-hæmatoxylin ; and Delafield's hæmatoxylin. The sections were usually stained so dark when killed in Flemming's solution that it was necessary to let them stand in turpentine exposed to the sunlight for some time in order to remove the black color which otherwise interfered greatly with the proper effect of the staining reagents. After this treatment the sections stained very well, and the details of protoplasmic structure were well differentiated.

My thanks are due to Dr. W. A. Kellerman and Mr. J. H. Schaffner for valuable assistance and criticism.

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[1] Contribution from the botanical laboratory of Ohio State University. IV.

The cells of Pinus are moderately large and the karyokinetic figures distinct, but usually there is a considerable amount of oil present which is stained readily by most of the stains used, and thus interferes with the observation of the finer details of structure, especially with the centrospheres.

In the resting nucleus (*fig. 1*) the chromatin is arranged in a granular network with rather large meshes. Several nucleoli of various sizes are usually present, surrounded by hyaline areas. In normal cells of this stage no centrospheres were observed, although a diligent search was made for them. This might be taken to indicate that centrospheres are entirely absent in the resting stage, which would be contrary to the condition Schaffner[2] reported for *Allium Cepa*, where centrospheres are said to occur in resting cells as well as in the stages of division. However, the cytoplasm usually contained many oil drops and other granular contents so that if centrospheres were present they could not be distinguished very easily. In the outer layer, near the epidermis, elongated cells are sometimes found (*fig. 3*) which contain greatly elongated nuclei having spindle-like projections with bodies resembling centrosomes at the outer ends. Sometimes these bodies have radiations around them which make them strongly resemble the poles of a true spindle. Although the nucleus is in the resting stage the bodies might represent the poles of spindles which formed earlier than usual. However, the cells in this region seldom divide, and the phenomenon may be only an accompaniment of the elongation of the nucleus, the centrosome-like bodies representing accumulations of cytoplasm.

In the stele the elongated cells (*fig. 4*) contain very large nuclei having numerous nucleoli. In such cases the nucleoli are usually very large and filled with vacuoles. The nucleoli stain very dimly, so that the chromatin network is hardly visible even in well stained sections, while the nucleoli take a deep red stain with safranin, and are arranged in a line within the nucleus at somewhat regular intervals.

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[2] BOT. GAZ. **19**: 445–459. 1894.

In some of the preparations very definite and distinct radiations surrounded the nuclei (*fig. 2*). These radiations are rather thick strands of cytoplasm, and do not show the fine structure found in spindle threads or in radiations around the poles. In the preparations where such radiations were seen nearly every cell showed them, whether in the resting condition or the early stages of division ; indicating that they were produced by the fixing agent. If not caused by this means they are probably the result of a streaming of the cytoplasm similar to that found in the cells of hairs on Tradescantia stamens.

Just before cell division commences the nuclei stain very readily. The first change to take place in the structure of the nucleus is the transformation of the chromatin network into a long thread or spirem. When the spirem is almost formed, and while the nucleoli are still visible in the nucleus, and before the nuclear membrane has disappeared, the spindle begins to form. When first seen it consists simply of two rounded or dome-shaped prominences (*fig. 5*), one on each side of the nucleus (*figs. 6–10*). These dome-shaped spindles gradually become elongated and pointed until they extend outward to two definite points at which centrosomes are often visible (*figs. 10–12*). These appear as small deeply stained bodies placed just at the point of the spindle (*figs. 24, 25*). In *fig. 16* the centrosome appears to be lying in a hyaline area which is surrounded by a darker portion of protoplasm. At about the time the spindle becomes pointed the spirem breaks into a definite number of chromosomes and the nuclear membrane disappears. At this time the nucleoli are no longer visible, having disappeared in the early prophase of division. They are not found again until cell division is about complete. The poles are usually approximately on opposite sides of the nucleus from the first appearance of the spindle. In a few cases, however, they were less than 180° apart (*fig. 12*), and did not become directly opposite until quite a late stage of karyokinesis. Radiations are frequently seen around the poles (*figs. 6, 11*).

F. Rosen[3] describes spindles quite similar to the above in the root tips of *Hyacinthus orientalis*. He finds the spindle arising as a cap-shaped prominence which is formed on two opposite points of the nucleus by the concentration of "kinoplasm" which had formed a hyaline area around the nucleus. This spindle originates before the dissolution of the nuclear membrane.

I examined carefully a large amount of material in search for radiations around the nuclei and for multipolar spindles in the prophases of karyokinesis as figured by Osterhout,[4] Mottier,[5] Juel,[6] and Debski,[7] but I was unable to find a single cell in these early stages that showed such structures. However, as above observed, in some preparations strands of cytoplasm were seen around the nuclei of nearly every cell. This was observed in cells both in the resting stage and during karyokinesis. These radiations were very coarse and could not, I think, be instrumental in spindle formation.

In some injured or sliced karyokinetic figures I found, though very rarely, spindles which appeared to be multipolar. The cells containing such spindles were all in the anaphase, mainly in the metakinesis and mother star stages (*fig. 21*), at which time the spindle is elongated and is more likely to be sliced in sectioning than those which are in other stages of karyokinesis.

In the material examined many cells were observed in the prophase, a large number of which showed definite spindles. In every case the spindle was bipolar, being short and rounded, or dome-shaped, when first visible near the nuclear membrane. The evidence furnished by my investigation is opposed to the theory that the spindle of Pinus originates as a multipolar structure.

With the segmenting of the spirem the metaphase begins. The spirem is scattered throughout the nucleus in the outer

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[3] COHN's Beiträge zur Biologie der Pflanzen 7 : 225–312. 1895.

[4] Jahrbücher fur wiss. Bot. 30 : 159–168. 1897.

[5] *Ibid.* 30 : 169–204. 1897.

[6] *Ibid.* 30 : 205–226. 1897.

[7] *Ibid.* 30 : 227–248. 1897.

part of the achromatin (*figs. 9–11*), and segments just before the spindle elongates to definite points. The nuclei in which I was able to count the segments contained sixteen chromosomes (*fig. 14*). They are somewhat difficult to count as they are usually massed together. Strasburger[8] counted twelve chromosomes in the pollen grain of *Pinus silvestris*. Dixon[9] found eight, twelve, and twenty-four chromosomes in the gametophyte of *Pinus silvestris*, with eight as the prevailing number. The nuclei in the primary meristem of the growing point of *Pinus Laricio* and *Picea orientalis* were found by the same author to contain sixteen chromosomes.

The chromosomes are at first scattered throughout the nucleus, but are gradually drawn toward the center to form the mother star (*fig. 15*). They seem to be arranged somewhat irregularly during this and the metakinesis stages (*figs. 15, 20, 22*). The longitudinal splitting of the chromosomes takes place about the time of the mother star stage. The daughter chromosomes then move toward the poles where they arrange themselves into the two daughter stars and form the network of the resting nuclei (*figs. 28, 29*). The spindle is usually quite pointed during metakinesis (*fig. 22*). Sometimes, however, when the cell is short, the spindle does not become pointed but remains dome-shaped (*fig. 18*), giving an appearance similar to that which would be produced by the spindle fibers passing through the cell wall. The centrosomes, however, show that the poles lie very close to the cell wall. *Fig. 17* shows one end of such a spindle with a double centrosome. In *fig. 24* the sides of the spindle are concave. This shape was probably produced by the protoplasm contracting near the lower end of the spindle. Radiations are more prominent during the anaphase than during either the earlier or later stages (*figs. 19, 23, 25*).

The centrosomes in Pinus appear as small but definite and readily stained bodies lying at the poles. Sometimes a hyaline area is visible around them in which the spindle threads termi-

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[8] Ueber das Verhalten d. Pollens. Hist. Beitr. **4** : —. 1892.

[9] Ann. Bot. **8** : 21–34. 1894.

nate. In other cases no such area can be observed, the spindle fibers appearing to meet at the centrosome. These bodies, on account of their common occurrence at the poles, should perhaps retain the name of centrosomes whether they are permanent bodies directing cell division or whether they are only temporary structures. Whatever these bodies may be they certainly seem to be the same in character as the bodies found at the poles of cells in animal tissue. They are not only the points to which spindle fibers converge, but they are also the centers for a system of radiations which pass outward into the cytoplasm.

H. L. Smith[10] is perhaps the first to have figured centrosomes in plants. He found a small body in diatoms, especially in *Surirella splendens*, which he called the germinal dot. This was no doubt a centrosome. Guignard[11] figured and described these bodies in resting cells as well as during karyokinesis. In his recent paper[12] he finds centrosomes in all phases of nuclear division in *Nymphæa alba*. He finds multipolar spindles also in *Nuphar luteum*, and says they are very frequent in *Limodorum abortivus*, but he does not give any explanation of their origin.

In the early part of the telophase the cell wall between the two daughter nuclei begins to form. It starts as a granular thickening of the middle of the central spindle fibers (*fig. 26*). This thickening gradually extends outward and the spindle at the same time gradually increases in diameter (*figs. 27, 28*) until its middle portion touches the cell walls. The cell plate then completely divides the daughter cells and the spindle soon disappears. In *fig. 28* traces of it may still be seen. Two centrosomes are now found at each pole, the single ones having divided. While the network is being formed the daughter nuclei change from an oval to a spherical form, sometimes having radiations around them (*fig. 29*).

COLUMBUS, O.

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[10] A contribution to the life history of Diatomaceæ, Proceedings American Society of Microscopists **1886**: 1–37.

[11] Ann. Sci. Nat. (Bot.) VII. **14**: 163–296. 1891.

[12] BOT. GAZ. **25**: 158–164. 1898.

EXPLANATION OF PLATES XXIII, XXIV.

The figures were drawn with combinations of Zeiss and Bausch and Lomb objectives and oculars by the aid of a camera lucida, and are reduced to about $\frac{3}{8}$ of their original size. The initial letter of the objectives and oculars are used to designate them. The four following combinations were employed: Z 2^{mm} ap. Z 18 (× 2250); Z 2^{mm} ap. Z 12 (× 1500); B & L $\frac{1}{12}$ Z 12 (× 2600); B & L $\frac{1}{12}$, B & L $\frac{3}{4}$ (× 1400).

Figures 1, 16, 17, 18, 26, and 29 were taken from *Pinus silvestris;* all the others from *Pinus Laricio.*

PLATE XXIII.

FIG. 1. Resting nucleus with large oil drops in the cytoplasm. B & L $\frac{1}{12}$ Z 12.

FIG. 2. Resting cell, with radiating streams of cytoplasm around the nucleus. B & L $\frac{1}{12}$; B & L $\frac{3}{4}$.

FIG. 3. Resting cell containing an elongated nucleus with a spindle and centrosome-like bodies. Z 2^{mm} ap. Z 18.

FIG. 4. Part of cell containing a very large nucleus in which are several nucleoli with vacuoles. B & L $\frac{1}{12}$ Z 12.

FIG. 5. Early stage of division showing first appearance of spindle. B & L $\frac{1}{12}$ Z 12.

FIG. 6. Spindle elongating showing centrosomes and radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 7. Same stage, somewhat later, showing few radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 8. Dome-shaped spindle showing neither centrosomes nor radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 9. Dome-shaped spindle showing centrosomes and a few radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 10. Same stage more advanced. Z 2^{mm} ap. Z 12.

FIG. 11. Spindle becoming pointed showing centrosomes and radiations. Z 2^{mm} ap. Z 18.

FIG. 12. Spindle pointed but poles not entirely opposite. B & L $\frac{1}{12}$ Z 12.

FIG. 13. Nuclear membrane absent; spindle not so much pointed as is usual at this stage. B & L $\frac{1}{12}$ Z 12.

FIG. 14. Loose mother skein stage showing appearance and number of chromosomes. Z 2^{mm} ap. Z 18.

PLATE XXVI.

FIG. 15. Mother star stage. B & L $\frac{1}{12}$ Z 12.

FIG. 16. Showing one end of spindle with a large centrosome; chromosomes massed together. Z 2^{mm} ap. Z 12.

FIG. 17. Same as above with pole of spindle near cell wall. Z 2^{mm} ap. Z 12.

FIG. 18. Metakinesis; poles of spindle crowded against cell walls. Z 2^{mm} ap. Z 12.

FIG. 19. Metakinesis; pole with centrosome and distinct radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 20. Metakinesis. Z 2^{mm} ap. Z 12.

FIG. 21. Metakinesis; injured, showing multipolar spindle; chromosomes are partly displaced. B & L $\frac{1}{12}$ Z 12.

FIG. 22. Metakinesis. B & L $\frac{1}{12}$ Z 12.

FIG. 23. Near close of metakinesis, showing centrosomes and radiations. Z 2^{mm} ap. Z 12.

FIG. 24. Same as above. Z 2^{mm} ap. Z 12.

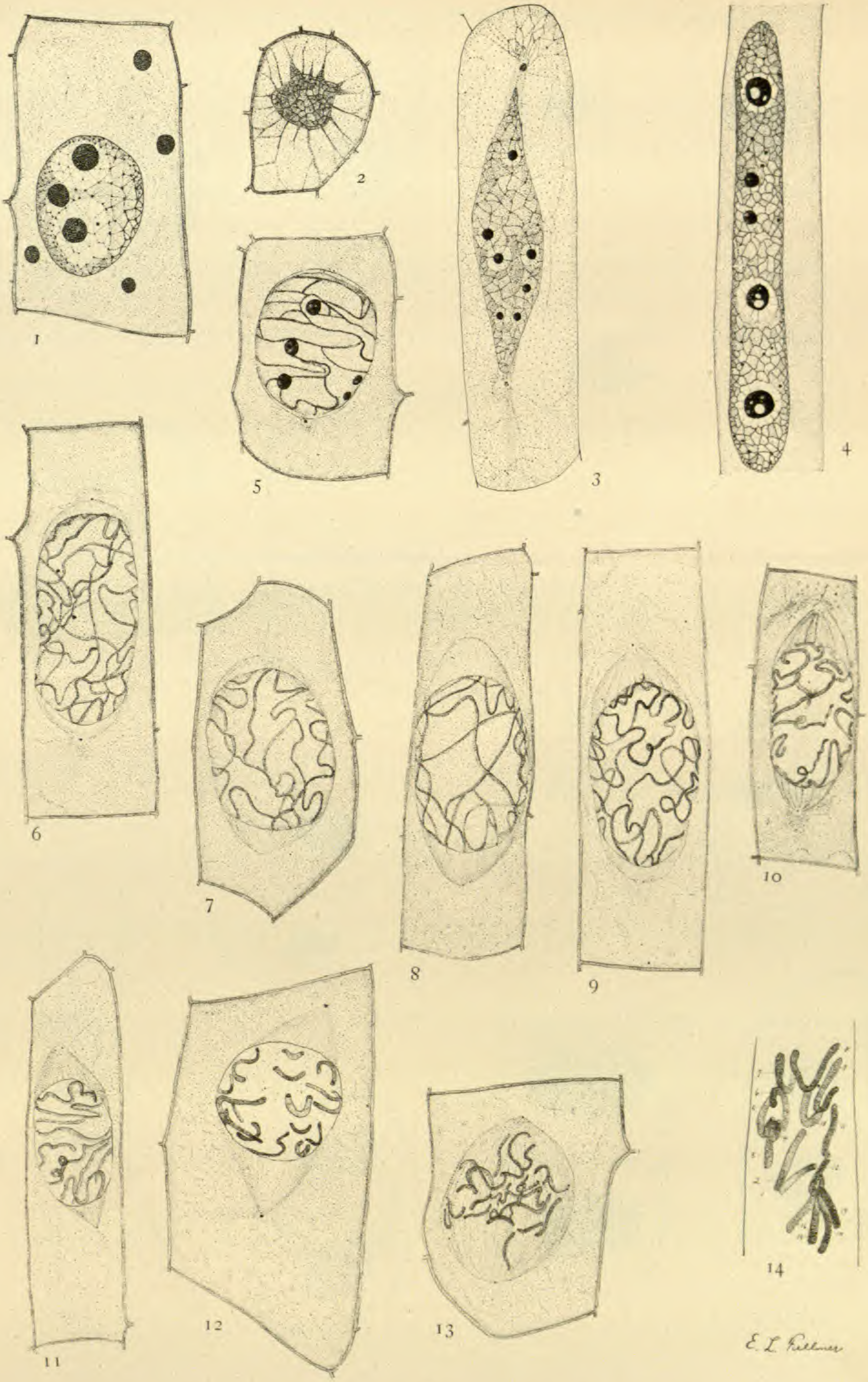
FIG. 25. Daughter star with centrosomes and radiations. B & L $\frac{1}{12}$ Z 12.

FIG. 26. Loose daughter skein. B & L $\frac{1}{12}$ Z 12.

FIG. 27. Close daughter skein; cell plate formed. Z 2^{mm} ap. Z 18.

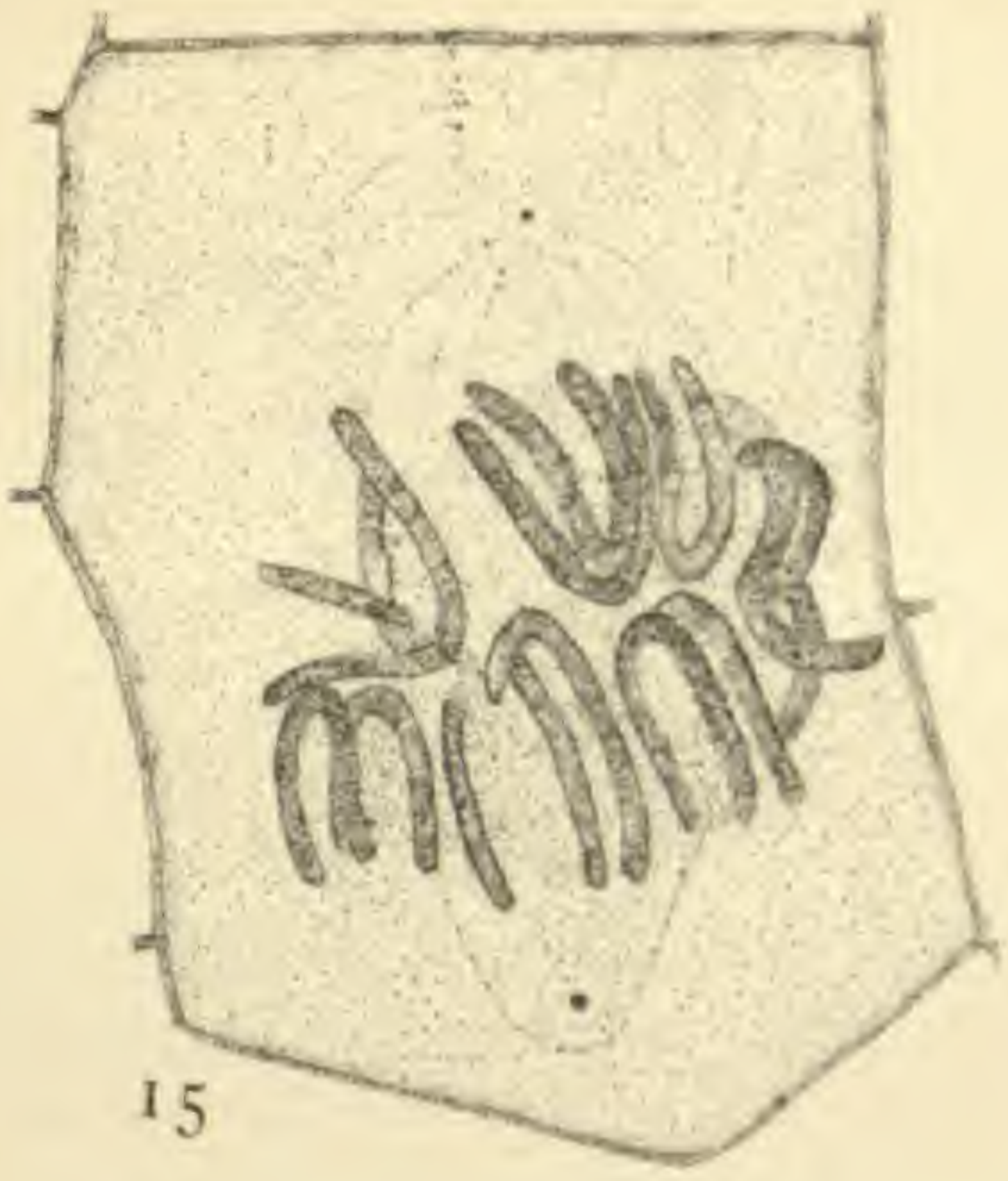
FIG. 28. The same but somewhat more advanced. Z 2^{mm} ap. Z 18.

FIG. 29. Near end of close daughter skein; nuclei are becoming globular. B & L $\frac{1}{12}$ Z 12.



E. L. Fullmer

FULLMER on CELL-DIVISION.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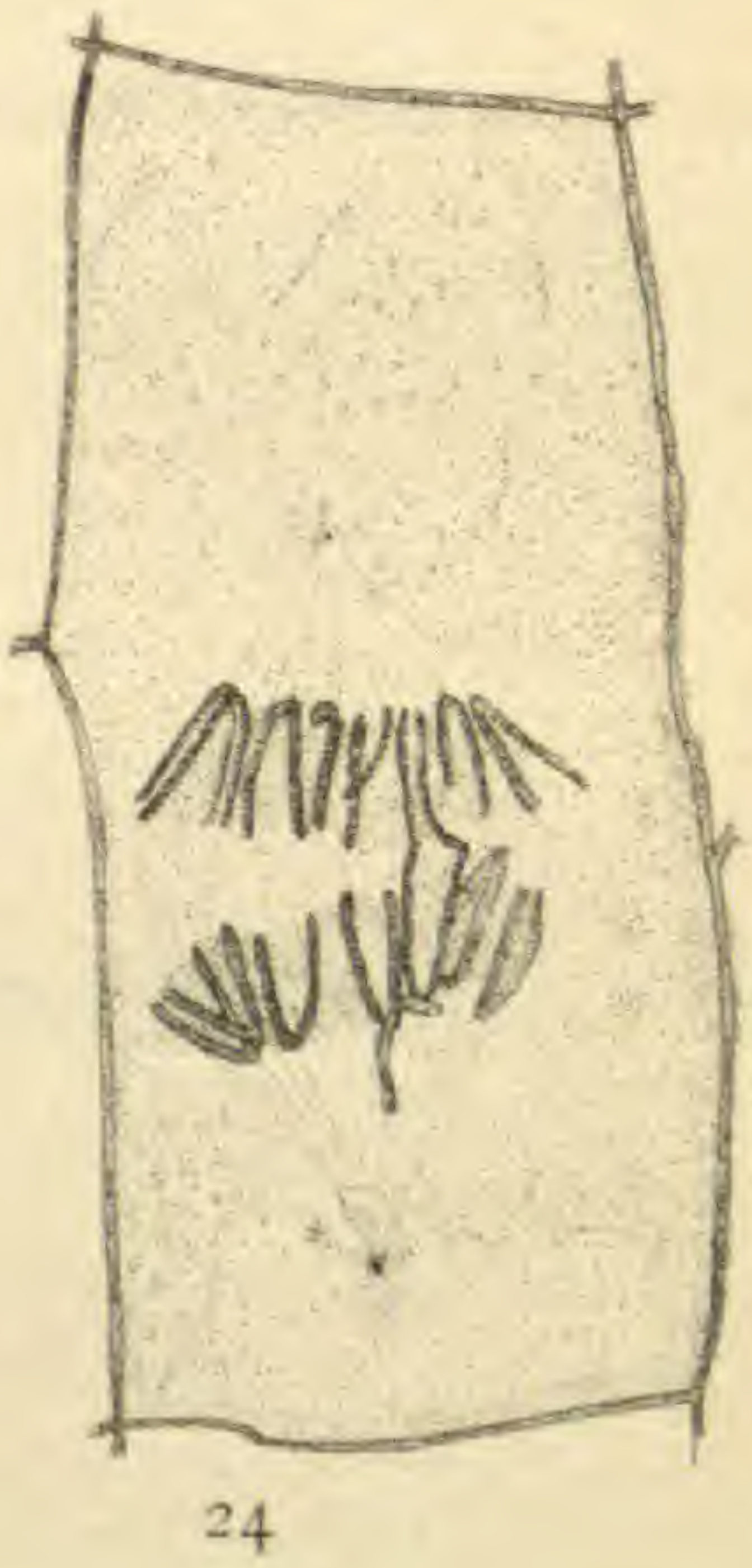
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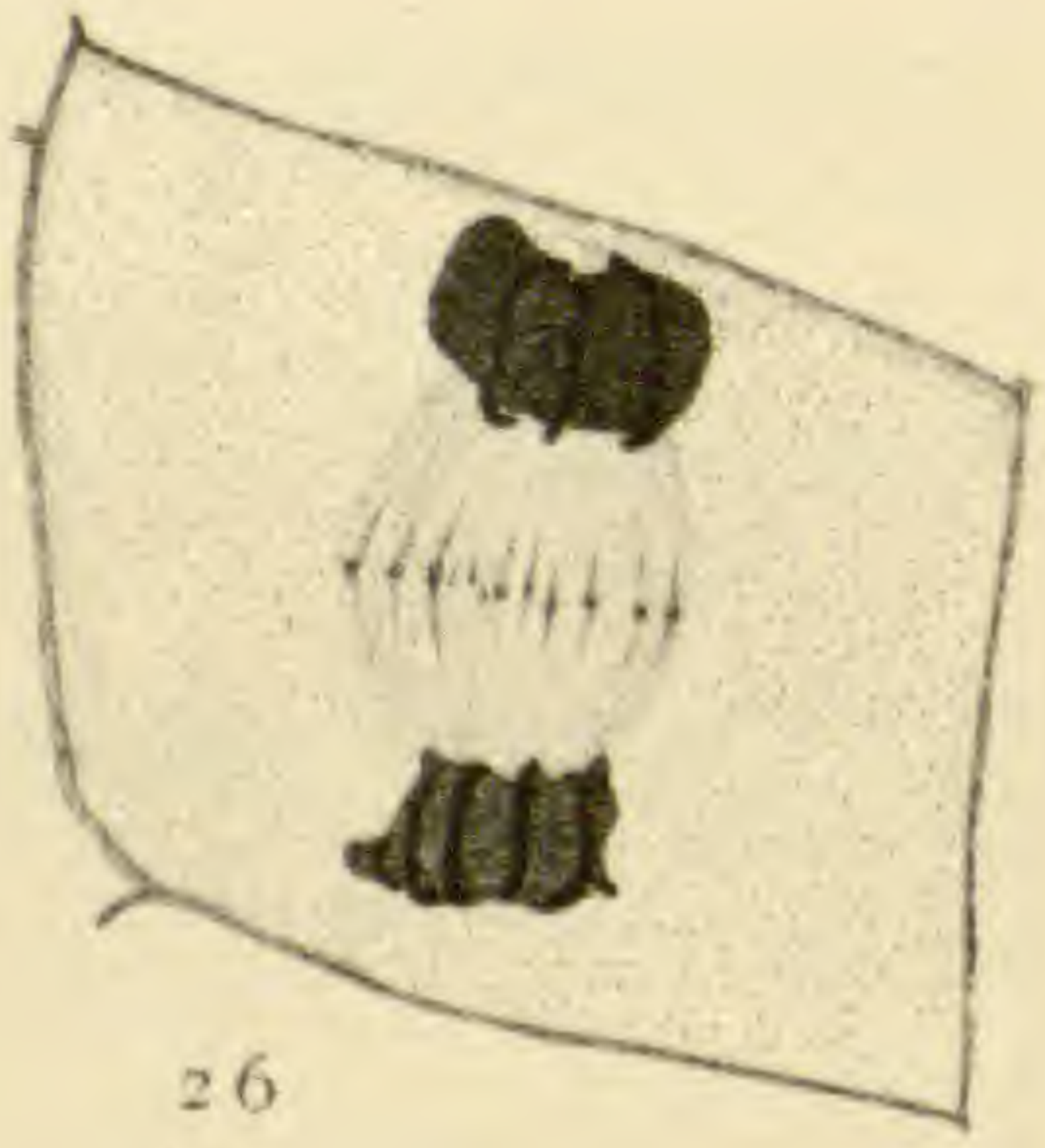
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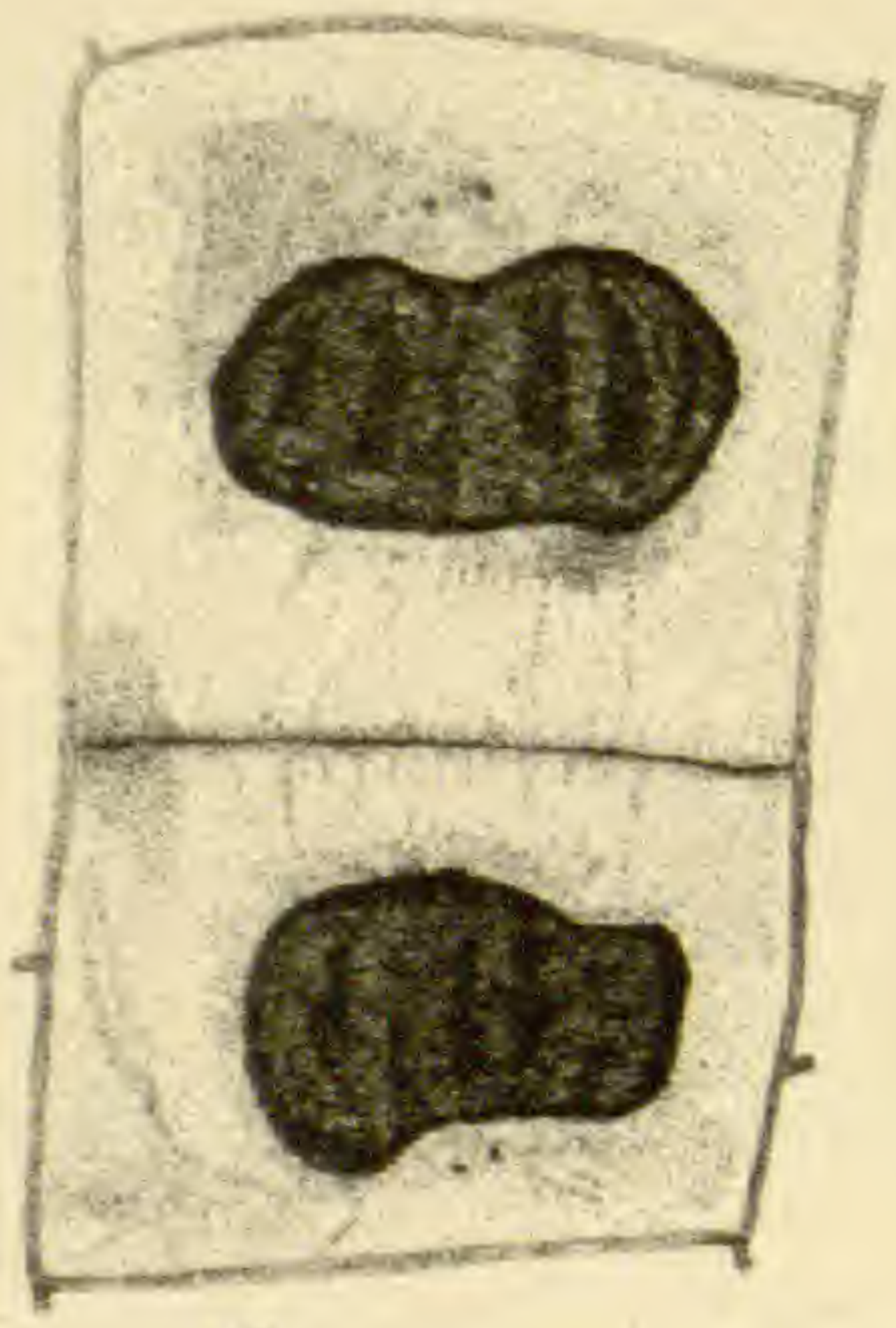
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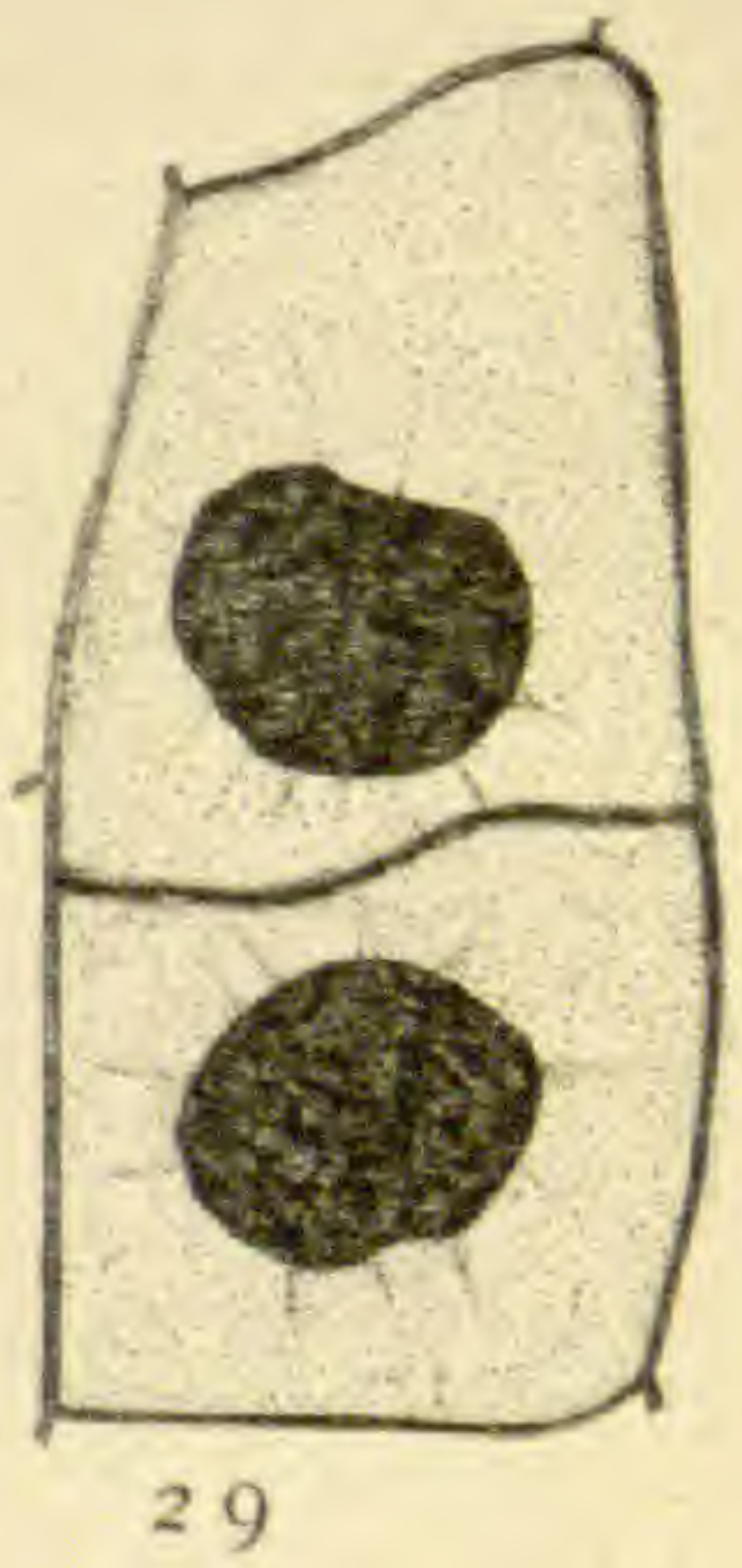
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E. L. Fullmer

FULLMER on CELL-DIVISION.

POPULAR AMERICAN PLANT-NAMES. V.

FANNIE D. BERGEN.

LOBELIACEÆ.

Lobelia cardinalis, L., queen-of-meadow, Southold, L. I.

CAMPANULACEÆ.

Campanula Americana, L., hibelia (*i. e.* high lobelia),[1] Sulphur Grove, Ohio.

ERICACEÆ.

Andromeda ligustrina, Muhl., maleberry, York, Me.
Arctostaphylos Andersonii, Gray, little apple, manzanita, Cal.
Azalea viscosa, L., June pink, N. H.
Chimaphila maculata, Pursh., wax flower, Southold, L. I.
Chimaphila umbellata, Nutt., wintergreen, Oxford County, Me.
Chiogenes serpyllifolia, Salisb., Moxa or Moxie, Paris and Dixfield, Me.
running tea, Bethel, Me.
sugar-berry (locality ?).
spice-berry, tea-berry, New Brunswick.
Epigæa repens, L., shad-flower, New England and New Jersey.
real mayflower,[2] Norridgewock, Me.
Gaylussacia ursina, T. and G., bear huckleberry, Mountains of New England.
Kalmia latifolia, L., sheepsbane, Long Island.
ivy, West.
Ledium latifolium, Ait., Labrador, Paris, Me.
gowiddie, Newfoundland.
Monotropa uniflora, L., ghost-flower, S. Berwick, Me.
Rhododendron Rhodora, Don, laurel, Paris, Me.
Sarcodes sanguinea, Torr., snow plant, Sierra Nevada, Cal.
Vaccinium ovatum, Pursh., California huckleberry, Cal.

PRIMULACEÆ.

Anagallis arvensis, L., poison chickweed, Cal.
red chickweed, West.
Dodecatheon Meadia, L., cyclamen, Ala.
Lysimachia mummularia, L., money plant, infant's breath, Oxford Co., Me.
money-bags, Medford, Mass.

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[1] Spokes of flowers seen from afar resemble those of *Lobelia syphilitica*.

[2] The hepatica is called mayflower in Norridgewock, Me.

Primula Mistassinica, Michx., drip-primrose, Harding's "With the Wild Flowers," p. 214.

Primula officinalis, Jacq., tuberose, Colo.

Trientalis Americana, Pursh., Star of Bethlehem, Fairhaven, Mass., and Vermont.

SAPOTACEÆ.

Mimusops Sieberi, A. DC., wild sapodilla, Florida keys.

OLEACEÆ.

Fraxinus pubescens, Lam., yellow ash, West.

APOCYNACEÆ.

Apocynum androsæmifolium, L., Chickasaw, wildweed, Paris and Hartford, Me.

Vinca minor, L., myrtle, Paris, Me.
myrtle, wintergreen, Sulphur Grove, Ohio.

ASCLEPIADACEÆ.

Asclepias tuberosa, L., swallow wort, West.
pleurisy root, chigger[1] flower, Southwestern Mo.

Enslenia albida, Nutt., honey-vine, Tex.

GENTIANACEÆ.

Erythræa Douglassi, Gray, Canchalagua, chill and fever plant, Cal.

Menyanthes trifoliata, L., marsh trefoil, West.

Sabbatia angularis, Pursh., Texas star, Tex.

POLEMONIACEÆ.

Gilia coronopifolia, Pers., standing cypress, Ala.
Texas plume, Tex.

Phlox ovata, L., sweet William, Sulphur Grove, Ohio.

Phlox pilosa, sweet William,[2] Mo.

Phlox subulata, L., moss pink, creeping phlox, Sulphur Grove, Ohio.

Phlox (all species), sweet William, Ind.

Polemonium reptans, L., snake root, blue valerian, Parke County, Ind.

HYDROPHYLLACEÆ.

Emmenanthe penduliflora, Benth., yellow bells, Cal.

Eriodictyon glutinosum, Benth., mountain balsam, yerba santa, Cal.

Nemophila insignis, Dougl., baby-blue-eyes, Cal.

Phacelia tanacetifolia, Benth., tansy-leaf phacelia, Cal.

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[1] From a popular belief that the insect of that name is found there.

[2] *Phlox pilosa* and related species are confounded with *Verbena Aubletia,* and all called sweet William in southwestern Missouri.

BORRAGINACEÆ.

Amsinckia (five species), tar weed, Cal.

Cynoglossum (all species), beggar lice, Sulphur Grove, Ohio.

Echinospermum floribundum, Lehm., stick weed, Cal.

Echinospermum Lappula, Lehm., forget-me-nots, Madison, Wis.

Echinospermum Virginicum, Lehm., beggar ticks,[1] Southwestern Mo.

Echium vulgare, L., blue weed, Jackson County, Mo.

Lithospermum canescens, Lehm., blood root, Indian paint,[2] Southwestern Mo.

Myosotis, sp., scorpion weed, West.

Symphytum asperrimum, Sims, bugloss, Paris, Me.

CONVOLVULACEÆ.

Convolvulus sepium, L., Rutland beauty, Kentucky hunter, pea vine,
Sulphur Grove, Ohio.
Kentucky hunter, Paris, Me.

Cuscuta, sp., love vines,[3] Southwestern Mo.
corn silk, Southold, L. I.

Cuscuta Gronovii, Willd., angels' hair, La.

Ipomœa hederacea, Jacq., blue morning glory, Southwestern Mo.

Ipomœa leptophylla, Torr., wild potato vine, man of the earth, morning glory bush, Cal.

Ibomœa pandurata, Mey., and *Convolvulus sepium*, L., wild potato, Southwestern Mo.

Ipomœa pandurata,[4] Mey., wild potato, Ala.
wild sweet potato, pea vine, Sulphur Grove, Ohio.

Ipomœa purpurea, Lam., red morning glory, Southwestern Mo.

SOLANACEAE.

Datura meteloides,[5] DC., Jamestown weed, thorn apple, Cal.

Lycium vulgare, Dunal., Washington's bower, Southwestern Mo.

Nicandra physaloides, Gaertn., globe, Sulphur Grove, Ohio.

Nicotiana glauca, Graham, tobacco tree, Cal.

Physalis, sp., cherry tomatoes, Eastern end of Long Island.

---

[1] Confounded with *Galium*.

[2] From a tradition that the Indians thus utilized its root.

[3] From a popular custom among young people of throwing a portion of this plant backward over the head of another plant, and naming it for some one. If it lives, that one loves them.

[4] Sold by J. Lewis Childs, Floral Park, N. Y., under the name of "hardy tuberous-rooted moonflower."

[5] The seed is made into an intoxicating drink by the Arizona Indians.

Solanum Carolinense, L., bull nettle, Southwestern Mo.

Solanum Dulcamara, L., myrtle vine, Sulphur Grove, Ohio.
wood nightshade, West.

Solanum nigrum, L., bonewort, West.

Solanum radula, Vahl, soap berry, Florida keys.

Solanum rostratum, Dunal., Kansas thistle, Southwestern Mo.

Solanum triquetrum, Cav., potato jasmine, Waco, Tex.

Solanum verbascifolium, L., mugged (? mug-weed, mug-wood, mugwort), Florida keys.

SCROPHULARIACEÆ.

Castilleia sessiliflora, Pursh., honeysuckle, Burnside, S. Dak.

Linaria vulgaris, Mill., Jacob's ladder, Long Island.
ladies' slippers, Mass.
butter and eggs, Auburndale and Cambridge, Mass.

Pedicularis Canadensis, L., chickens' heads, Southold, L. I.

Pentstemon Digitalis, Nutt., dead men's bells,[1] West.

Pentstemon gracilis, Nutt., beard-tongue, Greene County, Mo.

Pentstemon, sp., foxglove, Tex.

Scrophularia nodosa, var. *Marilandica,* Gr., carpenter's square, Southwestern Mo.

Verbascum Blattaria, L., slippery mullein (in distinction from fuzzy mullein, *V. Thapsus*), Southold, L. I.

Veronica Virginica, L., black root, Southwestern Mo.

Veronica, sp., speedwell or brooklime, Harding's "With the Wild Flowers."

OROBANCHACEÆ.

Aphyllon or *Boschniakia,* sp., squirrels' grandfather, Cal.

BIGNONIACEÆ.

Chilopsis saligna, Don, desert willow, Ariz. and Colo.
catalpa willow, Tex.

VERBENACEÆ.

Avicennia oblongifolia, ? Nutt., black wood, Florida keys.

Calicarpa Americana, L., French mulberry, Miller County, Mo.

Lantana involucrata, L., var. Floridana, sage tree, Florida keys.

Lippia cuneifolia, Steud., chapparal, Mexican heliotrope, Tex.

Verbena Aubletia, L., sweet William,[2] Southwestern Mo.

Verbena augustifolia, stricta, and *urticæfolia,* L., bur-vine, Southwestern Mo.

Verbena stricta, Vent., thimble-weed, St. Joseph, Mo.

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[1] From growing on graves.

[2] Flowers have a sweetish taste when eaten, like the flowers of phlox.

LABIATÆ.

Brunella vulgaris, L., wild sage, Paris, Me.
hearts' ease, Cambridge, Mass.
cure-all, West.

Galeopsis Tetrahit, L., Keays-weed, Bisbee-weed, bur-weed, Paris, Me.

Hedeoma pulegioides, Pers., pudding grass, West.

Lycopus sinuatus, Ell., rattlesnake weed,[1] Southwestern Mo.

Lycopus Virginicus, L., archangel, Dixfield, Me.
sprig-of-Jerusalem, South Berwick, Me.

Mentha Canadensis, L., wild bergamot, or bergamont, Oxford County, Me.

Mentha piperita, L., manzania, Cal.

Micromeria Douglasii, Benth., good herbs, "yerba buena," Cal.

Molucella lævis, L., Molucca balm, shell flower, old maids' bonnet, Sulphur Grove, Ohio.

Nepeta Glechoma, Benth., Gill-run-over-grass, run-away-Jack, blue bells, Cambridge, Mass.
run-away-Nell, Medford, Mass.

Origanum vulgare, L., wild marjoram, West.

Salvia Columbariæ, Benth., wild sage, chia, winter oat, Cal.

Scutellaria laterifolia, L., hoodwort, West.

Teucrium Canadense, L., betony, head betony, wood betony, West.

PLANTAGINACEÆ.

Plantago lanceolata, L., nigger-heads, hock cockle, Southold, L. I.
soldiers, Cambridge, Mass.

NYCTAGINACEÆ.

Abronia latifolia, Esch., yellow sand verbena, Cal.

Boerhaavia erecta, L., jigger weed, Florida keys.

Mirabilis Jalapa, L., pretty-per-night,[2] Sulphur Grove, Ohio.

AMARANTACEÆ.

Amarantus Albus, L., tumble weed,[3] Southwestern Mo.

Amarantus retroflexus, L., light-houses,[4] Southold, L. I.
curls, red root, Sulphur Grove, Ohio.
wild beet,[5] Oxford County, Me.

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[1] Herb said to be an antidote for the bite of rattlesnakes.

[2] Not pretty by night, although it means the same.

[3] From its habit of drying in a round mass, and being rolled about by the wind.

[4] From speed with which they tower above crops in the fields.

[5] Said to taste like beets when cooked for "greens."

Gomphrena globosa, L., globe amaranth, bachelor's button, Sulphur Grove, Ohio.
bachelor's button, Ala.

CHENOPODIACEÆ.

Chenopodium album, L., black weed,[1] Eastern Long Island.
Chenopodium capitatum, Watson, garden strawberry, Paris, Me.
Salicornia ambigua, Michx., lead grass, lead weed,[2] Southold, L. I.

PHYTOLACCACEÆ.

Phytolacca decandra, L., poke berry, poke root,[3] Sulphur Grove, Ohio.
cocum, pocum, pigeon berry, West.
ink bush, ink-berry bush, Southold, L. I.
haystack weed, Conn.

POLYGONACEÆ.

Polygonum aviculare, L., dog-tails, St. Joseph, Mo.
Polygonum convolvulus, L., wild bean, Oxford County, Me.
Polygonum dumetorum, L., var. *scandens*, Gray, wild buckwheat, Burnside, S. Dak.
Polygonum erectum, L., goose grass, Sulphur Grove, Ohio.
Polygonum orientale, L., Gentleman's cane, prince's feather, Sulphur Grove, Ohio.
kiss-me-over-the-fence, Sulphur Grove, Ohio.
ragged sailor, Paris, Me.
Polygonum Persicaria, L., heart weed, Oxford County, Me.
black heart, Lubec, Me. ; Mass. ; Southern Vt.
Polygonum terrestre, heartsease, Nebr.
Polygonum (twining species), pull-down, blind weed, Sulphur Grove, Ohio.
Polygonum, sp., heart's ease, Erie County, Pa.
Rheum Rhaponticum, L., wine plant, Sulphur Grove, Ohio.
Rumex crispus, L., narrow dock, curled dock, Sulphur Grove, Ohio.
Rumex obtusifolius, L., sour dock, poison dock, Sulphur Grove, Ohio.

ARISTOLOCHIACEÆ.

Asarum Canadense, L., colt's foot, West.

CAMBRIDGE, MASS.

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[1] Because it stains the fingers black.

[2] From its weight in the salt-meadow hay.

[3] The friends of J. K. Polk used this plant as their symbol when he was running for president, and marked their hats with juice of the berries.

POPULAR AMERICAN PLANT-NAMES. VI.

FANNIE D. BERGEN.

LAURACEÆ.

Umbellularia Californica, Nutt., pepper-wood, Cal.

THYMELÆCEÆ.

Dirca palustris, L., Indian wickape, West.
wickopy, Hartford, Me.

ELÆAGNACEÆ.

Shepherdia argentea, Pursh, buffalo berry, Nebr.

EUPHORBIACEÆ.

Euphorbia corollata, L., milkweed, Madison, Wis.
Euphorbia Cyparissias, L., milkweed, Vermont.
graveyard moss, Ind.
Euphorbia hypericifolia, and *E. maculata*, L., corn-pusley, Southold, L. I.
Euphorbia maculata, L., French pursley, Sulphur Grove, Ohio.
Euphorbia marginata, Pursh, snow-on-the mountain, Sulphur Grove, Ohio; N. Dak.
milkweed, ghost-weed, snow-on-the-mountain, Waco, Tex.
Jatropha stimulosa, Michx., bull nettle, South.
Ricinus communis, L., castor-bean, Sulphur Grove, Ohio.
Simmondsia Californica, Nutt., pig-nut, Arizona.
Tragia nepetæfolia, Cav., stinging nettle, Southwestern Mo.

URTICACEÆ.

Laportea Canadensis, Gaudich, wood nettle, Southwestern Mo.
Maclura aurantiaca, Nutt., Osage orange, hedge-tree, "bois d'arc," Southwestern Mo.
Pilia pumila, Gray, water weed, Sulphur Grove, Ohio.
Ulmus Americana, L., red elm, white elm, Southwestern Mo.
Ulmus fulve, Michx., slippery elm, white elm, Southwestern Mo.

JUGLANDACEÆ.

Carya alba, Nutt., walnut, New England.
black hickory, Southwestern Mo.
Carya microcarpa, Nutt., black hickory, Sulphur Grove, Ohio.
Carya porcina, Nutt., spignut,[1] Ind.

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[1] A corruption of pignut.

Carya sulcata, Nutt., shell-bark hickory, Southwestern Mo.

Carya tomentosa, Nutt., white hickory, Southwestern Mo.
pull-nut, mocker-nut, Sulphur Grove, Ohio.

Juglans cinerea, L., oil-nut tree, West.
white walnut, Southwestern Mo.

CUPULIFERÆ.

Betula balsamifera, sycamore, black poplar, West.

Carpinus Caroliniana, Walt., swamp beech, hornbeam, Sulphur Grove, Ohio.

Fagus ferruginea, Ait., white beech, red beech, black beech, West.

Quercus coccinea, Wang., and var. *tinctoria*, Gray, black oak, Southwestern Mo.

Quercus imbricaria, Michx., swamp oak, pin oak, Southwestern Mo.

Quercus rubra, L., red oak, Spanish oak (lowland variety), Southwestern Mo.

SALICACEÆ.

Salix cordata, Muhl., var. *vestita*, And., diamond willow, Burnside, S. Dak.

Salix, sp., with catkins very prominent, pussy willow, Sulphur Grove, Ohio.

EMPETRACEÆ.

Empetrum nigrum, L., squirt plum, Rumford, Me.

CONIFERÆ.

Abies alba, Link, cat spruce, Andover, Me.

Juniperus communis, L., juniper, West.

Juniperus Sabina, L., juniper, West.

Juniperus Virginiana, L., juniper, West.

Larix Americana, Michx., juniper, West.
cypress, Oxford County, Me.

Pinus Banksiana, Lambert, shrub pine, West.

Pinus resinosa, Ait., Norway pine, hard pine, Oxford County, Me.

Pinus strobus, L., yellow pine, West.

Torreya Californica, Torr., California nutmeg tree, Cal.

ORCHIDACEÆ.

Arethusa bulbosa, L., swamp pink, meadow pink, Mass.

Cypripedium acaule, Ait., valerian, nerve root, Paris, Me.
Indian slipper, Oxford County, Me.

Cypripedium spectabile, Swartz, shepherd's purse, Lepreau, N. B.

Goodyera repens, R. Br., adder's tongue, Paris, Me.

Habenaria psycodes, Gray, and *Habenaria fimbriata*, R. Br., wild hyacinth, Woodstock, Me.

Spiranthes cernua, Richard, hens' toes, Paris, Me.

IRIDACEÆ.

Iris versicolor, L., blue lily, Madison, Wis.
Sisyrinchium angustifolium, Mill., forget-me-not, Hartford, Me.

AMARYLLIDACEÆ.

Agave Parryi, Engelm., century plant, Ariz.
Cooperia Drummondii, Herb., rain lilies, star flowers, Waco, Tex.
Narcissus (all species), Easter flowers, Sulphur Grove, Ohio.

LILIACEÆ.

Camassia esculenta, wild hyacinth, "kmass," Cal.
Chlorogalum pomeridianum, Kunth, soap root, soap plant,[1] "amole," Cal.
Clintonia borealis, Raf., hound's tongue, calf corn, Hartford, Me.
wild corn, corn flower, Oxford County, Me.
Dasylirion Wheeleri, Watson, bear grass, Ariz.
Erythronium albidum, Nutt., tulip, Southwestern Mo.
Erythronium Americanum, Ker., wild yellow lily, Norridgewock, Me.
jonquil, cornflower,[2] Oxford County, Me.
Hemerocallis flava, L., lemon lily,[3] Sulphur Grove, Ohio.
Hesperocallis undulata, Gray, California day lily, Cal.
Lilium Philadelphicum, L., freckled lily, South Berwick, Me.
Maianthemum bifolium, DC., wild lily of the valley, Fairhaven, Mass.
Muscari racemosum, Mill., var. *plumatilis*, feather hyacinth, sugar loaf, Sulphur Grove, Ohio.
Oakesia sessilifolia, Watson, wild oats, Paris and Hartford, Me.
corn-flower, Oxford County, Me.
Smilax Bona-nox, L., bamboo vine, stretch-berry, Waco, Tex.
Smilax rotundifolia, L., horse brier, dog brier, Mass.
Streptopus roseus, Michx., Jacob's ladder, Paris, Me.
Solomon's seal, West.
Trillium erectum, L., red Benjamin, Woodstock and Paris, Me.
wild peony, or "piny," Oxford County, Me.
Trillium erythrocarpum, Michx., white Benjamin, Woodstock and Paris, Me.
Trillium recurvatum, Beck., cowslip, Parke County, Ind.
Jack-in-the-pulpit, Central Ill.
Trillium sessile, L., nigger-heads, Ind.

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[1] Used in washing.
[2] Sometimes used for "greens."
[3] Lemon-colored.

Veratrum viride, Ait., Indian poke, Oxford County, Me.

Xyrophyllum setifolium, Michx., turkey-beard, N. J.

Yucca filamentosa, L., Adam's needle and thread, Harding's "With the Wild Flowers."

Yucca gloriosa, L., Roman candle, the Lord's candlestick, So. Cal.

PONTEDERIACEÆ.

Pontederia cordata, L., moose-ear, Grand Lake, N. B.

COMMELINACEÆ.

Tradescantia crassifolia (green), Jacob's ladder, Wandering Jew, Sulphur Grove, Ohio.
(striped), Joseph's coat, Sulphur Grove, Ohio.

Tradescantia, sp., in greenhouses, small white flowers pointed like corn, corn lily, Sulphur Grove, Ohio.

Tradescantia, sp., Indian paint,[1] Mineral Point, Wis.

ARACEÆ.

Arisæma triphyllum, Torr., wake-robin, West.
bog onion, Rumford, Me.
memory root, Rutland, Mass.

Calla palustris, L., water arum, West.

ALISMACEÆ.

Sagittaria variabilis, Engelm., water lily, Southwestern Mo.
arrow-head, swan root,[2] Cal.

CYPERACEÆ.

Cyperaceæ (all grass-like species), ornamental grass, Sulphur Grove, Ohio.

Scirpus lacustris, L., cat-tail flag,[3] Cal.

GRAMINEÆ.

Agropyrum repens, L., witch grass, Oxford and York counties, Me.

Andropogon furcatus, Muhl., and related species, blue-stem grass, Southwestern Mo.

Cenchrus tribuloides, L., sand spur, Fla.
sand bar, Waco, Tex.

Danthonia spicata, Beauv., witch grass, Oxford and York counties, Me.

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[1] The juice said to irritate the skin and make it red.

[2] Used as food by Indians.

[3] Used as food by Indians.

Panicum capillare, L., tickle grass, Sulphur Grove, Ohio.
Panicum virgatum, L., switch grass,[1] Central Neb.
Setaria glauca and *viridis*, Beauv., barn grass, Oxford County, Me.
Sorghum, sp., cane, sugar cane, Sulphur Grove, Ohio.
Sporobolus Buckleyi, Vasey, crawly grass,[2] tickle grass, Waco, Tex.
Sporobolus serotinus, Gray, blue ruin, Oxford County, Me.
Triticum repens, twitch grass, dog grass, Oxford County, Me.
Zea mays, L. (yellow striped with red), bloody butcher, Sulphur Grove, Ohio.
(hard grains without dents), flint corn, Sulphur Grove, Ohio.

EQUISETACEÆ.

Equisetum hiemale, L., gun-bright,[3] Penobscot County, Me.
snake weed, Jones and Delaware counties, Iowa.

FILICES.

Aspidium Noveboracense, Swartz, bear's paw, Plattsburg, N. Y.
Cystopteris, sp., bladder fern, N. Y.
Onoclea sensibilis, L., polypod brakes,[4] Oxford County, Me.
sugar brake, Penobscot County, Me.
Polypodium (a Florida species), resurrection fern,[5] Fla.
Pteris aquilina, L., poor man's soap,[6] Ala.
Woodwardia, sp., chain fern, N. Y.

OPHIOGLOSSACEÆ.

Botrychium Virginianum, Swartz, indicator,[7] Jackson, West Va.

LYCOPODIACEÆ.

Lycopodium clavatum, L., stag-horn evergreen, Concord, Mass.
Lycopodium complanatum, L., trailing Christmas Green, West Va.
trailing, running, or creeping vine, Ferrisburgh, Vt.
evergreen, Oxford County, Me.
Lycopodium, sp., fox-tail, St. Andrews, N. B.

[1] Also called "wild red-top" by the farmers.

[2] Very troublesome to the mower, eluding the scythe.

[3] Said to have been used by the Indians for polishing their guns.

[4] It would be an interesting investigation to trace out the origin of this application of a name evidently derived from *Polypodium*.

[5] From its habit of unrolling upon being wet with rain.

[6] Because it will make a lather with water.

[7] Name derived from the fact that its growth is thought to indicate the presence of ginseng.

MUSCINEÆ.

Polytrichum commune, bear's grass, Penobscot County, Me.
bird's wheat, Kennebec valley, Me.

FUNGI.

Boletus, sp., cow mushroom, N. H.
Exobasidium, sp., May apple, N. J.
Phallus, sp., carrion flower, Mass.

ALGÆ.

Spirogyra, sp., frog slime, N. H.
Ulva latissima, glit, Mace's Bay, N. B.

CAMBRIDGE, MASS.

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OBSERVATIONS UPON THE NEWER BOTANY.[1]

BYRON D. HALSTED.

THE LEAF A LIGHT-RELATED ORGAN.

UNDER life relations it may be an advantage to some that an instance be stated even though it be in brief terms. Let us take the leaf as it is, one of the three vegetative organs.

The leaf is divided into three parts — the stalk, stipules, and blade. Furthermore, the blade is made up of the framework, the pulp, and the skin that envelops all and holds the parts together. It has been stated that the leaf is a light-related organ, and it will be to the point to consider this relationship.

It is the pulp that interests us in considering the leaf as related to the light, and this is the soft portion lying between the upper and lower skin, and supported by the framework. It consists of minute cells somewhat loosely placed.

It is now that the microscope lends valuable assistance, for by it it is seen that the cells consist of three parts, the wall or sac, the liquid, and the green granular contents.

It is these minute masses of protoplasm, colored green by chlorophyll that interest us in a study of the light relation, for it is in these that the energy of motion is transformed into energy of position — kinetic into potential.

Within these chlorophyll granules the energy of the vibrating rays of the sun splits up the molecules of water, coming from the soil through the roots and stem, and those of the carbonic dioxide from the atmosphere driving off a portion of the oxygen. Thus, if we should have six groups of the carbon dioxide molecules ($6\ CO_2$) and five of water ($5\ H_2O$) there might be a separation of twelve atoms of oxygen, and the union

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[1] Remarks following a paper upon Botany for the Secondary Schools, by Dr. J. M. Coulter, before the Natural Science Section of the National Educational Association, Washington, D. C., July 1898.

of the remaining portion would give a molecule of starch ($C_6 H_{10}O_5$). This is food making reduced to its simplest terms, and the chlorophyll granules that float in the semi-liquid plasma are the centers of synthesis of organic compounds.

Each starch granule, whether of wheat, potato, sago, or rice, represents a potential energy that may remain unnoticed until the occasion for oxygen to unite again with the elements in the compound when it ceases to exist as starch, and with the liberation of sensible energy carbon dioxide and water result. In other words, the sun's force raises the inorganic compounds to a higher plane by deoxidation and union, and from that plane they may fall back, yielding, in the descent, an energy that physicists tell us is equal to that by which it was raised.

In considering the leaves in their relationship to the sun and the whole realm of life upon the earth, it is evident we are face to face with the most potent of vital activities, and are getting at the heart of the forces that move the world.

We might well, with much solemnity, approach the subject that lies before us, for the green leaf, as it stands upon its supporting twig, is a minute laboratory in which a noiseless chemist is constructing compounds that possess a potency peculiarly their own.

With these facts in mind it needs be a very heedless child who will not be impressed with the worth of the wealth of greenness that is met with in the living vegetable fabric that is woven with sunlight to clothe the otherwise barren earth.

From this central thought concerning light relations of plant foliage there are a thousand starting points for study, and time permits of but the briefest mention of a few. Many plants have no green color, but doubtless prosper. These are the parasites, plants that have long ago formed the habit of gaining their nourishment at secondhand, and from those who do their own work of synthesis. The golden-threaded dodder, the sickly-hued mistletoe are of this class. They form no exception in the true sense, for they steal instead of labor for their living.

The mushroom, toadstools, molds, and mildews are other low forms of plants that live upon organic matter similar to the more exalted flower-bearing parasites.

There are many plants that, while making their own food, are seemingly without green. This is only a seeming, for beneath all the bright color there is an abundance of the chlorophyll, which may be as readily extracted from the showy coleus leaf as from the green grass.

There is a long list of questions that naturally arise in the thoughtful mind as to the behavior of plants in relation to the sunshine. To illustrate this we will go out in imagination into the woods and clearing.

A BIT OF FIELD WORK.

It is possible that a little study like the following may be made. Let me draw the outline of the problem that is to be investigated. Imagine, if you will, you are standing upon a slope of land facing the north, that the sun may not blind your eyes. To the right is a wood lot, with its oak, hickory, chestnut, birch, and other trees, standing neighborly, with arms interlocked, not too closely for comfort, and through the branches the broken shafts of light reach the shrubbery and herbaceous vegetation beneath. There are the alders, huckleberries, and their close of kin, the Virginia creeper, running upon the ground and over the smaller trees in the vicinity of a sleepy rivulet bordered by skunk cabbage and jack-in-the-pulpit. Where it is not quite so marshy the ground view of the woods is delightfully obscured by a luxuriant growth of the cinnamon fern, for it is midsummer.

To the left is a similar piece of young wood lot, not a primeval forest in either instance, and here the wild grape clings to the young maple, and the poison sumach may be lurking in the low land. In front of you, however, lies a strip twenty rods wide, where the woodman's axe has done its destructive work, and the clumps of small growth you see are the sprouts from the maple and other stumps. This is the second season from the time of clearing.

Have you the picture before you? A rectangle of vegetation stretching down to the rivulet that is lost under the direct rays of the summer sun and then on up the slope beyond, all framed in by right lines of forest trees and grateful shadows. If you have located the clearing from my brief outline you are ready to enter in and possess it botanically. If such a piece of land, even though it be but a single acre, is close at hand, you have a treatise upon vegetable ecology and physiology that contains no ends of treasures. Not that it bears any long list of species, but that it does possess the various conditions that, taken in connection with the border land, are more interesting than books, for it is the living volume, that vitalized cyclopædia of facts and the suggestion of principles, that make plant analysis seem tame and useless, save as it may help to catch the convenient handle to hold the subject that is undergoing some delightful transformation.

Let that clearing be your field of study day by day. When the days are long and the heat is intense make notes, and with specimens there gathered retreat into the shade of the wood lot upon either side. Compare the port of the sun-kissed, and it may be sunburned, herb with that of its shaded neighbor of the same species. Both were once alike, but the axe of the woodsman has let in the full sun upon the one, with drying effect upon the soil surroundings. One bears or attempts to bear the burden and heat of the day while the other is nursed in broken sunshine and a moister soil.

The Osmunda in the sun has its fronds strict and upright, the pinnæ uplifted and twisted to lessen the direct exposure. In the shade the habit is that of some other species, with the fronds gracefully curved outward, and the delicate pinnæ so placed as to catch every broken shaft of the sunlight that penetrates the tree tops. The ferns in the open are bleached, while those in the shade are deep green; the former are tough and the latter delicate.

Every plant in the clearing that has survived the ordeal of the exposure is a study of adaptation, the reason for the change in some instances not being upon the surface; but this only adds to the interest that is centered in the clearing and its surroundings.

This is the newer botany. It is not yet in the books, and, in one sense, never can be. It inheres in the plants themselves, and any attempt to lodge it elsewhere must needs be futile. I trust each teacher of the science of botany may find a field for study in the sense of the clearing above briefly outlined.

It may be more convenient for some student and teacher, and one needs to be both to be the latter, to have a garden patch where plants may be asked various questions. If it is in the line above indicated, a shading total or partial may be easily arranged. For example, a half shade may be provided by placing frames of lath upon stakes. The frames may be made, for a few cents, by nailing ordinary carpenter's laths to cross laths at the ends with a single lath interwoven through the middle. If half shading is desired, let the vacant spaces between the laths be equal to the width of the laths. Under such a shading ordinary plants, like bush beans, lettuce, etc., may be grown, and the variations in time of germination, size of plant, of leaf, time of blooming, size of fruit, longevity, etc., can all be studied with no small amount of interest and profit at a minimum of expense.

Should you like to make a record of the difference in thickness, for example, between the exposed and shaded leaves it can be done by actual measurement, but there is another way not mentioned in the books. Place the bean leaflets, one from the open and one from the shade, upon a slip of clean glass in a photographer's printing frame, and over the two specimens lay a sheet of sensitized paper, and expose them to the sun. When the work is done you will have a print of each, but the thinner one from the shade will have recorded the fact in the darker print. In short, the sun will have made its own registration of its own penetrability.

Nothing that has been named in the way of apparatus is expensive in the ordinary sense. Anyone who can afford to have a bicycle and keep it in repair is able to follow up the suggestions. That a child of nine years can be interested in this study of plants is certain, for it has been tested by the writer to his entire satisfaction.

RUTGERS COLLEGE,
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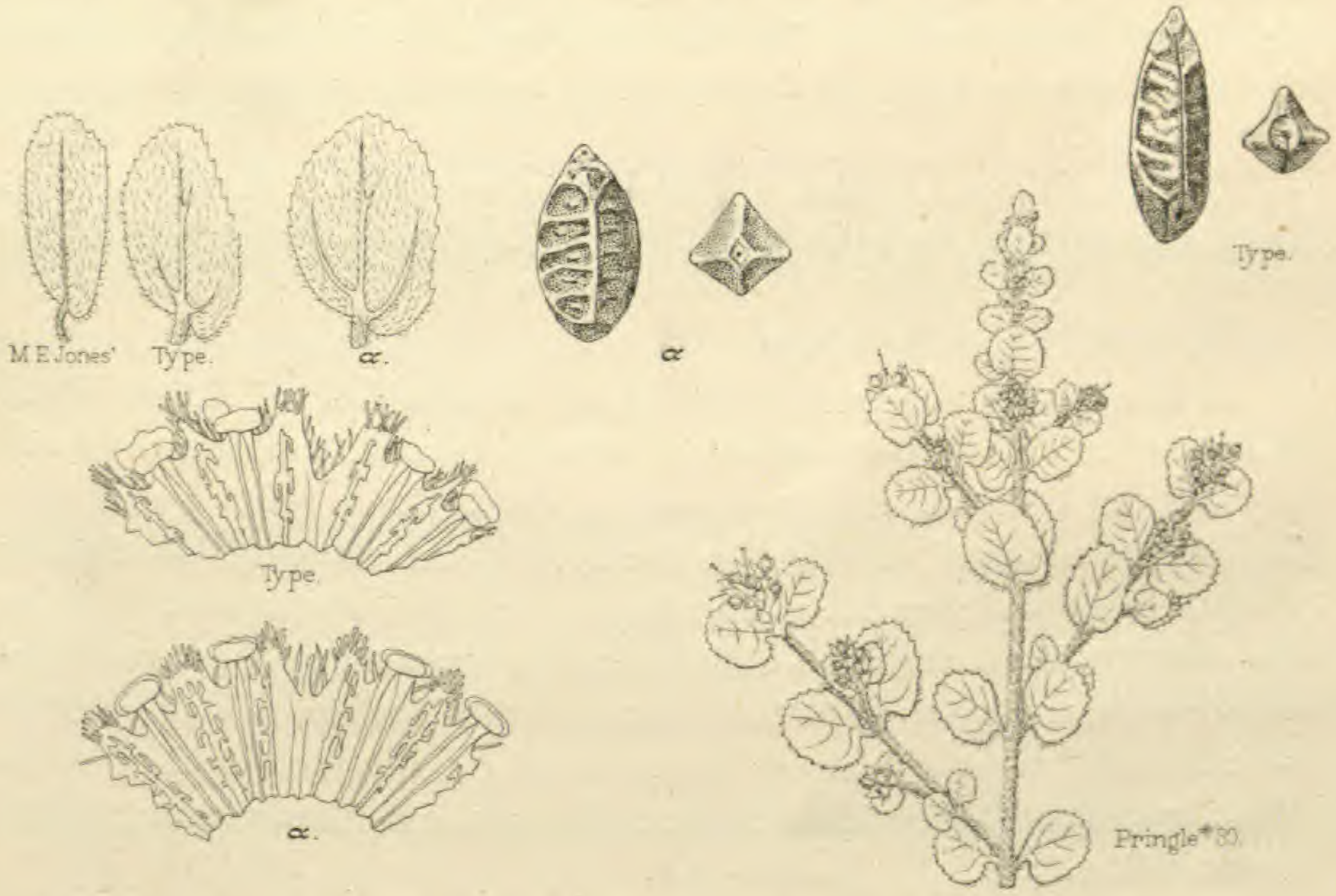
BRIEFER ARTICLES.

NOTES AND NEW SPECIES OF THE GENUS EUPHORBIA.

Euphorbia stictospora Engelm., Mex. Bound. Bot. 187.

The following characters are drawn from the type.

Involucral glands irregular, transverse, the fifth represented by a small lobe or absent; lobes triangular, hairy, the two flanking the deep sulcus columnar; appendages three-lobed, rudimentarily one-lobed, crenate, a mere semblance to an appendage, or entirely absent. Seeds pinkish-ashen, elongated-tetragonal, 1.4–1.5^{mm} long, .5^{mm} broad, section more triangular than tetrangular as the ventral angle is obscure, dorsal and lateral angles prominent, rounded, dorsal facets concave, the ven-



EUPHORBIA STICTOSPORA AND VAR. TEXENSIS.[1]

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[1] In the cuts the portions of plants and the leaves are natural size; the involucres enlarged and diagrammatic, and the seeds enlarged.

tral convex, linea ventralis slight; surface marked with short and irregular interrupted rugae, not pitted.

Type from Kansas, *Fendler* no. 789, co-types New Mexico, Santa Fé, *Fendler* no. 797 and Doña Ana, *Wright* no. 59 (*omnia visa*). The following specimens agree well with type: Colorado, *Marcus E. Jones* no. 786 (1878); Durango, Mexico, *Dr. Edward Palmer* no. 43 (1896), BOT. GAZ. **25**:19, 1898; Chihuahua Mexico, *C. G. Pringle* no. 1076 (1886) and his Coahuila, Mexico, no. 80 (1885).

Var. α. **Texensis**, var. nov.—Similar to the species in general habit, but less hairy and of looser growth, with longer internodes. Lobes of the involucre columnar, pseudolobe a deep sulcus with a long linear pseudogland at its fundus; appendages very narrow, entire, and generally present. Seeds bluish-ashen, strongly tetrangular, 1^{mm} long, $.6^{mm}$ broad, the dorsal facets concave, the ventral plane, all marked by strong, sharp, transverse rugae, that show only a tendency to anastomosis and interruption.

Texas, southern portion, altitude 1600–2000 ft., *A. A. Heller*, nos. 1913, 1918 (1894).

EUPHORBIA COROLLATA L.

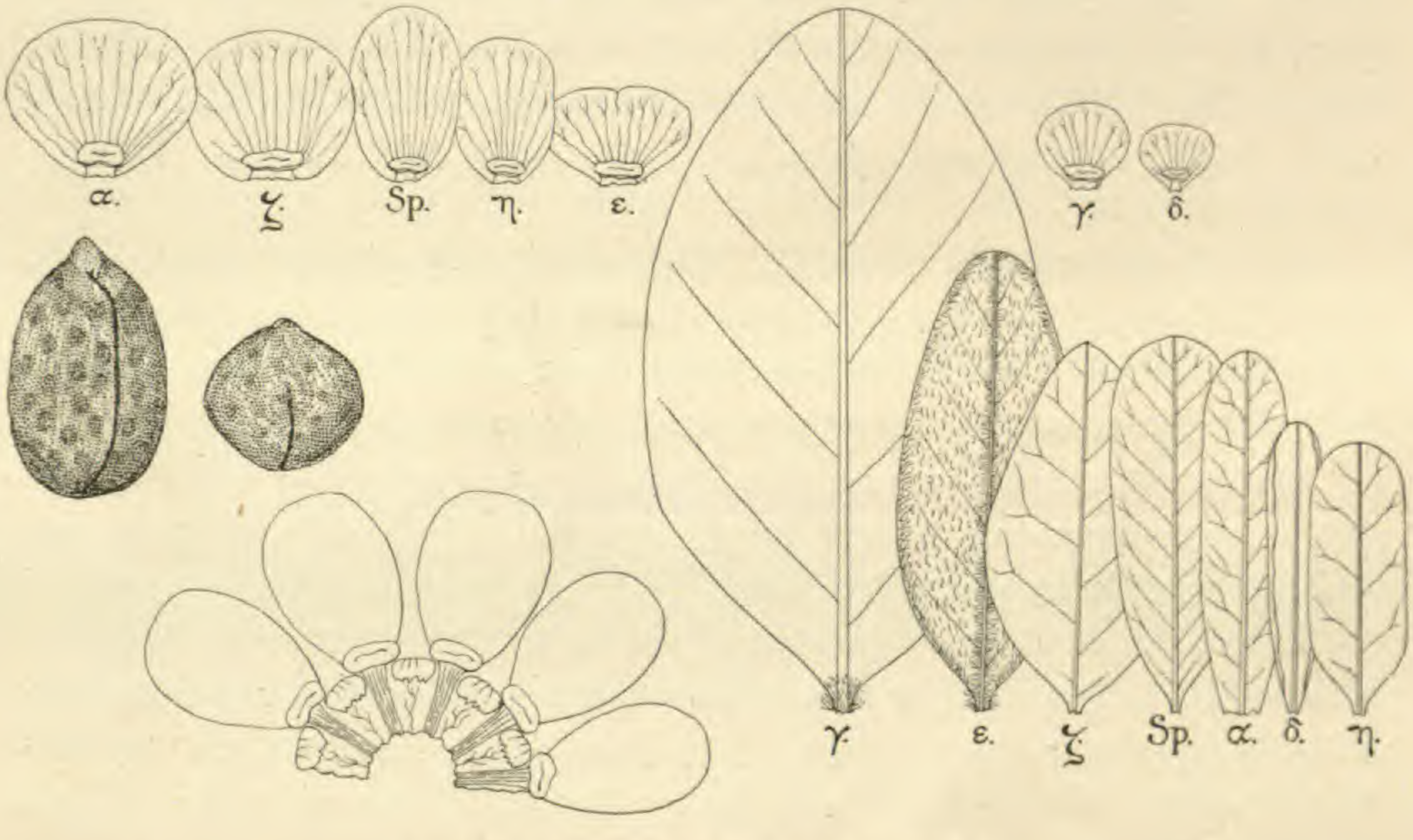
In this species, the most showy of the eastern United States, there is almost unlimited form variation in the general appearance of the plants from different localities, among which those given below may be considered good varieties by strong and reproducing differences in their leaves and glandular appendages. In all the forms and varieties the seeds maintain their full and distinctive characters; they are white-cinereous, ovate-pyriform with a strong nipple-like tip, sub-globular in section, 2.5^{mm} long, 2^{mm} broad, linea dorsalis a rounded evident keel, linea ventralis a dark evident groove, the surface marked with irregular, very shallow, pits.

Sp. COROLLATA L., Amœn. Acad. 3:122.—Leaves sub-petiolate, spatulate oblong, glabrous, green both sides, 3^{cm} long, 2^{cm} broad. Floral pedicels 4^{mm} long, strict and filiform; appendages oval, plane 3.7^{mm} long, 2.1^{mm} broad.

Var. α. GRANDIFLORA Boiss., DC. Prod. 15^2: 67.—Leaves strongly sessile, lanceolate to narrow-lanceolate, glabrous, green both sides, 2.8^{cm} long, 1.4^{cm} broad, less veined than in the species. Floral pedicels 8^{mm} long, strict and filiform, appendages broadly ovate, spreading and drooping, 3.3^{mm} long, 4^{mm} broad.

Var. β. SUBPETIOLATA Boiss., *loc. cit.*— I have not been able to recognize this form.

Var. γ. PANICULATA (Ell.) Boiss., *loc. cit.* (*E. paniculata* Ell., Sk. 2:660.)—Leaves petiolulate, hairy at the petiole only, green above, paler beneath, ovate, 5.5$^{\text{cm}}$ long, 3$^{\text{cm}}$ broad. Floral pedicels 3$^{\text{mm}}$ long, erect and sarcous appendages broadly oval, 1.6$^{\text{mm}}$ long, 2$^{\text{mm}}$ broad.



EUPHORBIA COROLLATA AND FORMS.

Var. δ. ANGUSTIFOLIA Ell., Sk. 2:659.— Open and widely spreading, openly paniculate-branched above. Leaves sessile, linear, the margins revolute, dark green above, pale beneath, veins not evident, 2–2.3$^{\text{cm}}$ long, 3$^{\text{mm}}$ broad. Floral pedicels filiform, ascending, 3-7$^{\text{mm}}$ long; appendages, ascending, oval 1.4$^{\text{mm}}$ long, 1.7$^{\text{mm}}$ broad.

Var. ε. **molle**, var. nov.— Hairy throughout, 25$^{\text{cm}}$ high; root fusiform: stems erect, denuded below, branches unbelliform, short, with leaves as on the stems: leaves petiolate, green above, pale green or lurid beneath, soft downy both sides but especially beneath, oblong ovate, 3.5$^{\text{cm}}$ long, 1.6$^{\text{cm}}$ broad, inflorescence solitary at the bifurcations, peduncles sarcous, 1.3–2.5$^{\text{cm}}$ long; involucres large; appendages broad and generally partially incised into more or less equal lobes 2.2$^{\text{mm}}$ long, 3.1$^{\text{mm}}$ broad. Alabama, *Earle & Baker* no. 13 (1897).

Var. ζ. **glauca**, var. nov.— Glabrous, 35–45$^{\text{cm}}$ high; stems denuded below, branches unbelliform, nude except a single leaf at the base:

leaves sessile, pale above, glaucous beneath, strongly oval to ovate, few veined, 3^{cm} long, 1.6^{cm} broad or smaller: inflorescence solitary at the bifurcations of the branchlets, peduncles filiform, 8^{mm}–2^{cm} long; appendages drooping, broadly oval, 3.2^{mm} long, 4^{mm} broad. Alabama, *Dr. Vasey*, 1880.

Var. η. JOORII Norton, Rept. Mo. Bot. Gard., 9: 155. 1898.—Low, 10–14^{cm} high, branching from the base, glabrous or pubescent: leaves ovate or oblong, subpetiolate, 2.2^{cm} long, 8–10^{mm} broad: inflorescence solitary in the bifurcations of the upper branchlets, peduncles filiform, 10–25^{mm} long; appendages elliptical, 3^{mm} long, 2^{mm} broad. Milano, Texas, *Dr. Joor.*

Var. θ. **apocynifolia** (Small). *Euphorbia apocynifolia* Small, Bull. Torr. Club **25**:467. 1898.—Leaves oblong, tapering at the base into a hairy petiole 3–6^{mm} long; inflorescence open umbelliform, rays ascending, wiry, dichotomous; involucre small, globular-bell shaped, hairy in our specimens, glands roseate like those of vars. *paniculata* and *angustifolia;* appendages 0.7 to 1^{mm} long, 0.9 to 1.2^{mm} broad, shaped like those of var. *paniculata.*

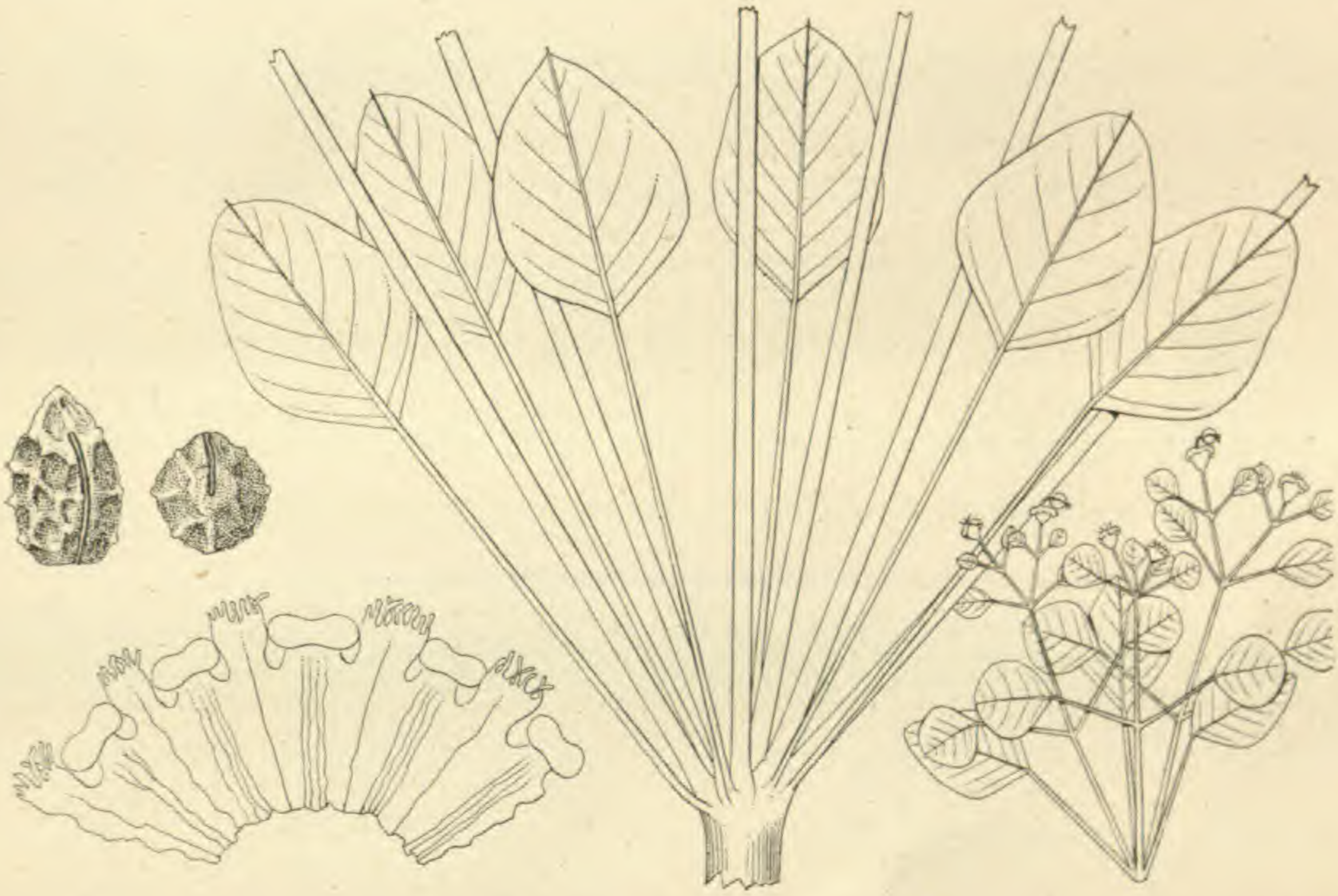
This form manifestly connects var. *angustifolia*, through Pollard's Mississippi 1289 (1896), with var. *paniculata;* it has no characters sufficiently prominent to consider it a species, while its seeds are not distinguished from those of *E. corollata.* Florida, Nash no. 2567 (1895), distributed as *E. corollata paniculata.*

Euphorbia Nelsonii, sp. nov.—Fruticosa, glabra, longe et corymbosæ ramosa, ramis teretis, internodiis longis, cortex maculatis, maculæ oblongis roseus. Foliis inferioris fasciculatis, petioliis longis filamentosis, pagina tenuis ovato-cuneatis, obtusis, apiculatis, foliis floralibus oppositis, orbiculatis petiolis limbum aequantis. Involucriis terminalibus corymbosis, pedunculatis, campanulatis glabris, lobis latis truncatis irregulariter 6–8-fimbriatis, glandulis 5, transversis oblongis integris, appendicibus minutis vel nullus. Stylis longis revoluto-circinalis. Capsulæ luridæ profunde tri-sulcatæ, semine sub-globosis pallide-fuscis, scrobiculatis, linea media nigra geminatis, rugæ anastomosantis tuberculatis 2^{mm} long, 1.9^{mm} lat.

Ad Insula Maria Madre, Insulæ Tres Mariæ, Mexici, coll. E. W. Nelson m. Maius 1897, num. 4284. Internodii 10–12^{cm} long., petiolo 3–4.5^{cm}, pagina 1.5–2^{cm} long, 1.3–1.5^{cm} lat., prox. *E. petiolariæ.*

Euphorbia Hellerii, sp. nov.—Glabra, caulibus pluries ascendentibus laxis foliatis, foliis alternatis spathulatis petiolulatis obtusis, umbellæ 3-

radiatæ, radiis 2-tum 3-fidis, foliis plus minus carnosis e basi sessili orbiculatis cuneatis obtusis apiculatis integris. Involucris breviter turbinatis solitariis in dichotomiis terminalibusque parvis, brevis pedicellatis, tenuissmus translucidis et laxis, lobis incurvis truncato-spatulatis, ad apice fimbriatis, ad sinus minor et erectis, glandulis 4, bicornatis quintus, pseudolobis columnaro-fimbriatis in sinus involucris substitutere. Stylis recurviis as apice in lobis claveo-stigmatosis bifurcatis. Capsulæ profunde trisulcatæ coccis dorso-rotundato laevis. Semine laevis cinereus vel virido-cinereus, ovato in sectio triangulo-subsphaerico 1.7$^{\mathrm{mm}}$ long, 1.2$^{\mathrm{mm}}$ lat., linea dorsalis notatis, caruncula conica tenuissima depressa.

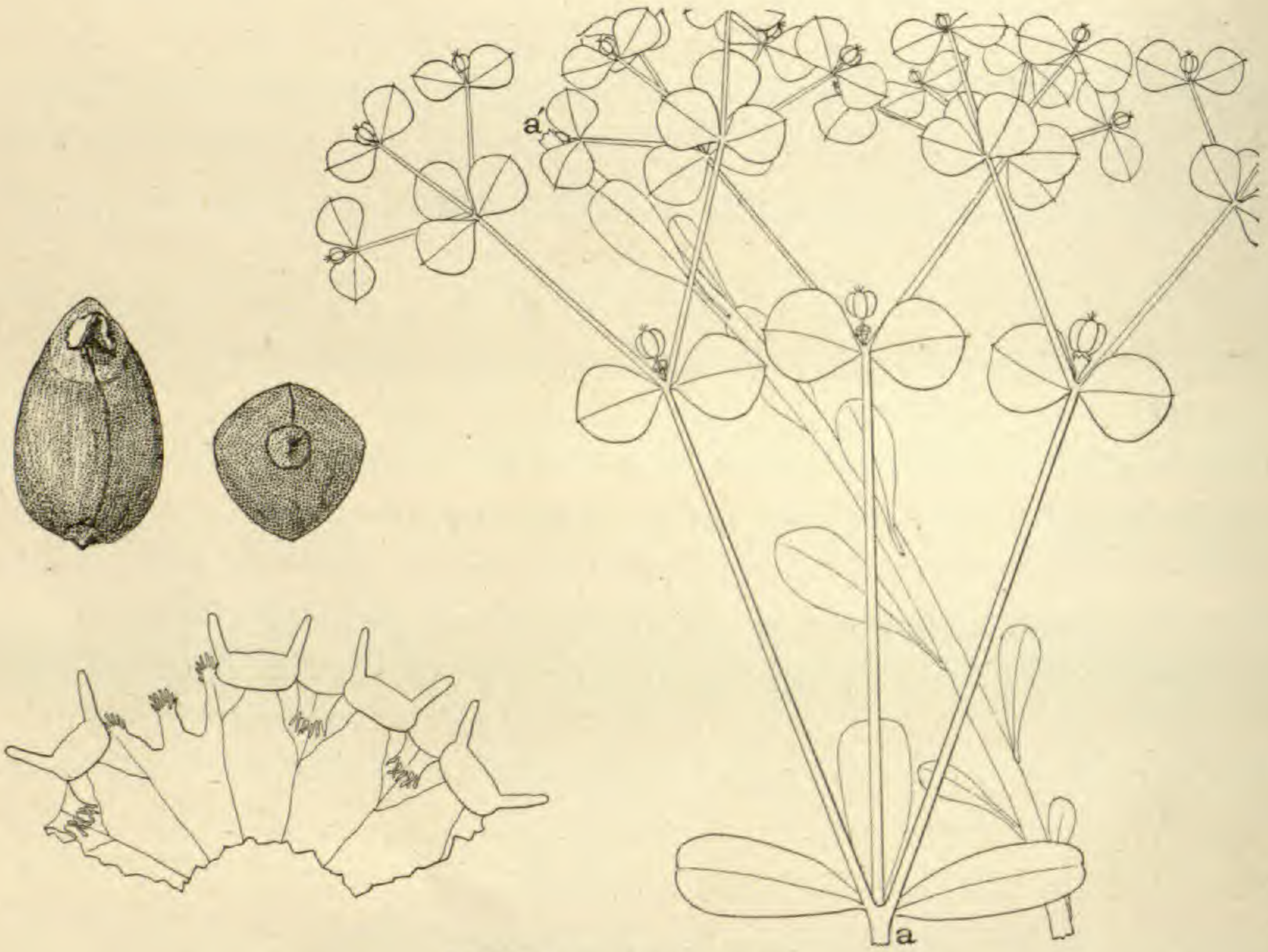


EUPHORBIA NELSONII.

Ad Corpus Christi in ditione Texas. A. A. Heller, m. Martius, 1894, num. 1509. Folius ramulosis, 1.7$^{\mathrm{cm}}$ long., 6$^{\mathrm{mm}}$ lat., fol. radiis 6–8$^{\mathrm{mm}}$ long. et lat. Habitus *E. Peplæ*, sed. prox. *E. multicaulæ*. Symboli in herb. C. F. M., et herb. U. S. Nat. Mus., num. 213 et 921.

Euphorbia hirsuta (Torr.) Wiegand.—In raising this form of *E. Preslii* Guss.? to a species in Bot. Gaz. **24**: 49–52. *pl. 3*. (Britt. & Brown Illustr. Flora N. A. 3: 518, *fig. 2341a*), Mr. K. M. Wiegand resurrects an old specific name, and adds one more synonym to the unfortunate American relative of that puzzling triune (?) *hypericifolia-*

Preslii-nutans, the types of which have never been studied closely by any American. *E. hirsuta* Kit. ex Boiss. in DC. Prod. 15^2:-116; and *E. hirsuta* Schur., Verh. Sieb. Ver. Nat. 4:66 are plants of a section far removed from Dr. Torrey's *E. hypericifolia* var. *hirsuta* which, for the present, at least, it is better to let alone. Professor Greene noting this synonymizing of Mr. Wiegand (Pitt. 3:207) adds one more name for good measure, *E. Rafinesquii*, and all because the good Linné did not mention the fact that his type of *E. hypericifolia* was hairy!



EUPHORBIA HELLERII.

EUPHORBIA BRASILIENSIS Lam.—In making up his Durango sets for distribution, Dr. Edward Palmer mixes this species with his *E. Preslii* Guss.? under no. 894. The black seeded specimens are *E. Preslii*, the cinereous ones *E. Brasiliensis*.— CHARLES F. MILLSPAUGH, *Field Columbian Museum, Chicago.*

JOSEPH F. JOOR.[1]

THE south has always been a land of peculiar botanical interest. Its vegetation, bordering on the tropical, many years ago attracted the

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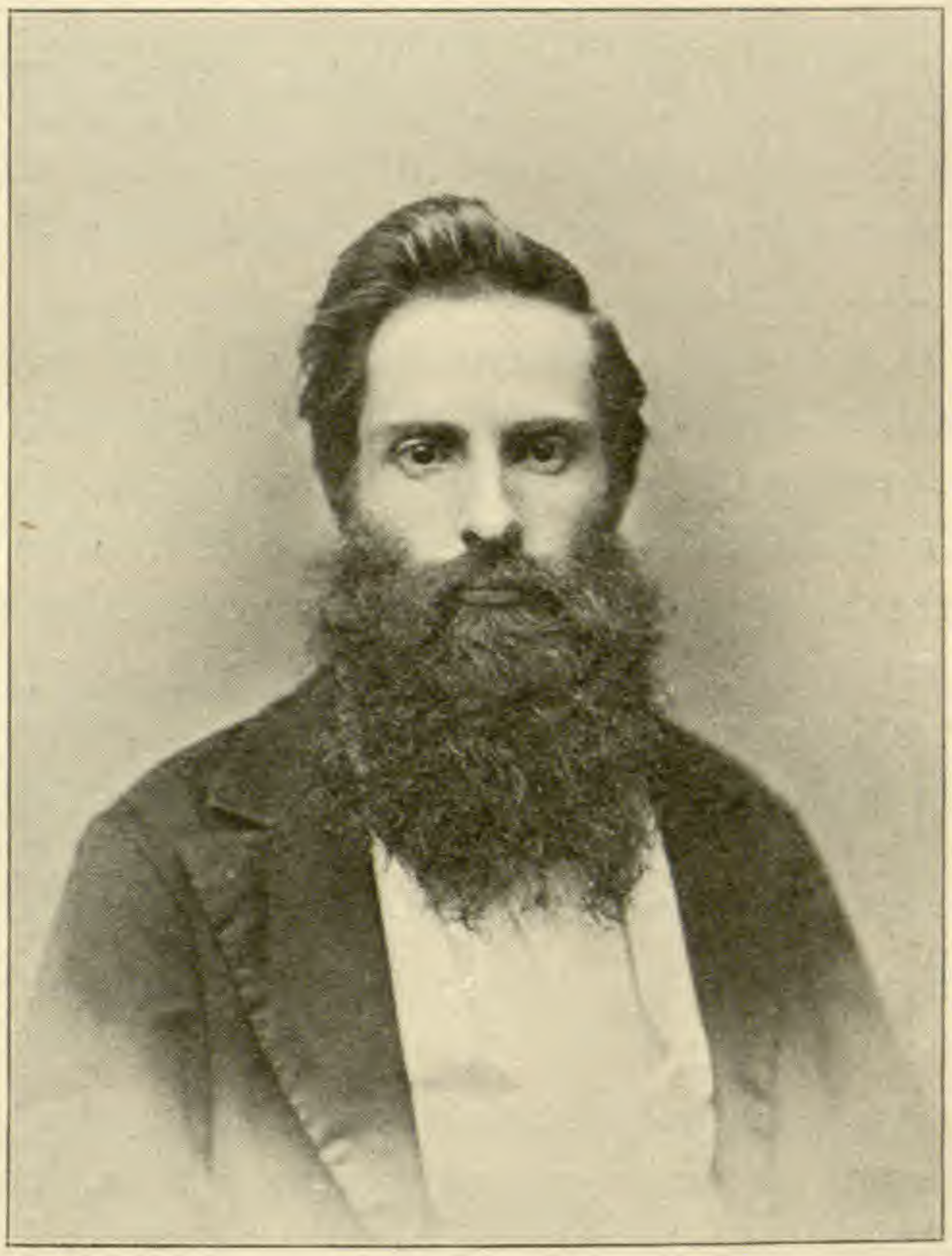
[1] While working with Dr. Joor's plants, purchased by the Missouri Botanical

attention of the pioneers of American botany. Since those times, except for the work of a few, the south has been much neglected. Scientific and other educational work was broken into by the war, and since then there has been little to excite botanical activity, except natural love for the work, and the inspiration of the rich flora. It was in this land, and under these conditions, that the subject of this sketch spent his active, but unassuming life as a botanist and collector.



Joseph F. Joor.

Joseph F. Joor was born on the Comite river in East Baton Rouge parish, Louisiana, on August 9, 1848. His parents removed to Illinois when he was quite young, where, as a boy, his botanical tastes were

Garden, I collected all the notes regarding him and his work that could be found with the specimens. Thinking it would be of some value, I have since completed this sketch of his life by the aid of Mrs. Joor and a number of botanists and other scientific men who knew him. To these I am indebted for the facts presented.

developed. Each holiday and Saturday when free from school duties he might be found engaged in his favorite study, wandering over the Illinois prairies. His Latin teacher, one of that honored class of botanist physicians to whom we owe most of the early botanical work of this country, assisted him much in his botanical recreations.

In 1865 his parents returned to Baton Rouge, where he continued his studies under the tutorship of Professor McGruder, but soon afterward left school to enter a drug store in Baton Rouge, where he began to read medicine, and soon surprised his preceptor, Dr. Day, by the rapidity with which he acquired knowledge.

He was soon a resident student in the Charity Hospital of New Orleans, and in the New Orleans School of Medicine, graduating in 1870, when he was only a little over twenty-one years old, and receiving an offer of an assistant professorship in his alma mater. Dr. Joor's duties were to begin the following autumn, but the disastrous end of a law suit, which closely concerned the college, resulted in closing its doors forever. Through these years of hard study the young physician by no means lost his interest in botany, but kept adding collections from the southern flora to those made in Illinois.

In October 1870, Dr. Joor obtained the position of Assistant Quarantine Surgeon at Ship Island Station. Here and at other places along the Gulf coast the rich flora so attracted him that he sometimes even endangered his life to obtain desirable plants. His health, broken down by study, was much restored by this outdoor life, and he soon entered into private practice in Thibodeaux, Louisiana.

In 1873 we find our physician-botanist practicing his profession on the Texas prairies in the midst of the rich flora of eastern Texas, first at Harrisburg and then at Birdston. Here, when Nealley was collecting grasses in Texas, they met and were together at every opportunity in their work. But the life of a practicing physician on the plains was too much for his naturally weak constitution, and for years he was hindered by severe illness from carrying on his work.

In preparation for the World's Industrial and Cotton Centennial Exposition at New Orleans in 1884-5, Dr. Joor was appointed Assistant Commissioner for Texas to prepare an exhibit of woods and other plants from that state. At the close of the Exposition, where he had charge of the collection he had made, Dr. Joor prepared the woods for a permanent exhibit at the state capital, where they now are. At the same time a smaller collection was made for the Geological and Scientific Association at Houston, of which he was a member. In the preparation of the New Orleans exhibit he traveled much in Texas and Louisiana, adding at the same time to his private collections and much improving his health. At the Exposition he met a number of botanists whom he had known before only by correspondence, and was especially delighted to meet Dr. Vasey, who went in search of him. They both had a common interest in the southern grasses then, and the inspiration of this meeting renewed Dr. Joor's activity in that direction. It is said that at this time he probably had a better field knowledge of Mississippi, Louisiana, and Texas, than anyone else.

The next year Dr. Joor was appointed Commissioner of Forestry in his native state, but soon accepted a position in Tulane University at New Orleans, and in October 1888, assumed charge of the Museum there as Assistant Curator. He spent much time arranging and enlarging the neglected herbarium of the institution, which already contained the collections of Hale, Riddell, and Carpenter. Dr. Joor increased it much by exchanges and additions from his own herbarium.

Three months later he was elected Professor of Botany. As there were no classes he never taught in the University, but is said to have taught some botanical classes in the New Orleans high school. He held the position at Tulane until death ended his labors, July 25, 1892, at the age of forty-four.

Though Dr. Joor was naturally retiring, he inspired in those who knew him that regard for himself and his favorite study which the true student of nature always does. He was a close observer and an intensely enthusiastic collector, but had no means of describing the new things he discovered.

Very little from his pen has ever been published. A single paper, "Forests and Climate," in "Papers read before the New Orleans Academy of Science," 1 : 72–80, 1887, is the only one I have seen. He is said to have published an article in the *Medical Record* concerning a supposed medicinal tree in Louisiana with which he had experimented; and also one in the Texas *Farm and Ranch* discussing a plant being sold in Texas as the tea plant. Reports of his work in connection with the Exposition were prepared, but I cannot find that they were ever published. He long contemplated publishing a flora of Mississippi, Louisiana, and Texas, the lists of plants having been prepared in manuscript, but his enthusiasm was far greater than his strength and resources. With very few facilities for successful botanical work, and a weak physical constitution, he was compelled in discouragement to give up this large undertaking.

Dr. Joor's herbarium, which is the main record of his work, is not large, but is rich in specimens from the region where his life was spent. It is especially valuable because from that part of the south not well known to botanists, and covered by none of our manuals. A part of his collections, as before stated, were incorporated into the herbarium of Tulane University when he was connected with it. The rest were purchased from Mrs. Joor in 1897 by the Missouri Botanical Garden.

Most of the collections were made about New Orleans and Baton Rouge, Galveston bay, and other parts of Harris county, Texas, where he lived, and in Navarro and adjoining counties when he lived at Birdston, with occasional excursions into other parts of the south. In the last year of his life he spent several weeks along the Mississippi gulf coast, making large collections and preparing a list of the plants of that region. His herbarium was also enriched by the collections of botanical friends and others in whom his own devotion had inspired an interest in plants. Dr. Joor was a correspondent of Vasey, Engelmann, Mohr, Chapman, and other botanists of this country. He was the first collector of several new southern plants. Though he described none himself, his herbarium notes show that some afterward described by others were recognized by him as new. Among others of which he was the first discoverer, *Panicum Joorii* Vasey, *Carex Joorii* Bailey, *Barbula Jooriana* Müller, and *Euphorbia corollata Joorii* Norton, bear his name.—J. B. S. NORTON, *Missouri Botanical Garden.*

FOUR GENERATIONS OF BOTANISTS IN ONE FAMILY.

IT is seldom that the names of more than one generation of a family appear in connection with any one branch of scientific research. The history of science appears to show that genius or ability is not handed down, at least to any remarkable degree, in most families from one generation to another. As a general thing the pursuit of science is not lucrative enough to keep more than one generation from becoming paupers, and even where there is some wealth and ability the succeeding generation, as a rule, is not fortunate enough to inherit the characteristic traits necessary to follow the calling of its predecessors. However, exceptions occur where similar traits have shown themselves in a decided manner for more than one generation in a single family. Among these may be mentioned the Darwin and Schimper families, and the DeCandolle family offers one of the most striking illustrations. Indeed, the history of science scarcely shows another name representing so many illustrious and able workers in one family, devoting themselves to one branch of science.

It was my fortune to stop a few days at Geneva during the summer of 1896, where I had the pleasure of spending some delightful and profitable hours with the DeCandolle family. The family is one of the oldest as well as one of the most highly esteemed in Geneva, having fled from Provençe to Geneva in the year 1591, where they have been held in esteem for many years as public spirited and highly accomplished citizens.

Augustin-Pyrame De Candolle is known to botanists as a rare genius, who accomplished a prodigious amount of work, and who left behind him a name second only to that of Linnæus. The charming traits which this renowned botanist is said to have possessed are known only to the younger generation of botanists through his memoirs. However, these traits are quite readily realized by those who have met the present members of the family.

It is not my intention to mention the various works of the elder DeCandolle or of those of his son Alphonse, as such an enumeration would be quite unnecessary.

The name of Casimir DeCandolle, the son of Alphonse, has also long been familiar to American botanists, but the name of his youngest son Augustin, who is now devoting his attention to botany, is probably not familiar on this side of the Atlantic.

M. Augustin DeCandolle, who now represents the fourth botanical generation in this family, and who bears the name of his illustrious great-grandfather, is about 27 or 28 years old, and was born and educated in England, which was formerly the home of his mother. He studied a number of years at Rugby, and after finishing his course there he spent a year at Heidelberg, going from there to the University of Leipzig, where he took a course in jurisprudence.

Although he did not take the university course in botany while at Leipzig, his interest in the subject was quite marked, and his opportunities and associations were always such that he naturally acquired a considerable knowledge of this subject.

Since his return from Leipzig he has spent most of his time assisting his father at the herbarium in Geneva, besides carrying on some original work along histological lines, some of the results of which have already appeared as abstracts in the *Archives des sciences physiques et naturelles*, of Geneva.

M. Augustin DeCandolle occupies a villa pleasantly situated in the suburbs of Geneva, which also includes about sixty acres of land; while that of his father is on the shores of Lake Geneva, near Versoix, and about ten or twenty minutes' ride from Geneva. Both residences are provided with greenhouses and gardens.

One of the most interesting features connected with Geneva for a botanist, however, is the herbarium and library which is contained in the old DeCandolle homestead at Cour de St. Pierre, and which was formerly occupied by the elder DeCandolle. The building is situated in the older parts of the city, and is not far from the University and Botanical Gardens, which were laid out by the elder DeCandolle; and here is to be seen a very good life-size statue of its founder. The herbarium and library and working rooms occupy the upper stories, and, with the exception of the large number of cases which have been added, the rooms are just as they were when occupied for residence by the elder DeCandolle.

Here one can not only find interest in the large herbarium, but he will find the rarest and most valuable collection of old botanical books in existence. The library contains many other interesting features, such as photographs and autographs of nearly all the botanists the DeCandolles have known. It contains also all the prominent periodicals and recent botanical literature of various countries up to date. The expense of maintaining the herbarium and library is met entirely by the DeCandolles. It is the desire of M. Casimir DeCandolle to make the library as complete as possible, and he is always pleased to receive contributions from American botanists.

New plants are continually being added to the herbarium, which are placed in the general collection. The special collection relating to the *Prodromus* is kept by itself. As this work is of considerable consequence, an experienced curator is employed to look after it, together with the many details connected with the ever increasing library.

It is here that Casimir DeCandolle and his son Augustin do their botanical work, and although the library and collection is a private one, the keeping up of which involves considerable expense, they are always willing to have other botanists avail themselves of any appointments which the large collection offers.

M. Casimir DeCandolle speaks English fluently, and his intense interest in all matters pertaining to botany, and his characteristic modesty, together with his exceedingly broad and comprehensive knowledge, afford a striking contrast to what one often meets in other parts of the continent. As in the case of the other DeCandolles, he has contributed to every department of botany. We find the name associated not only with an enormous amount of systematic investigation, but also with the physiology, histology, morphology and history of plants.—G. E. STONE, *Mass. Agric. College, Amherst.*

SOME RESULTS FROM THE STUDY OF ALLIUM.

DURING the summer of 1897, at the University of Chicago, I began a morphological investigation of certain species of Allium, being attracted chiefly by the often quoted polyembryony of *A. tricoccum* Ait. My results in the case of this species indicate that if polyembryony occurs at all, it is very rare. Besides *A. tricoccum*, I examined more or less thoroughly *A. cernuum* Roth, and *A. Canadense* Kalm, with the same general result. Seventy-five embryo-sacs of *A. tricoccum* were examined at the stage in which both egg apparatus and antipodal cells ought to have been found. The egg apparatus was found in seventy of them, and the appearance of the sacs in which it was not found would indicate that it had been lost by accident, as all other structures were normal. Of the seventy-five sacs, only sixteen contained antipodal cells, and these antipodal cells were usually small, and it was seldom that more than one or two could be found. In one sac there were three antipodal cells in a row, but in other cases where three were found they were crowded together irregularly. Wherever antipodal cells were found, they had a shriveled, dead appearance, and stained with difficulty or not at all. Twenty-six embryos were examined, all of which had developed from the egg cell. No trace of antipodal cells could be found in any sac in which the embryo had begun to develop.

The results from *A. cernuum* were nearly the same as for *A. tricoccum.* Ninety-five embryo sacs were examined in the eight-celled stage. The egg apparatus was found in all of them, while antipodal cells were found in only twenty-nine; and, as in *A. tricoccum*, these were invariably small, and apparently about to disappear. It was seldom that more than one or two could be found. Of the ninety-five specimens, thirty were collected on or after August 16, and no trace of antipodal cells could be found in any of these. Fifteen embryos were examined, all of which were normal in position and number. No antipodal cells were present in any sacs in which the embryo had begun to develop.

My collection of *A. Canadense* was made from a patch covering about half an acre, at West Pullman, Illinois. In nearly every specimen the nucellus had died long before the stage when fertilization might have taken place; and later in the season it was found that only six embryos had developed from the whole patch in which there had been thousands of blossoms. All of these embryos, however, were in the normal position.

Since in *A. tricoccum* only about 21 per cent., and in *A. cernuum* about 30 per cent. of the sacs examined contained antipodal cells, and these cells in all cases were small and not found at all except in the earlier stages, the development of embryos by antipodal cells in these species seems very doubtful.—CLARENCE J. ELMORE, *Crete, Nebraska.*

OPEN LETTERS.

THE AMERICAN BOTANIST.

UNDER THE TITLE of "The American Botanist, vol. I, no. 1" a four-page octavo leaflet was issued September 15, 1896. While no place of publication is stated, the editor of this newly launched periodical gives his temporary address as the Gray Herbarium, Cambridge, Mass. It is true that he has received such facilities of reference to books and specimens as are usually accorded to visiting botanists, but to prevent a possible misunderstanding, it seems necessary to state that his publication has no official connection whatever with this establishment.—B. L. ROBINSON, *Curator of Gray Herbarium.*

ESCHSCHOLTZIA MEXICANA-PARVULA.

ESCHSCHOLTZIA finds its extreme eastern limit in the Organ mountains of New Mexico, and the adjacent region about El Paso. The pretty little species there found, which I have had occasion to study in connection with its bee-visitors, is commonly known as *E. Mexicana* Greene, Bull. Cal. Ac. Sci. 1 : 69. 1885. I want to know why it is not to be designated *E. parvula* (A. Gray), for it is assuredly the *E. Douglasii* var. *parvula* Gray, Plantæ Wrightianæ 2 : 10. 1853. The few words of description given by Gray, with the locality, readily identify the plant. There is no other *parvula* of prior date. Is it not just a little absurd to refuse to recognize a name for a species, because first applied in a varietal sense? Such a course seems hardly to accord with a Darwinian conception of species, nor is it supported by the codes of nomenclature.

Another principle which is generally recognized, in zoology at any rate, is that the specific name must be at least as old as the names applied to varieties of the species. Thus it will sometimes happen that the type form of a species is by no means the commonest form; it may be quite a rare variety. On Darwinian grounds I see no objection to this, as the oldest (and therefore true) type of a variable species is hard to ascertain, and the probabilities are perhaps against its being the most common.

It follows from the above that *Philibertella Hartwegii* (Vail, 1897) *heterophylla* (Engelm., 1856–7), as given in Bull. Torrey Bot. Club **24** : 308. 1897, will not do. The species must stand as *Philibertella heterophylla* (Engelm.), and the *Hartwegii* form, if properly belonging to the same species, can be treated as a variety.—T. D. A. COCKERELL, *Mesilla Park, N. M.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plant Life.[1]

THIS is the suggestive title of a new text-book of elementary botany, for its standpoint is function rather than structure. There can be no question as to the usefulness of the book, and as to its value as a contribution to our botanical texts. The style is clear and simple; the presentation is very logical; and many things are said which needed to be said. Teachers apart from the universities are in constant danger of holding to abandoned views, and a book is needed now and then to bring a rapidly developing subject up to date.

The book before us has done this service admirably, and its four parts present a clear elementary statement of present views of the vegetative body, physiology, reproduction, and ecology. This division of the subject enables the author to present these great subjects continuously, without breaking them up into fragments, and the comparative view thus becomes very prominent.

While all the parts are fresh, those which deal with physiology and ecology are especially noteworthy. The facts of physiology are accumulating and the views are shifting so rapidly that an elementary statement was needed, and it would be hard to find a completer outline in forty-six pages than is found in this book. The ecological view of plants is new in elementary instruction, to which it is especially adapted, and it is to be hoped that this modest beginning is but a promise of the time when it will dominate all of our texts for elementary instruction.

Only less commendable is the comparative and separate presentation of vegetative and sexual reproduction, which are in great danger of being confused in elementary instruction. In this part it was necessary to adopt some consistent terminology. How successful the author's suggestions will prove remains to be seen; they certainly could not be simpler.

Five appendices give information as to laboratory study, collecting and preserving material, apparatus and reagents, reference books, and an outline of classification.

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[1] BARNES, CHARLES REID.—Plant life, considered with special reference to form and function. Pp. x + 428, with frontispiece and 415 figures. New York: Henry Holt & Co. $1.12.

However admirable the book may be as a general statement of the essential facts of botany, it will suggest criticisms from the standpoint of teaching. The most important of these the author has forestalled by stating that "this is not a book to be recited." In the text the same plant is discussed several times under different headings, a method that would not commend itself either for recitation or for laboratory work, but in the directions for laboratory work all the essential structures are called for while each plant is in hand. It is very evident, therefore, that the intelligent teacher is to use the book for assigned readings suitable to the material under examination in the laboratory and supplementary to it. It is hard for some teachers to get away from the idea of the recitation of consecutive pages.

Another criticism will be that the book is better designed for schools as they ought to be, than for schools as they are. The author practically confesses that he is writing for a somewhat ideal condition, and probably he is; certainly for a condition less realized in the east than in the west, where elementary instruction in science is so much further advanced. However, it is a matter of doubt to the reviewer whether any but the exceptional secondary schools will ever be able to do completely such morphological work as this book calls for; and also whether it is the most desirable work for them, handicapped as they are by lack of equipment, time, and age. First impressions must be correct, but it may not be necessary to include at first recondite things even if they are essential. There cannot be too much of ecology and physiology in elementary work, but it has seemed to the reviewer that recondite morphological structures are in danger of being pressed too far with elementary students.— J. M. C.

The Illustrated Flora.[2]

WITH the appearance of the third volume this important work is complete, and the authors should be congratulated upon its prompt publication, the first volume having appeared in 1896. Volume one was reviewed in the GAZETTE **22**: 269. 1896, volume two in **24**: 120. 1897, and little need be added in reference to the present volume, which contains the great sympetalous families. Use of the work has proved its adaptation to the needs of those who wish to determine plants, and it should certainly find a place in the library of all interested in taxonomy. When it is remembered that 4162 species are described and illustrated, representing 177 families and 1103 genera, it is surprising that the illustrations are so well done. The present volume, in an appendix, adds the descriptions and illustrations of eighty-one

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[2] BRITTON, NATHANIEL LORD, and BROWN, ADDISON.—An illustrated flora of the Northern United States, Canada and the British Possessions. In three volumes. Vol. III. Apocynaceæ to Compositæ. 8vo. pp. xiv + 588, fully illustrated. New York: Charles Scribner's Sons. $3.00.

species, mostly western, which are new determinations or new discoveries made while the work was going through the press.

Certain special features of the volume deserve mention, such as a general key to the orders and families, a glossary of special terms, a general index of Latin names with very full synonymy, and an English index including popular plant names. This last is the completest compilation of American plant names hitherto published, containing about 10,000 names, and over 12,000 references to the illustrations.

It will be remembered that the territory covered by the work extends from Newfoundland to the parallel of the southern boundary of Virginia, and from the Atlantic ocean westward to the 102d meridian, a territory extending somewhat further to the north and west than that covered by the sixth edition of Gray's *Manual.* A comparison of the number of species of spermatophytes recognized by the two is interesting, and is shown in the following table:

	Gymnos.	Monocot	Archichlam.	Sympet.	Total
Manual	22	785	1226	1022	3055
Ill. Flora	27	1058	1601	1361	4048

This difference of a thousand species is explained partly by the more extensive range of the *Illustrated Flora,* but is most largely due to a different conception of species. The two works may be considered as complementary, and both are very useful.— J. M. C.

Report of Missouri Botanical Garden.

THE ninth annual report of this very active establishment was issued last March, and continues its valuable contributions, chiefly to taxonomy. Thompson's paper on Lemnaceæ has already been noticed in the GAZETTE (**24**: 440. 1897). The other papers are as follows:

1. GLATFELTER, N. M.: "Notes on *Salix longipes* Shuttlw. and its relations to *S. nigra* Marsh.," in which the author attempts to prove their title to be considered distinct species.

2. IRISH, H. C.: "A revision of the genus Capsicum with especial reference to garden varieties." This is really the completion of work undertaken by the late Dr. E. L. Sturtevant, for which he collected a great amount of material and literature, all of which with his drawings, notes, etc., were given to the Missouri Botanical Garden in 1892. The work was further prosecuted by F. W. Dewart and then by J. G. Smith, and finally, in 1896, was undertaken by Mr. Irish. The last revision of the genus was that of Dunal in 1852, in which fifty species were recognized; and but three new species have

been described since. The *Index Kewensis* cites about ninety specific names, and recognizes fifty-four as good. Students of the genus have long suspected that most of the so-called species are but forms of a few exceedingly variable species, and Mr. Irish has reached the conclusion that there are but two species, *C. annuum* and *C. frutescens*, the one annual or biennial, the other perennial. He has preserved the well-fixed types of cultivated forms as botanical varieties. Twenty-one plates fully illustrate the paper, which is a remarkable piece of patient work in a very perplexing subject.

3. HITCHCOCK, ALBERT S.: "List of cryptogams collected in the Bahamas, Jamaica, and Grand Cayman." These collections were made the winter of 1890–1, and a list of the spermatophytes and pteridophytes was published in the fourth annual report of the Garden. The list of cryptogams contains seventy-three species, some of them new, and all determined by specialists in the several groups.

4. ROSE, J. N.: "*Agave Washingtonensis* and other agaves flowering in the Washington Botanic Garden in 1897." The large collection of agaves in the Botanic Garden at Washington has never been critically studied, and promises to contain several undescribed species, one of which Mr. Rose and J. G. Baker describe and figure in the present paper.

5. THOMPSON, CHARLES HENRY: "The species of Cacti commonly cultivated under the generic name Anhalonium." Mr. Thompson has done good service in supplying full notes and excellent photographs of living plants of these disputed forms. He regards the group as consisting of two genera, *Ariocarpus* Scheidw. (*Anhalonium* Lem.) and *Lophophora* Coulter.

The report closes with a series of "Notes and observations" as follows: "The *Epidendrum venosum* of Florida," by W. Trelease, with full description and two plates; "Miscellaneous observations on Yucca," by W. Trelease, with four plates; "The Missouri dogbanes," by W. Trelease, with two plates; "A coloring matter found in some Borraginaceæ," by J. B. S. Norton; "Notes on some plants chiefly from the southern United States," by J. B. S. Norton, with five plates and three new species; "A new disease of cultivated palms," by W. Trelease; and "*Parmelia molliuscula*," by Henry Willey.— J. M. C.

The flora of Africa.

THE activity, not to say rivalry, displayed by taxonomists of Belgium, England, France, and Germany in the publication of the African flora is remarkable. The book before us[3] is a Belgian contribution, the first part

[3] DURAND, TH. et SCHINZ, HANS: Conspectus Floræ Africæ. Vol. I, part 2. Dicotyledons (Ranunculaceæ–Frankeniaceæ). 8vo. pp. 268. Berlin: R. Friedländer and Sohn. Paris: Paul Klincksieck. *fr.* 12.50.

of which (Vol. V), containing monocotyledons and gymnosperms, appeared in 1895, and was noticed briefly in the GAZETTE (**20**:278. 1895). The long delay in the appearance of a second part was due to various reasons, but has had its advantages in permitting the authors to include the results of the recent extraordinary activity in the study of the African flora. As the present volume has been in process of publication since 1895, the authors have wisely indicated the date of publication of the different parts of the volume, extending from October 1895 to April 1898. The work is not descriptive, but is simply a catalogue of described species, with bibliographical citations, synonymy, distribution, and occasional critical notes. The work will be complete in six volumes of about 500 pages each.— J. M. C.

A new botanical text.

A RECENT French work,[4] which is a valuable contribution to botanical texts, is that of Professor L. Courchet, of the School of Pharmacy at Montpellier. The author purposes only to write a treatise for the use of students in the professional schools of France, which seem to demand mainly work with spermatophytes. The first part is devoted to the general morphology (in the old sense) of spermatophytes, and a second much larger part to a systematic description of the natural families. The most striking feature is the unusual space given to the dicotyledons, a proportionate space unequaled in any English text we have seen. Thallophytes are given 130 pages of amply illustrated text, to bryophytes are allotted 12, pteridophytes are presented in 44 pages, while spermatophytes occupy 1540 pages, 1356 of which are devoted to the dicotyledons. Such a distribution of space in a general text must make the plant kingdom seem like a huge mushroom to the observing student. The text throughout is accompanied by good illustrations, and the keys and summaries which accompany each family are worked out with great completeness.— J. G. COULTER.

The study of lichens.

THIS group has few special students in America, and certainly receives but little attention from amateurs. As lichens are found almost everywhere, they would speedily attract collectors and students if some suitable book were provided as an introduction. Such a book Dr. Schneider[5] has prepared, stating that it "is especially written and arranged for the use of amateurs in the study of lichens." Just how useful it will prove remains to be seen, but we wish it all the success that its purpose deserves. The author's general

[4] COURCHET, L.— Traité de Botanique. 2 vols. 8 vo. pp. viii + 1320. *figs. 514.* Paris: J. B. Bailliere et fils. 1897. *fr.* 12.

[5] SCHNEIDER, ALBERT.— A guide to the study of lichens. Small 8vo. pp. xii + 234, *pl. 11.* Boston: Bradlee Whidden. 1898.

views in reference to lichens were fully stated in a review of his *Text-book of general lichenology*, published in the GAZETTE (25 : 284. 1898), and there is no need to repeat them here. On account of existing difficulties of nomenclature, the author omits all citation of authorities, stating that "the names given are well authenticated, so that those who have the desire and the opportunity may enter into the consideration of the synonymy and the nomenclature controversy." A selection is made of the more common forms of lichens occurring in the United States, those with which the collector is most likely to come in contact.

The first part of the book discusses lichens in general, under such headings as "The history of lichenology," "The use of lichens," "What are lichens," "The morphology and physiology of lichens," "The occurrence and distribution of lichens," and "Lichens and the naturalist," under which last title directions for collection, study, and preservation are given.

The second part is devoted to the systematic presentation of the group, an artificial key being provided for the more important genera, and a natural key for the families. A check list of lichens occurring in the United States is also given, useful to those who wish to make exchanges or to get some knowledge of the extent of the group and its various genera.— J. M. C.

MINOR NOTICES.

A NEAT MANUAL of seventy-nine pages and half a hundred cuts has been recently issued by W. Edgar Taylor, professor of biology in the Louisiana Industrial Institute, for the use of his classes. The printing was done and many of the drawings were made by pupils of the school, and the result is creditable. It is intended solely to meet local needs, including lessened cost to the pupils, and, although in book form, is of the nature of extended laboratory notes. It goes over the ground of the cryptogamous plants and unicellular animals, with an introduction on the cell.—J. C. A.

THE SECOND PART of the Welwitsch Catalogue of African plants, by W. P. Hiern, and published by the British Museum, has just appeared, including Combretaceæ to Rubiaceæ. The occasion of the publication was stated in the review of the first part published in the GAZETTE (23 : 210. 1897). Although the date of the collections is 1853–1861, the region has been so little explored that the book is full of new material. In the present part the great family Rubiaceæ is of much interest, three new genera (*Pentacarpæa, Justenia*, and *Chalazocarpus*) and fifty-eight new species being described. The only other new genus is *Campylochiton* (Combretaceæ).— J. M. C.

A LITTLE BOOK before us by Clarence Moores Weed, entitled *Seed travellers*, has been prepared as a supplementary reader in connection with nature study in the schools.[6] The author recommends "that this little book be used in connection with observations upon the specimens treated of; that the studies be read by the individual pupils, either with the objects in hand or for the purpose of inciting them to search for the specimens. . . . . It may then be advisable, after most of parts have been read, to review the whole subject by having the pupils begin at the first of the book and read it through consecutively, with or without studying the objects again." With this purpose in mind the author has described the way in which the wind and birds act as distributors of seed. He has, also, very briefly shown the method of seed distribution by spines and hooks. The book is attractively written and is accurate as to its facts. The illustrations, as a whole, are fairly good, but are very unequal in quality. The style is not always simple, but the book generally will be quite intelligible to children. This is an addition to the list of available nature readers, and as such is to be warmly welcomed.—C. R. B.

THE GENUS Cyclamen has been studied by Dr. Friedrich Hildebrand, whose results have recently been published.[7] The necessity of associating ecologic and taxonomic studies is becoming more and more apparent, and the monograph before us is a worthy type of the most effective method of investigating plant groups. The genus was very favorable for such study, containing only thirteen species, and all of them accessible, being restricted to the Mediterranean region. In the disentanglement of herbarium material and literature, the author has found sufficient names already provided, except in the case of *C. alpinum*. It is the so-called "biological" part, however, that is of chief interest, and that deserves especial commendation to our taxonomists. Any adequate review would mean a synopsis of the work.—J. M. C.

THE SERIES of classics in various exact sciences, which are being published by Engelmann, has been enriched by the addition of no. 95, which includes four papers by Ernst von Brücke.[8] These papers are as follows: I, Bluten des Rebstockes; II, Bewegungen der Mimosa pudica (1848); III, Elementarorganismen (1861); IV, Brennhaare von Urtica. All these papers are interesting, especially to show how at an early period in the study of plant physiology exact and careful experimentation led to well-founded and stable results. Probably the best known of the four papers is the second one, which Sachs calls a model of accurate experimentation and clear presentation. Brücke was trained for medicine, and in 1843 became an assistant in the Museum of Comparative Anatomy through his relations with Johannes Müller.

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[6] WEED, CLARENCE MOORES.— Seed travellers: study of methods of distribution of various common seeds. 12mo. pp. vii + 53, *figs. 36*. Boston: Ginn & Co. 1898.

[7] HILDEBRAND, DR. FRIEDRICH.— Die Gattung *Cyclamen* L., eine systematische und biologische Monographie. pp. 190. *pl. 6*. Jena: Gustav Fischer. 1898. *M.* 8.

[8] Ostwald's Klassiker der exacten Wissenschaften no. 95. Physiologische Abhandlungen. 12mo. pp. 86. Leipzig: Wilhelm Engelmann. 1898. *M.* 1.40.

Shortly he turned his attention to physiology, and was soon made associate professor at Königsberg. In 1849 he was called to the professorship of physiology in Vienna. Here he remained to his seventieth year as teacher and indefatigable investigator, surrounded by numerous pupils, who were inspired by his vigor and enthusiam. In 1889 he retired from active work, and died in 1892. His industry and success are somewhat indicated by the long list of scientific papers — one hundred and thirty — which he published.— C. R. B.

NOTES FOR STUDENTS.

A THIRD ARTICLE, by the colonial botanist, F. M. Bailey, enumerating the fresh-water algæ of Queensland, is issued as Botany Bulletin XV by the Queensland Department of Agriculture. The thirty-eight pages are accompanied by seventeen excellent plates from pen drawings.—J. C. A.

ITEMS OF TAXONOMIC interest are as follows: In the last fascicle of *Pittonia* (3 : 329–344. 1898) Professor Greene continues his descriptions of new species of Convolvulus, nine of which are described; proposes four new species of Canadian violets, from Macoun collections; and describes a fascicle of new labiates, thirteen in number.— S. B. Parish has begun in *Erythea* (**6** : 85–92. 1898) a series of important papers on new or little known plants of southern California. The first one discusses about fifty plants, describing five new species and six new varieties.— J. M. C.

A NEW SPECIES of Pleodorina, *P. Illinoisensis*, is described by C. A. Kofoid in a recent Bulletin of the Illinois State Laboratory of Natural History, and illustrated with two plates showing form and development. Comparisons are made with *P. Californica*, now known from Indiana and Illinois as well as California. It is also pointed out that there are some reasons for thinking that the new form may be only a stage in the development of Eudorina, probably of *E. elegans*. We note an omission in the bibliography of the article by Severance Burrage on "A new station for Pleodorina Californica" in *Proc. Ind. Acad.* **1895**: 99–100.—J. C. A.

AT A RECENT meeting of the Imperial Academy of Sciences in Vienna, Dr. Wilhelm Figdor, assistant in the institute for plant physiology of the University of Vienna, read a paper entitled "Investigations upon the phenomena of sap pressure (Blutungsdruckes) in the tropics." A summary of his results is translated from the *Österreichische Botanische Zeitschrift* 48: 359. 1898.

"1. In the tropics in contrast with the prevalent relations in our latitudes, there is always a positive sap pressure, which shows a very different intensity in the various plants observed.

"2. The amount of sap pressure attained in general is two or three times as great as with us. The strongest pressure observed was somewhat more than eight atmospheres in *Schizolobium excelsum* Vog.

"3. The sap pressure varies, often very markedly, in one and the same plant within twenty-four hours. This phenomenon cannot be ascribed to daily periodicity alone, but must be referred to the influence of external factors, especially to the transpiration, which even in the tropics, is very copious."— C. R. B.

PROFESSOR WIESNER presented at the June meeting of the Imperial Academy of Sciences in Vienna a memoir entitled "Contributions to the knowledge of the photo-chemical climate in Arctic regions." His results (translated from *Österreichische Botanische Zeitschrift* 48: 360. 1898) are as follows:

"1. In high northern regions (Advent bay, Tromsö) the chemical intensity of the total daylight, with equal elevation of the sun and equal cloudiness, is greater than in Vienna and Cairo, but less than in Buitenzorg, Java. At Trondhjem the same is true, but with a considerably greater approximation to the conditions at Vienna.

"2. With a completely overcast sky, the intensity of the light was observed to increase much more regularly with the height of the sun at Advent bay than in any other vegetation region observed.

"3. At Advent bay with equal elevation of the sun and equal cloudiness, the chemical intensity of light in the morning and afternoon were nearly equal; however, in most cases the afternoon intensity is somewhat greater than the morning.

"4. The greatest intensity of the total daylight and the diffuse light is to be observed in all regions upon a vertical surface, which faces the sun; the smallest upon the opposite vertical surface. The intensity upon the intermediate planes lies somewhere between that of the first two.

"5. Even with a completely clear sky, the distribution of the light intensity upon the illuminated vertical plane is not completely symmetrical.

"6. With increasing elevation of the sun, the direct light (*Vorderlicht, i. e.*, the average light falling upon the vertical plane) in comparison with the sky light (*Oberlicht, i. e.*, the total daylight measured upon a horizontal plane) diminishes. In Advent bay at the beginning of August, the ratio of the direct light to the skylight is as 1 : 1.5–2.2, whereas in Vienna in May this ratio may exceed 1 : 4.

"7. For days of equal elevation of the sun at midday the daylight totals in Arctic regions are considerably greater than in temperate latitudes. At the beginning of August the average daylight total at Advent bay is about two and one-half times greater than on similar days in Vienna (at the beginning of November and February).

"8. The light climate of the high northern vegetation region is characterized by a relatively greater uniformity of light intensity than is attained in any other vegetation region. This great uniformity expresses itself first in the low maxima and the high minima of the intensity of the total daylight, which again is dependent upon the course of the daily position of the sun, The daylight totals rise from spring to summer in the high Arctic regions much more slowly, and fall from summer to autumn much more slowly, than in temperate latitudes. Besides, the intensity of the direct light (*Vorderlicht*) in the north is nearer to that of the sky light (*Oberlicht*) than in other regions. The strength of the light, with complete cloudiness, increases with increasing elevation of the sun in no other region so uniformly as in the Arctic. Finally, the fact that the midnights of the north are most strongly, and those of the south most weakly, illuminated contributes to the uniformity of light intensity.

"9. The observations made at Advent bay establish the point already made by the author, that the share of the total light which plants obtain is greater the smaller the intensity of the total light is; of course, except in those regions in which the rays of the sun actually retard the development of plants (steppes and deserts). The greatest amount of the total light is received by plants of the Arctic regions. Their great need of the existing light excludes any self-shading of plants (*i. e.*, by their own leaves) in extreme northern regions, and in the neighboring southern regions (*e. g.*, in Hammerfest) only a minimal (physiological) branching of woody plants is possible."

A later memoir will concern itself with the connection of the climate thus described with the character of the vegetation.—C. R. B.

MR. U. SUSUKI, after a short exposition of his experiments in the *Botanisches Centralblatt* 75 : 289. 1898, avers that "these results leave no longer any doubt that nitrates can be assimilated and proteids formed in darkness." Dr. O. Loew adds that this confirms what he had long ago deduced from analogy in the culture of molds. Mr. Susuki's full paper will be published in the bulletin of the Agricultural College of Tokyo.—C. R. B.

IN GENERAL STYLE, Mr. F. N. Williams' recently issued *Revision of the genus Arenaria*[9] is not unlike his synoptic treatment of Silene, already noticed in these pages. Arenaria, however, is from its nature capable of more satisfactory division into subgenera and sections than Silene, and Mr. Williams seems also to have made a somewhat more detailed statement of the minor varieties and forms than in his earlier paper. He limits the genus Arenaria to the species which have estrophiolate seeds and divided or bidentate capsule-valves, thereby excluding Alsine, Mœhringia, Honkenya, etc. But, even as thus restricted, Arenaria includes the following reduced genera: *Alsinella* S. F. Gray, *Bigelowia* Raf., *Brachystemma* Don, *Brewerina* A.

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[9] Journal of Linnean Society **33**:326–437. 1898.

Gray, *Dolophragina* Fenzl, *Dufourea* Gren., *Eremogone* Fenzl, *Euthalia* Rupr., *Gouffia* Robill. & Cast., *Leptophyllum* Ehrh., *Lepyrodiclis* Fenzl, *Odontostemma* Benth., *Pettera* and *Plinthine* Reichb.,—a list sufficiently formidable to show the widely divergent views which have been held as to the generic limitations of the group.

Mr. Williams recognizes seven subgenera of which the salient characters may be summarized thus:

Euarenaria. Glands of disk obsolete; capsule-teeth 6.

Eremogoneastrum. Glands prominent; capsule dehiscent to below the middle by six valves; mostly cespitose perennials.

Pentadenaria. Glands 5; capsule 6-toothed; perennials, often suffruticose.

Dicranilla. Glands present; capsule dehiscent beyond the middle by six valves; flowers solitary, terminal, minute; S. American tufted alpine species.

Arenariastrum. Capsule dehiscent by 4 teeth; glands inconspicuous.

Odontostemma. Capsule dehiscent by 4 valves; filaments bidentate near the base.

Macrogyne. Capsule dehiscent by 4 valves; styles much exserted.

All but the last subgenus are again divided into two to five tolerably well marked sections. Our interest naturally centers upon the treatment of the North American species. Of these Mr. Williams recognizes fourteen, which he arranges thus:

Subg. EUARENARIA.
  § *Euthaliana* (with seeds granulate-tuberculate).
    A. Benthamii.
    A. serpyllifolia.
  § *Leiosperma* (with smooth globose, reniform, or lenticular seeds).
    A. lanuginosa.
    A. saxosa.
  § *Eremogoneæ* (with smooth, compressed, pyriform or oblong seeds).
    A. congesta.
    A. Franklinii.
    A. Hookeri.
    A. compacta.
    A. aculeata.
Subg. PENTADENARIA.
    A. ursina.
    A. capillaris.
    A. macradenia.
    A. Fendleri.
    A. ciliata.

This subdivision is certainly natural and theoretically clear. It is to be feared, however, that the gland distinction between Pentadenaria and Euarenaria § Eremogoneæ will prove difficult, if not impossible, in practice. It will be noted that in the number and limitation of our North American species, Mr. Williams suggests scarcely any change. Of *A. Benthamii* he proposes a var. *diffusa*, based upon Mr. Heller's no. 1686 from Kerr county, Texas. Concerning *A. serpyllifolia* he says, "introduced into North America, but scarcely naturalized there;" but certainly no introduced caryophyllaceous plant except the cerastiums has taken more kindly to American soil, for it is frequent from Maine to the Pacific coast and may often be found in places quite remote from dwellings. In the subdivision of this species, var. *tenuior* Koch does not appear even in the synonymy. On page 412, *A. ursina* is again separated from *A. capillaris*, on the ground that "none of the many forms of *A. capillaris* have glaucous leaves and emarginate petals." But the emarginate character of the petals is not a strong one and on a succeeding page Mr. Williams himself says, "As Ledebour points out, typical *A. capillaris*, which is widely distributed in Siberia, is a glabrous plant with short barren shoots and rigid glaucous leaves."

From Mexico Mr. Williams recognizes nine species and six varieties, his *A. megalantha* (*A. lanuginosa* var. *megalantha* Rohrb., *A. alsinoides* var. *ovalifolia* J. D. Smith) being new in conception.

In a prefatory note it is stated that in the spelling of geographic names the "Times" atlas has been followed. We are unacquainted with this work but should not place implicit confidence in it if "Chinautla" and "Sempaaltepec" are samples of its orthography.

Once more it must be said that Mr. Williams could add greatly to the value of his papers through citing by numbers a few authentic specimens under each species and variety. However, the treatment of Arenaria shows on the whole even more to praise and less to criticise than that of Silene. —B. L. ROBINSON.

A RECENT work of Cavara[10] deals largely with the finer structure of the nucleolus. *Ornithogalum umbellatum, Cucurbita maxima, Crinum giganteum, Narcissus poeticus, Lilium Martagon*, and others, furnished material. Absolute alcohol, alcoholic corrosive sublimate, Carnoy's fluid and Merkel's fluid were the principal fixing agents. Zimmerman's iodine-green and fuchsin was recommended for staining on account of its rapid and effective work, but many other stains were used including the methyl-green-eosin-orange of Erlich, and Flemming's safranin-gentian-violet-orange. Celloidin was used for embedding.

He believes that nucleoli are not thrust out but are taken up by the nuclear thread. A series of figures, apparently somewhat diagrammatic, represents the nucleoli in great detail, but the nuclear thread does not receive equal

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[10] CAVARA, F.—Intorno ad alcune strutture nucleari. Atti dell' Istituto botanico della R. Università di Pavia II. 5: 1–49. *pl. 2.* 1898.

attention. During mitosis the structure of the nucleolus is lost, its staining power is lessened and it breaks up into small pieces which show no staining capacity. These pieces are taken up by the nuclear thread and are to be regarded as condensation bodies of nutritive material. They may form plastin for spindles or chromatin for chromosomes. He says that this view resembles that of Hertwig, Flemming, and others. If it should be correct, it argues against the individuality of chromosomes.— C. J. CHAMBERLAIN.

IN THE WINTER of 1895–6, Börgesen and Paulsen carried on some important ecological studies in the West Indies. The results of their investigations have been published only recently.[11] The work is divided into two main parts: I. The halophytic vegetation, by Börgesen; II. The forests and thickets, by Paulsen. In addition there is an appendix containing a statement of the new spermatophytes, and a list of the algæ and fungi observed. The book is fully illustrated with eleven full-page plates from Börgesen's photographs, and many text figures.

The halophytic vegetation is treated of under five heads: 1. *The sea weeds.* Of chief importance are the Halimeda and Caulerpa forms, growing so densely as to form a solid mass. Some extraordinary Caulerpas are described, one closely resembling *Carex arenaria* in its external form. Its creeping, sharp-cornered stem sends out assimilation shoots and rootlets.

2. *The vegetation of the sandy beaches.* These beaches are composed principally of coral fragments, lime, and particles of limy algæ. On account of the weight of these sand grains no dunes are formed, even by the strongest winds. All the plants are protected in various ways against loss of water. The blades of grass are rolled up, and on other plants the leaves are bluish-gray and often very fleshy. Their elliptical or spatulate forms also give a small proportion of leaf exposure. The runners are above ground, as there is no danger of harm by flying sand. The Canavalia has dorsiventral leaves, the epidermis is provided with glandular, bristly hairs, some of the cells are arranged as stomata but do not function as such, and become crystal bearing. The Cocoloba has brilliant, upward turned leaves, the upper epidermis is strongly cuticularized, without stomata, and is impregnated with tannic acid. Many other forms are described, some having water cells, oil glands, cells containing calcium oxalate crystals, etc.

3. *The vegetation of the rocky coasts,* consisting of characteristic agaves, cacti, bromelias, and croton forms.

4. *The mangrove vegetation,* surrounding and encroaching upon all the bays, brackish lakes, and salt ponds, wherever there is found protected water. One of the most prominent forms is the Rhizophora, which has two kinds of aerial roots. Some spring from the principal stem standing at right angles

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[11] The vegetation of the Danish West Indies. Copenhagen. 1898. *Cf.* Bot. Centralbl. 74 : 143. 1898.

and later turning downwards. The others grow from the branches of the tree perpendicularly downwards, branching at the surface of the water where the tips die and decay. The structure of these aerial roots is fully described.

5. *The vegetation of the salt clay plains.* These stretches surround the lagoons and salt ponds and upon them is an overflow of some of the forms described above. In drier localities live some herbaceous forms and some of those growing erect on the beaches are here recumbent.

Under the forest and thicket vegetation each island is discussed separately. The Hurricane island, which forms the western boundary of the harbor of St. Thomas, is sparsely inhabited and mostly covered with a xerophytic vegetation, whose density is increased by thorn growths and lianas. The trees are generally smooth leaved, the shrubs hairy leaved, and the most important succulents are the agaves, bromelias, and some opuntias.

In the interior of the island of St. Thomas grow many croton bushes, as well as forests of larger trees, a long list of which is given. Epiphytic orchids, arums and ferns also abound, *Cuscuta Americana* being especially widespread. St. John is very fertile, though little cultivated on account of the indolence of the natives.

Lately some promising experiments with the cultivation of coffee and cocoa have been undertaken. The croton underbrush has been pretty well crowded out of this island, and there are great grassy stretches near the deeper forests. St. Croix is the most important of the Danish Antilles, and is the chief seat of the Danish cane-sugar industry. In the uncultivated portions the vegetation is similar to that of the other islands. Upon the fallow fields the weeds are always woody. The gray crotons cover most of the eastern half of the island, and are more xerophytic and smaller than elsewhere. Only a few trees are found, and lianas are scarce, but the succulents richly supply their place. The chief characteristic of the vegetation is its xerophytic adaptation. With the exception of the legumes, the leaves are entire, stiffy haired, usually ovate and short stemmed. Thorns of every sort abound. In the valleys we find the luxuriant vegetation of the tropics, oranges, figs, etc. Upon the trees was seen the Tillandsia, and in damp places Psilotum and *Pilea macrophylla*.

In the last division of the second part the author treats of the anatomy of the xerophytic foliage leaves, having investigated three groups: (1) the decidedly hairy leaves; (2) the slightly hairy and smooth leaves; (3) two types of leguminous leaves. He thinks the structure of the smooth leaves not anatomically different from that of the hairy leaves, but the outer epidermal walls are very much thicker. This is also true of the leguminous leaves. The abundant glandular hairs are depressed on the smooth leaves, and stand among the other hairs on the hairy leaves. They closely resemble the hydathodes described by Haberlandt. The leaf anatomy of *Evolvulus nummularis* and of *Loranthus emarginatus* is fully described.—S. M. COULTER.

NEWS.

PROFESSOR L. H. BAILEY has returned from Europe before completing his proposed year abroad.

THE PENN PUBLISHING COMPANY announces a booklet by Mrs. Julia McNair Wright to be called *The story of plant life.*

MR. E. O. WOOTON has been appointed professor of botany at the New Mexico Agricultural College and Experiment Station.

FROM *Erythea* we learn that Dr. Marshall A. Howe has nearly completed an illustrated monograph of Californian Hepaticæ.

HENRY HOLT & CO. announce for publication this fall an elementary botany by Professor George F. Atkinson, of Cornell University.

PROFESSOR STANLEY COULTER, of Purdue University, who spent most of the time of his vacation trip in the botanical laboratory at Bonn, has returned to his home.

DR. CHARLES R. BARNES was elected vice president, and chairman of section G (botany), A. A. A. S., for the fifty-first meeting, which is to be held at Columbus, Ohio.

PROFESSOR A. F. W. SCHIMPER, of the University of Bonn, has been called to Basel as the successor of Professor Dr. George Klebs, who goes to the University of Halle.

MR. F. O. GROVER, of Harvard University, has been appointed instructor in botany in Oberlin College to succeed Professor H. L. Jones, whose untimely death we chronicled last month.

THE ENGLISH TRANSLATION of Dr. Franz Lafar's *Technical mycology*, already published in England, is announced for fall publication by the Lippincott Company, of Philadelphia.

DR. O. BREFELD, director of the Botanical Garden and Institute at Münster, has been unanimously called to the University of Breslau, to succeed the late Dr. Ferdinand Cohn.

DR. O. LOEW, of Munich, has accepted a call to the Department of Agriculture at Washington. He brings to the department his thorough knowledge and high reputation as a chemist devoted to the problems of plant physiology. The department is to be congratulated upon procuring the services of a man whose contributions to chemical physiology are so widely and favorably known.

MRS. WILLIAM STARR DANA is shortly to add another work to the series of which she is author. This one is to be entitled *How to know ferns.* It will be published by Charles Scribner's Sons.

THE UNIVERSITY OF ABERDEEN has received a legacy of £15,000 for founding the Cruickshank Botanical Garden. The director of the garden will be James W. Traill, professor of botany in the university.

MR. W. T. SWINGLE, who has been spending the year abroad, part of the time in the laboratory of Professor Pfeffer at Leipzig, will remain away several months longer before resuming his duties in the U. S. Department of Agriculture.

MR. M. A. CARLETON is now in Russia as an agent of the U. S. Department of Agriculture to study the cereals of that region. The results of his extended investigations upon the rusts of cereals were sent to press before his departure, and will be issued as a Bulletin of the Division of Vegetable Physiology and Pathology.

THE LLOYD MYCOLOGICAL MUSEUM was increased during 1897 by nearly a thousand named specimens, and a list of the species and donors is given in the third report of the museum just issued. Fleshy fungi, both dry and preserved in alcohol, are desired. Correspondence should be addressed to Mr. C. G. Lloyd, Cincinnati, Ohio.

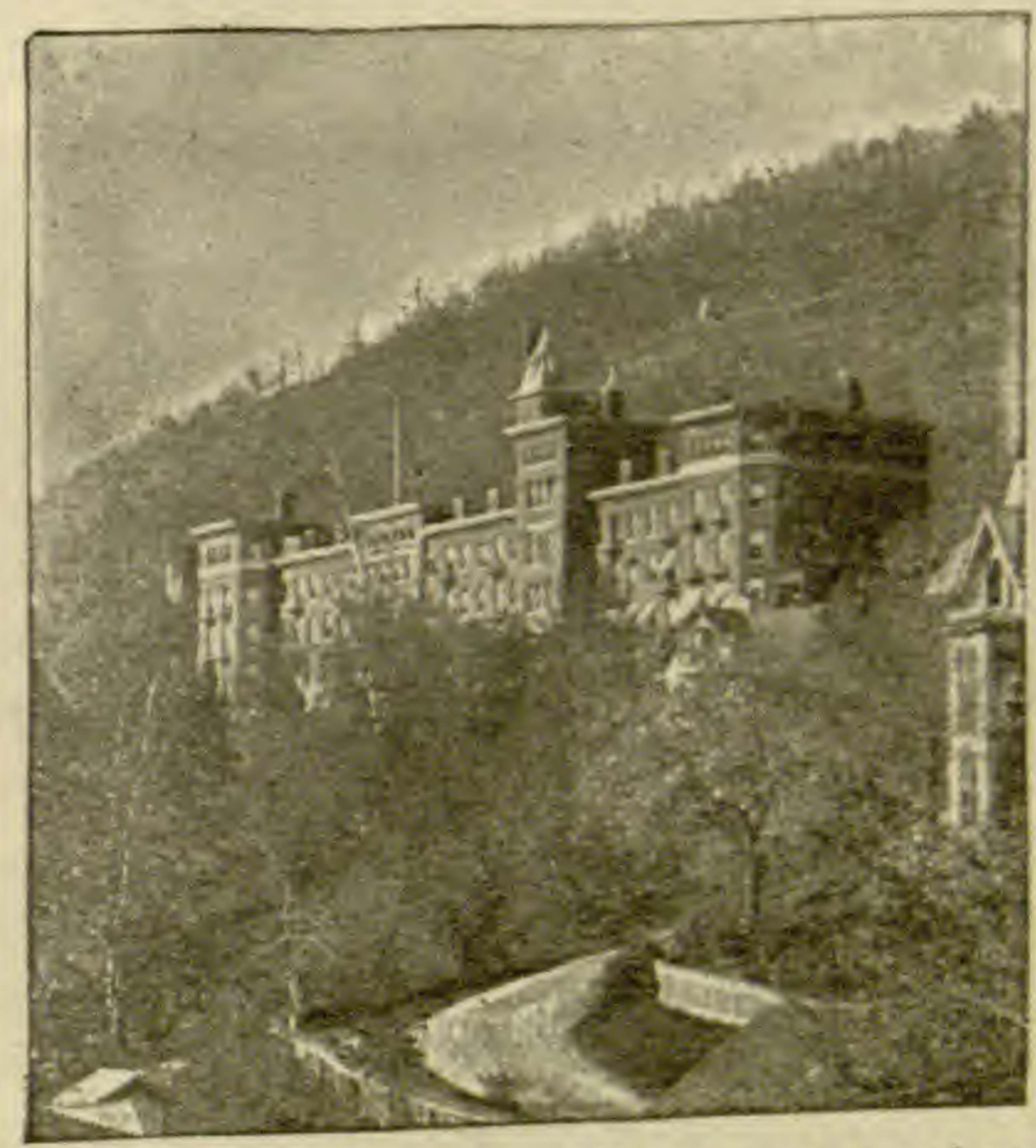
DR. DANIEL MORRIS, assistant director of the Kew Botanical Gardens, has resigned this post to accept a government appointment as Imperial Commissioner of Agriculture for the British West Indies, having in charge the newly established "Botanical Department." We are not informed what the relations of the commissioner to the present garden directors is to be. *Natural Science* suggests that he "will not be welcomed with open arms by the many botanists in those parts, which already have an excellent botanical garden and staff in Jamaica." Dr. Morris sailed from England September 21st, for Barbadoes, where he will establish his headquarters.

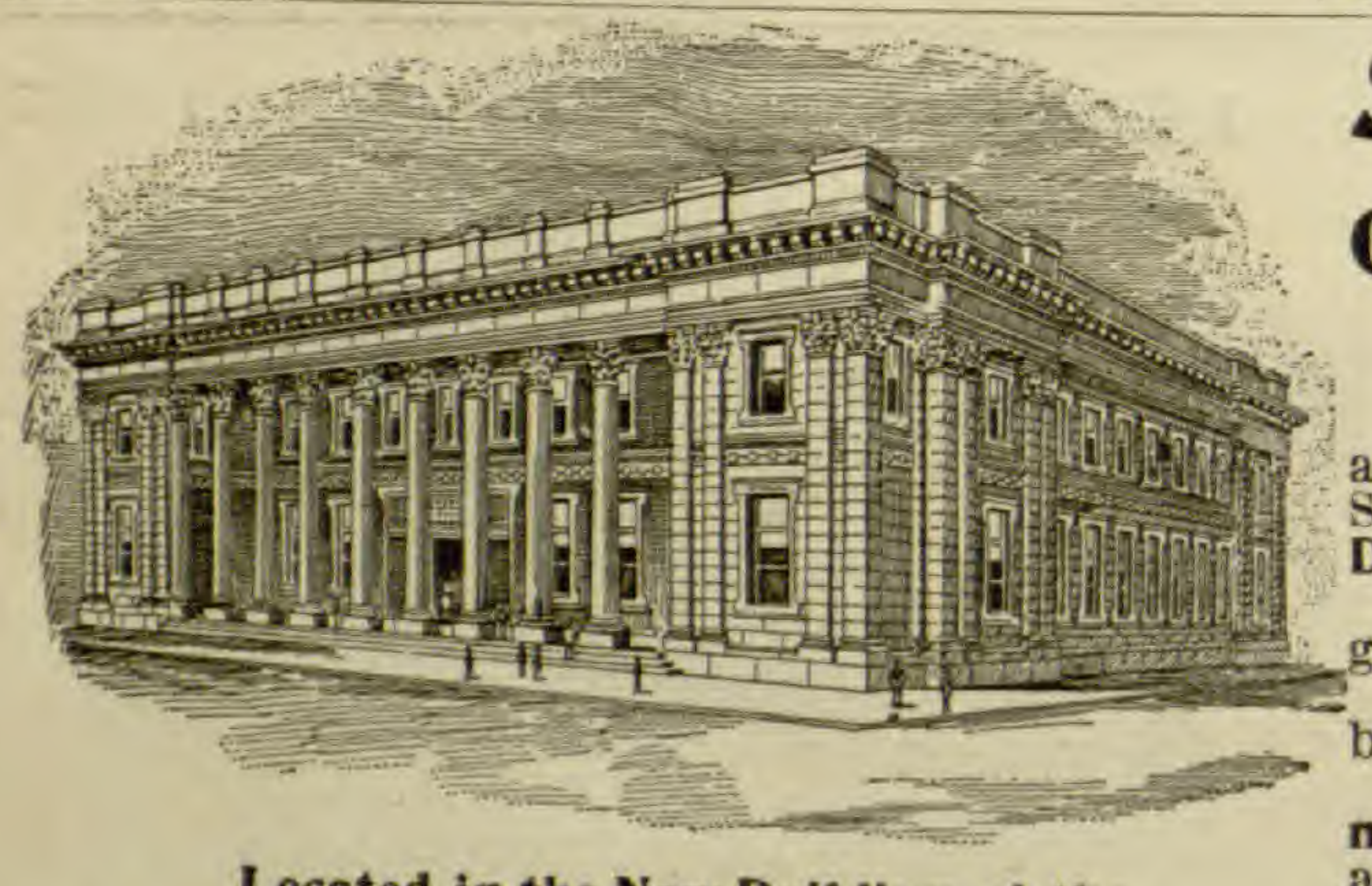
THE BOTANICAL SOCIETY OF AMERICA elected the following officers for the coming year: *President,* Lucien M. Underwood, of New York; *Vice President,* Benjamin L. Robinson, of Cambridge; *Secretary,* George F. Atkinson, of Ithaca; *Treasurer,* C. Arthur Hollick, of New York; *Councillors,* Charles E. Bessey, of Lincoln, and Wm. P. Wilson, of Philadelphia. The following were elected members of the society: Robert A. Harper, University of Wisconsin, Madison; Edward A. Burt, Middlebury College, Middlebury, Vt.; Herbert J. Webber, Department of Agriculture, Washington, D. C.; L. H. Pammel, Iowa Agricultural College, Ames; Albert S. Hitchcock, Kansas Agricultural College, Manhattan; Herbert Maule Richards, Harvard University, Cambridge, Mass.; David G. Fairchild, Department of Agriculture, Washington, D. C.; David M. Mottier, University of Indiana, Bloomington.

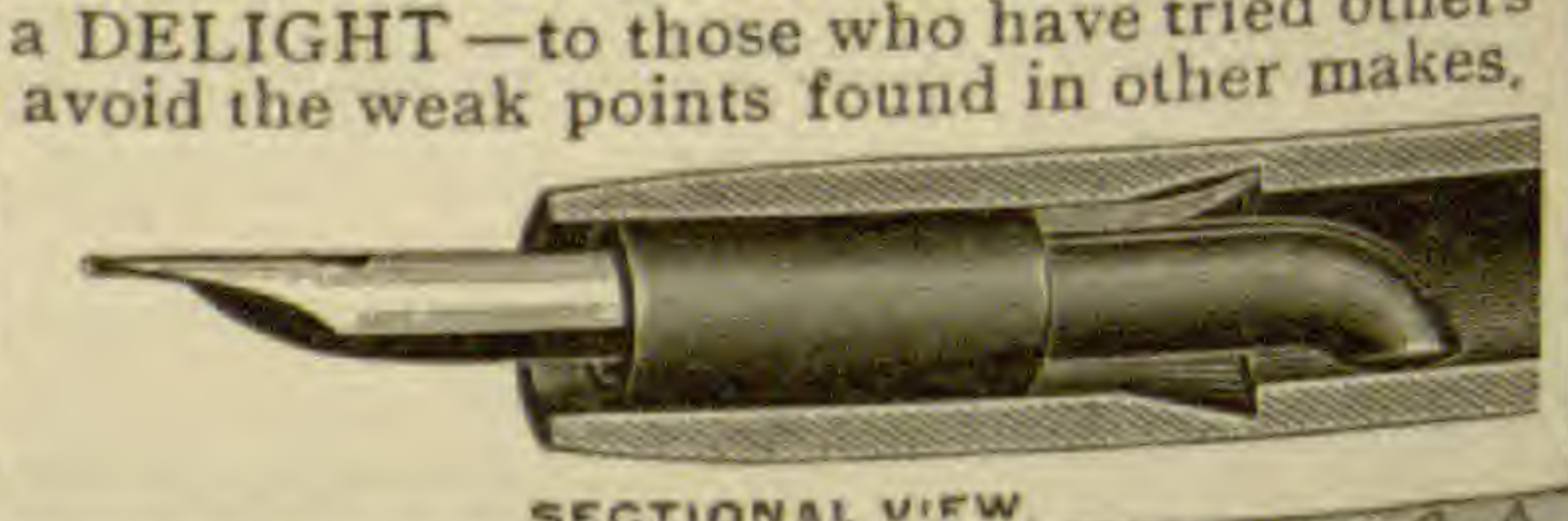
THE MACMILLAN CO. announce for early publication two books by Professor L. H. Bailey, of Cornell University, one a *Text-book of Agriculture for Schools,* and the other a volume entitled *The Evolution of our Native Fruits.* Among their other volumes announced for the autumn is the one upon the *Evolution of Plants* by Dr. Douglas H. Campbell, of Leland Stanford University, and a new volume of the Rural Science series on the *Physiology of Plants* by Dr. J. C. Arthur, of Purdue University. Welcome information to physiologists, also, is the statement that a translation of Verworn's *Allgemeine Physiologie* is in preparation by Dr. F. S. Lee, adjunct professor of physiology in Columbia University.

THE STATE OF HAMBURG has just established at Freihafen a station for plant protection. Dr. C. Brick has been transferred from the Botanical Museum of Hamburg to the direction of this station, and Dr. L. Reh has been appointed zoologist. Occasion for the establishment of the station was afforded by necessary investigation of American fruits imported into Hamburg in order to protect orchards against the San José scale. Besides this, the station will look after the introduction of injurious insects with the shipments of living plants from abroad. Its duties will include, also, the combating of plant diseases, the oversight of the schools of viticulture, and the inspection of vineyards and orchards in the Hamburg region, together with such questions as arise in the prosecution of this work.

THE FIFTH annual meeting of the Botanical Society of America was held in the Rogers Building of the Massachusetts Institute of Technology, Boston, August 19–20, 1898. The sessions of the society on the 19th were devoted to business matters. The literary sessions on the 20th were presided over by president N. L. Britton. The address of the retiring president, John M. Coulter, in his absence, was read by Dr. B. M. Davis, and is published in full in this issue. The following papers were read before the society: Reducing division of the chromosomes in *Arisæma triphyllum,* by ring and tetrad formation during sporogenesis: *Geo. F. Atkinson.* Symbiotic saprophytism: *D. T. MacDougal.* Sporogenesis in *Trillium grandiflorum*: *Geo. F. Atkinson.* Forest distribution in New Jersey and its relation to geology: *Arthur Hollick.* The centrosphere in Corallina: *B. M. Davis.* Tetrad formation in *Tsuga Canadensis: W. A. Murrill;* presented by Geo. F. Atkinson. Notes on a Helianthus from Long Island: *N. L. Britton.* Preliminary note on fertilization in the white pine: *Miss M. C. Ferguson;* presented by invitation of the Council. A fossil moss from the state of Washington: *Mrs. E. G. Britton.*—G. F. A.







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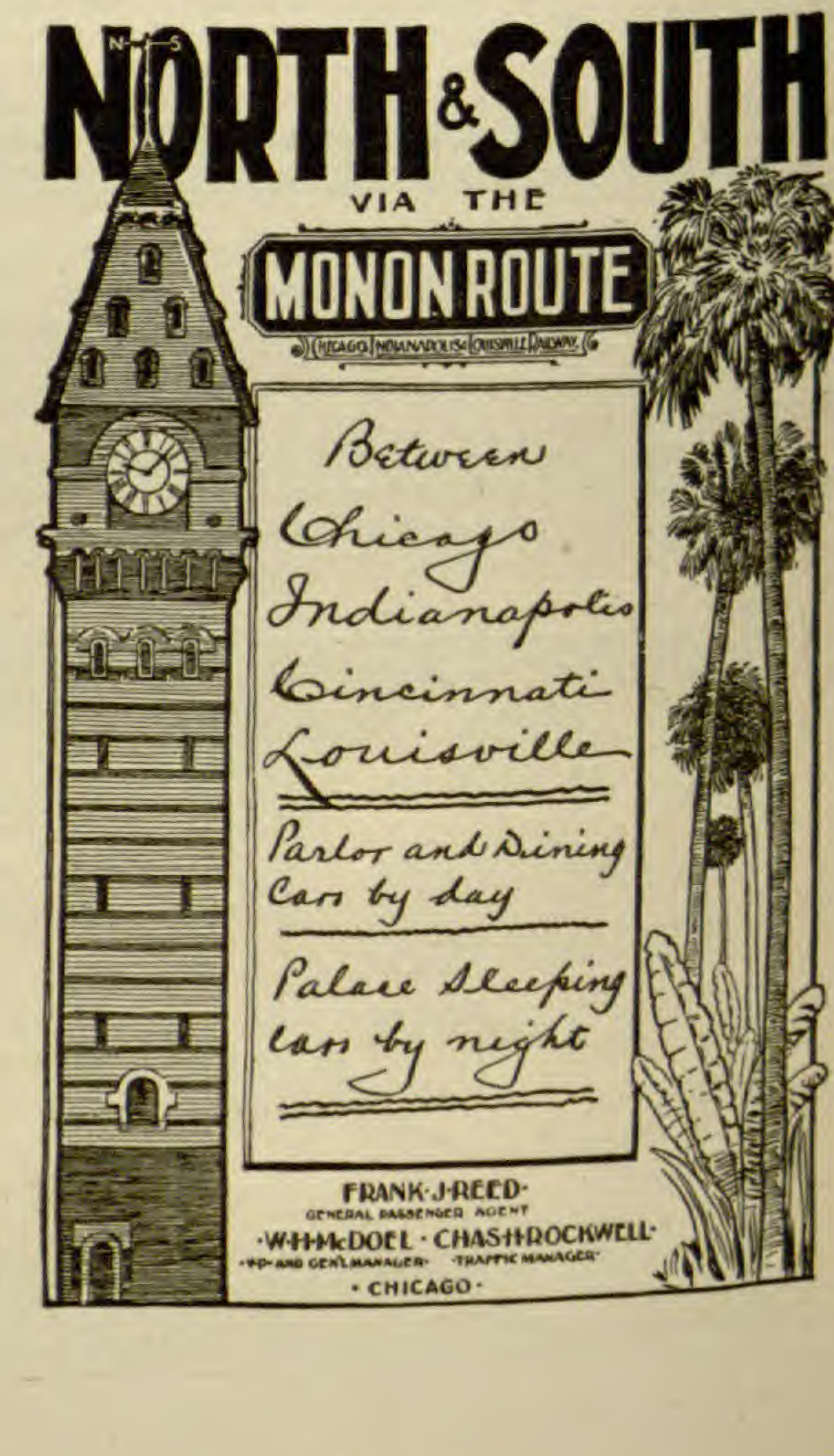

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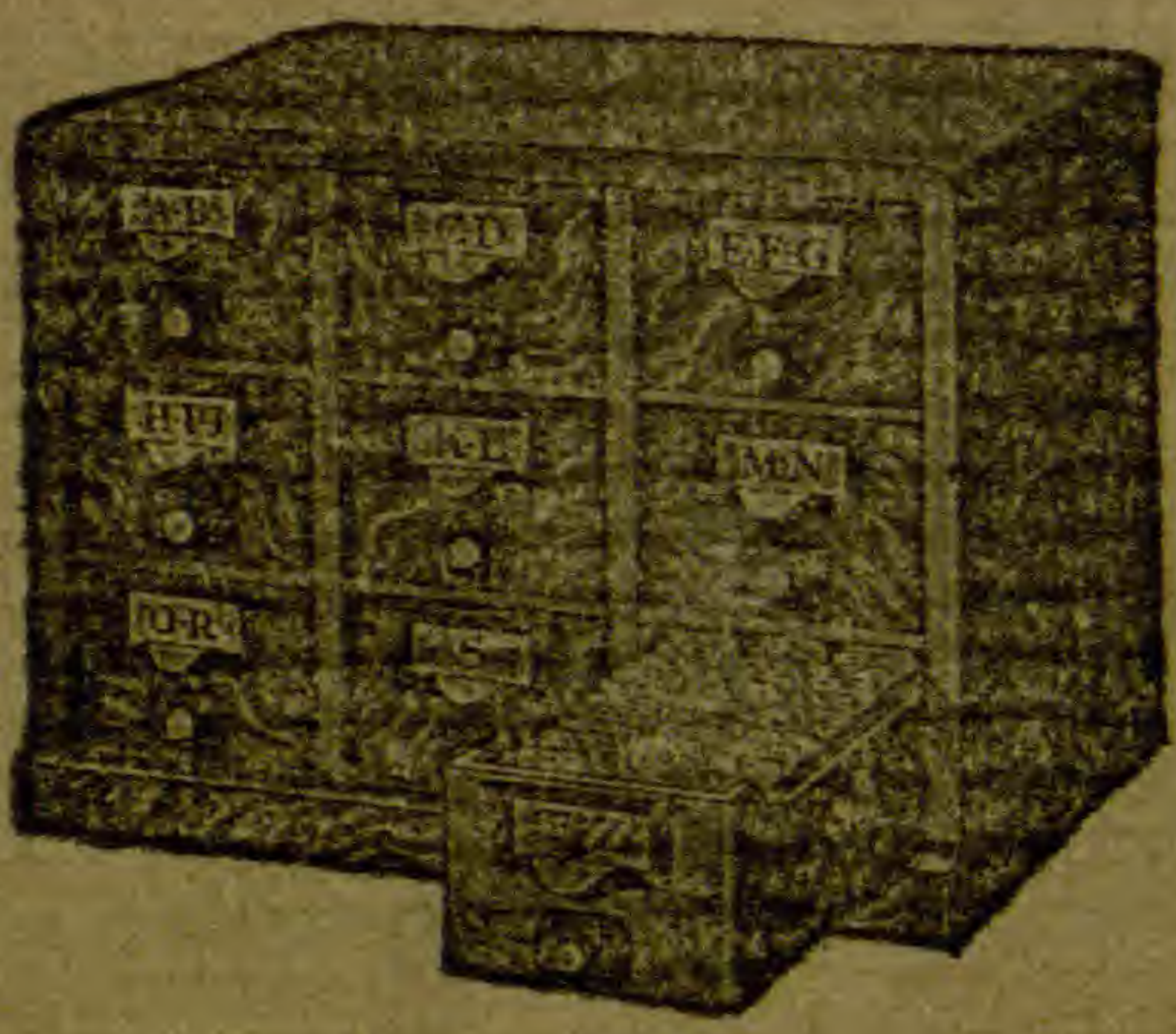

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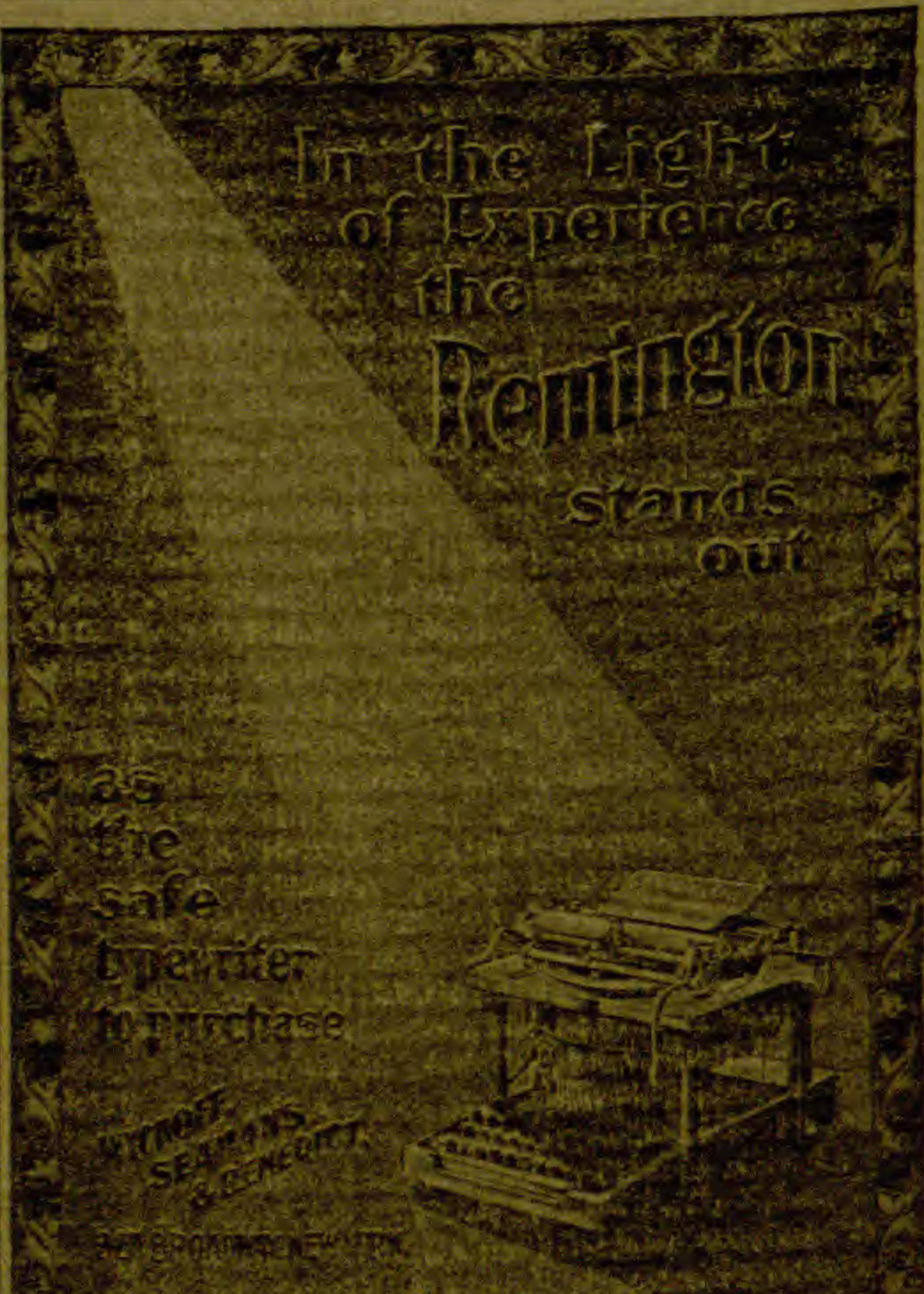

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THE BOTANICAL GAZETTE

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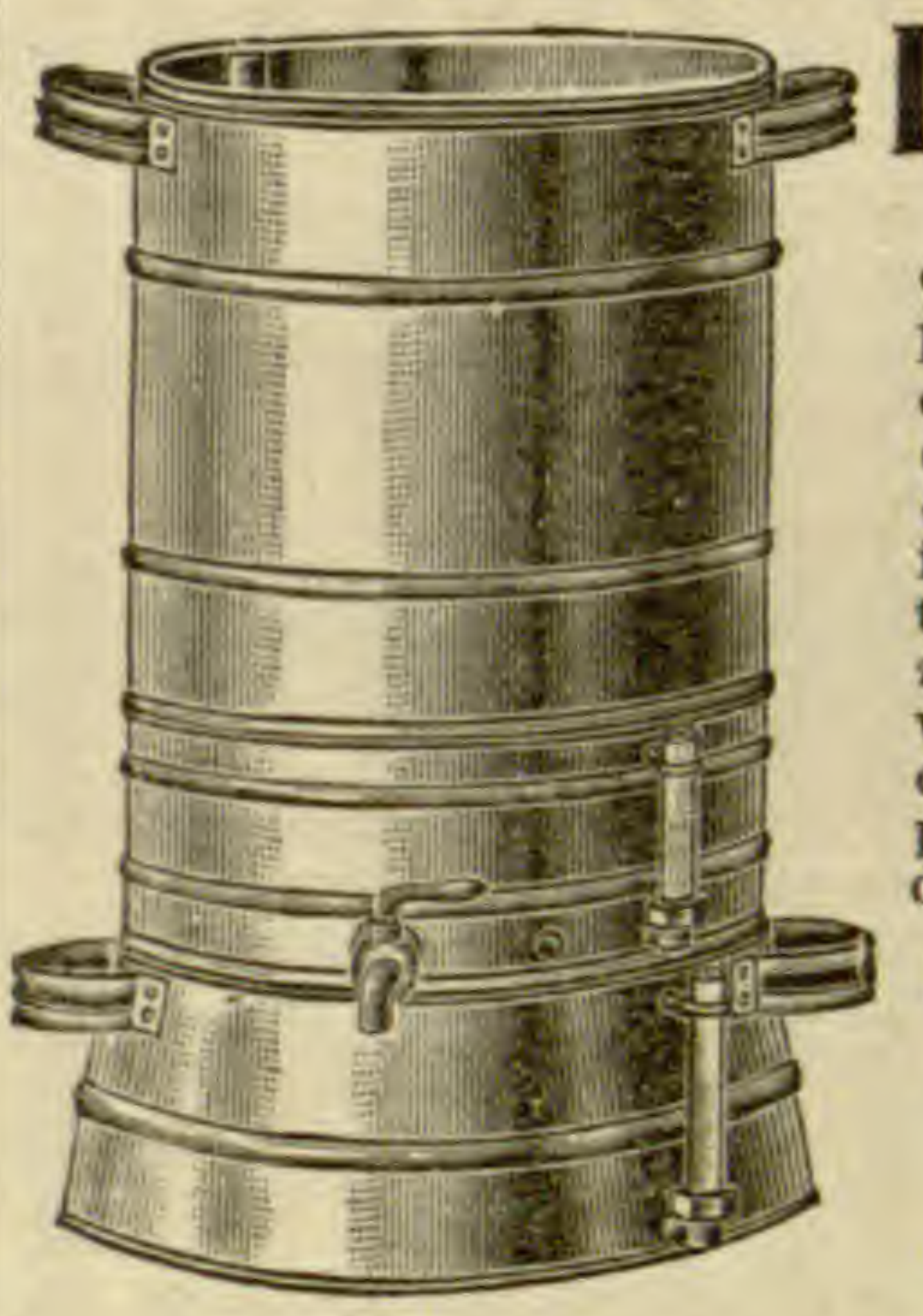

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VOLUME XXVI NUMBER 5

BOTANICAL GAZETTE

NOVEMBER 1898

THE COMPARATIVE MORPHOLOGY OF THE PISTILS OF THE RANUNCULACEÆ, ALISMACEÆ, AND ROSACEÆ.[1]

ERNST A. BESSEY.

(WITH PLATE XXV)

RANUNCULACEÆ.

THERE are two types of pistil present in this family. In the first there is but a single ovule in each pistil; in a specialized form of this type there are, besides the one principal ovule, two to six rudimentary ovules subsequently developed, but never reaching maturity. The second type consists of those pistils which have two to many ovules, all or nearly all reaching maturity. Pistils of the first type are found in the Ranunculeæ, Anemoneæ, and Clematideæ, and of the second type in the Helleboreæ and Paeonieæ.

The species studied to determine the mode of development of the pistils were the following: *Ranunculus abortivus* L., *R. eremogenes* Greene, *R. delphinifolius* Torr., *R. ovalis* Raf., *R. glaberrimus?* Hook., and *Myosurus minimus* L., all representing the strictly uniovulate type; and *Anemone Caroliniana* Walt., *A. cylindrica* Gray, *A. Canadensis* L., *Pulsatilla hirsutissima* (Pursh) Britt., and *Clematis ligusticifolia* Nutt., representing the uniovulate type where rudimentary ovules are developed. For the study

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[1] A thesis for the degree of Master of Arts, in The University of Nebraska, 1898.

of the multiovulate type, use was made of *Delphinium Carolinianum* Walt., and *Caltha leptosepala* DC.

RANUNCULUS ABORTIVUS. The pistil first makes its appearance as a slight rounded projection from the surface of the then small receptacle. This projection enlarges, as does the receptacle, until it is almost hemispherical. It then begins to elongate, and during this process a second, rounded projection appears in the axil of this as yet only slightly developed carpellary leaf (*fig. 1*). The second rounded mass of cells is produced as a result of the rapid division of the hypodermal cells, and is not epidermal, but is covered with epidermis. At this time a cross-section of the pistil shows that the upper side is slightly flattened. This flattening becomes more pronounced until, in a short time, the pistil is seen to be slightly concave above, *i. e.*, the edges of the carpellary leaf are beginning to fold around, eventually to meet to form a closed pistil (*fig. 2*).

In addition to this lateral folding, the outer part of the pistil soon begins to bend upward, until its apex, which was at first directed at right angles to the surface of the receptacle, now points in a direction parallel to it. The lateral folding, also, continues, nearly closing the upper part of the pistil (*figs. 3, 4*). In the meantime the axillary mass of cells has been growing, especially at the side towards the receptacle, causing its apex to turn away from the receptacle and down into the cavity in the upper part of the pistil, which has been bending upward, and towards the receptacle. It has now become possible to distinguish two parts in the axillary mass of cells; a thicker basal part (which I will call the "axillary placenta," since it arises in the axil of the carpellary leaf) and a slender apical part, the ovule, which bends down between the laminae and thus into the hollow of the pistil (*figs. 5, 6*). The axillary placenta itself is really not within the pistil, but forms part of the wall on the ventral side. The laminae of the pistil extend to it and are continuous with its outer layers of cells, and extend from it to the apex of the carpellary leaf, which has bent around almost in a semicircle. When these laminae finally come together to close the pistil, they curve in over the top of the axillary placenta, forming a forked suture shaped like an inverted letter Y.

While the carpel has thus been curving upward, the growing nucellus has been bending downward, the former describing an arc of 180°, while the latter passes through only 120°. A short time before this stage is reached the archesporial cell is differentiated, the exact time being very variable. The wall of the pistil furthest from the receptacle now elongates considerably, with the result that the longest axis of the pistil instead of being, as at first, at right angles to the surface of the receptacle, is now parallel to it. The ovule still continues to bend until it, too, lies in the main axis of the pistil, but with the micropyle pointing down. The last small opening of the pistil is now closed by the meeting of the edges of the laminae. It is the line of meeting of the laminae with the upper side of the axillary placenta, or in other words, one of the arms of the inverted Y-shaped suture, that shows so distinctly in all median or almost median sections of the pistil (*fig. 8, a*).

The main fibrovascular bundle supplying the pistil divides just after entering it. One branch passes around in the median line in a position corresponding to the bundle of the mid-rib of a leaf. The other passes up into the axillary placenta, through the funiculus and into the base of the nucellus, also in the median line (*fig. 8*). Later other branches run to the side walls of the pistil.

RANUNCULUS EREMOGENES. The development of the pistil in this species is almost identical with that in *R. abortivus.* The pistil begins as a rounded outgrowth from the receptacle (*fig. 9, a*), which is more developed in this species at this stage, than in the preceding. Immediately above the base of this outgrowth there arises another, eventually to become the ovule. This is shown in *fig. 9*, at *b*, which is a rudimentary pistil, with the still more rudimentary ovule three or four cells higher. The pistil flattens dorsiventrally and the edges begin to fold together, while the apex also curves upward. The axillary papilla at the same time elongates and the distinction of ovule and placenta is made. The ovule bends down into the space between the laminae of the carpel. The single integument now begins to make its appearance, and the archesporium becomes visible as a specialized cell. By this time the ovule has described an arc of 120° from the position held by the axillary papilla when it first appeared. The development is now so rapid that by the time the archesporium has divided into two cells and each is beginning to divide again, the ovule has bent 30° more (*fig. 10*), and at the completion of the division has bent another 30°. At the same time the apex of the carpel has passed through an arc of 180°, and the main axis of the pistil has become parallel to that of the receptacle. A noteworthy fact in connection with the development of the archesporium is that the two megaspores nearest to the micropyle lie in a line nearly at right angles to the main axis of the nucellus (*fig. 10*). Soon after this stage is reached the pistil becomes closed through the meeting of the edges of the laminae. A front view of a nearly mature pistil shows that in this species, as in *R. abortivus*, the suture is shaped like an inverted Y (*fig. 19*).

Ranunculus ovalis, R., *glaberrimus ?* and R. *delphinifolius* show in their later stages the same structure as described above, indicating that they probably have a similar course of development.

MYOSURUS MINIMUS. This species has a long, narrow receptacle, in strong contrast to the short hemispherical one of Ranunculus. On it is shown more vividly what is apparent to a slight degree on the receptacle of Ranunculus, viz., the acropetal development of the pistils. In Ranunculus the difference in age of the pistils on the different parts of the receptacle is only slight, and soon disappears. On the other hand, in Myosurus, even when the pistils on the lower part of the receptacle are well developed, others are just appearing at the top. As in the preceding genus, the pistil appears as a slight papilla on the surface of the receptacle. As it elongates, its apex is directed slightly downwards. On the upper side of the pistil, next to the receptacle, is then developed an axillary papilla whose axis, at first, forms an angle of about 35° with the surface of the receptacle, while the apex of the pistil is directed so as to form an angle of about 90° with the axis of this papilla (*fig. 11*). Even at this stage the outer part of the pistil is flattened above (*figs. 12, 13*). This flattening progresses until a longitudinal groove is formed in the upper surface of the carpellary leaf, extending back to the axillary placenta. The apex of the carpel now begins to bend upward, while the ovule begins to grow downward. By the time that the ovule has bent 45° from its original position, the archesporium appears. The outer part of the pistil has also changed its direction by 45°, thus bringing the ovule partly within the cavity formed by the laminae which connect the axillary placenta with the apex of the carpel (*fig. 14*). At the time that the first traces of the single integument appear, the archesporium has divided into two cells and the ovule points directly down, *i. e.*, in its curving it has described an arc of about 145°. The apex of the carpel has in the same time described an arc of only 125°, so that it lies parallel to the receptacle (*fig. 15*). For some time further the pistil does not change much except in size. The ovule, on the other hand, is active in its changes. By the time that the megaspore furthest from the micropyle has by its enlargement destroyed the others (two or three in number), the ovule has curved 90° more (*figs. 16, 17*). This process continues until at the time that the embryo sac is ready for fertilization the ovule lies with its axis parallel to that of the receptacle, a change in direction of about 325° (*fig. 18*). To accommodate the ovule thus bent upon itself the lower part of the pistil elongates somewhat, so that the fibrovascular bundle of the median line of the carpel, after leaving the receptacle and giving its branch to the ovule, passes first downward, then outward, and finally upward. The bundle going to the ovule passes first upward, then outward, then downward, and finally inward to the base of the nucellus. From this time on until the seeds drop, the position of the nucellus remains the same, so that by making longitudinal sections of the flower, it is easy to obtain longitudinal median sections of all the ovules, from one hundred to two hundred in number. As in Ranunculus, the pistils are not entirely closed until a very short time before fertilization, and then in the same manner. The further development of the pistil after fertilization is, however, a little different in the two genera. In Myosurus, instead of enlarging rapidly so as to leave a large cavity which the ovule fills only in part, the pistil enlarges only as does the ovule, leaving no cavity. The walls, too, do not become stony, thus allowing (what is very difficult in Ranunculus) the study of the development of the embryo.

ANEMONE. In the first stages of the development of the pistils this genus resembles Myosurus very closely. In fact, the development throughout of the single large ovule is as in that genus (*figs. 20–23, 26*). A slight difference in the shape of the pistil is noticeable, in that the cavity is prolonged somewhat above the ovule. In *Anemone Caroliniana*, after the ovule has curved down into the cavity of the pistil, there appear on the edges of the laminae, which are now closing together, two projections. These increase in size, growing down into the cavity of the pistil above the first ovule. They remain merely few-celled papillae in this species, one on each lamina, the central cells resembling archesporial cells (*fig. 24*). This occurs also in other species of this genus, the papillae in some species often becoming well-marked, rudimentary ovules. This is so common that Baillon describes[2] Anemone as being provided with five ovules, four being aborted and one descending and fertile.

CLEMATIS LIGUSTICIFOLIA. The pistils in this species are even more elongated than in Anemone, and have the cavity correspondingly elongated above the ovule. Unfortunately, it was impossible to obtain the younger stages, but the close agreement of the older stages with those found in Anemone makes it practically certain that the course of development is the same. The mature ovule is situated exactly as in Myosurus and Anemone. Like the latter, however, on each side above the large ovule the lamina bears one or two rudimentary ovules which project into the space above it (*fig. 25*). The only dif-

[2] BAILLON: Mémoire sur la famille des Renonculacées. Adansonia 4:50. 1864.

ference between this and *Anemone Caroliniana* is that the ovules are further developed, some of them in fact having embryo sacs with two or four nuclei. Guignard describes[3] and figures these accessory ovules in *Clematis cirrhosa* with embryo sacs containing two and four nuclei, showing conclusively their ovular nature. Some species of Anemone, too, have these accessory ovules developed to this extent, showing that in this there is no distinction between the two genera.

DELPHINIUM CAROLINIANUM. Owing to the ease with which the material could be obtained, this species was the one chiefly used in the study of the multiovulate type of pistil. *Caltha leptosepala* was used to corroborate the results obtained from the study of this species. It was evident from figures and descriptions of the pistils of this type, published elsewhere, that these two species give us typical examples, and it was accordingly decided that it would be unnecessary to make careful study of other species. Unfortunately it was impossible to obtain specimens of those genera with biovulate pistils, forming perhaps the transition from the uniovulate to the multiovulate genera. The pistils arise at the top of the nearly hemispherical receptacle. The stamens develop acropetally. The pistils do not show any signs of appearing until all the stamens have begun to develop. Each pistil first appears as a small conical papilla with rounded apex, and increases in size very rapidly. As this increase in size progresses, the ventral side begins to be hollowed out, until by the time that the pistil is a millimeter in height, and a little narrower than high, it has become closed by the meeting of the laminae (*figs. 27, 28*). Soon the ovules begin to make their appearance as small papillae on the inturned edges of the carpellary leaf. These increase rapidly in number and size until the edges of the laminae of the pistil are occupied entirely by horizontally growing ovules (*fig. 29*). In Delphinium the ovules arise opposite to each other, but later, owing to the crowding due to their growth in size, they become alter-

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[3] GUIGNARD, LEON: Récherches sur le sac embryonnaire des phanérogames angiospermes. Ann. Sci. Nat. Bot. VI. **13**: 163. *pl. 5.* 1882.

nate. The lowest ovule, having no ovule below to sustain it, may descend into the hollow at the bottom of the pistil.

In *Caltha leptosepala* the ovules are mostly alternate, and are fewer in number than in the pistils of Delphinium, the difference being apparently compensated by the greater number of pistils in the former. The only other difference worthy of mention is that the ovules of Caltha are two-coated, while those of Delphinium have only one integument (*fig. 31*).

ALISMACEÆ.

The two genera studied were Sagittaria and Alisma. These are in the main, alike so far as the development of the pistils is cerned, for the slight differences that do occur are easily explicable by the difference in number of the pistils, involving their relations to each other and to the receptacle. Thus in *Alisma Plantago aquatica* L. there is but a single whorl of pistils, while in *Sagittaria latifolia* Willd. the ovules are very numerous and arranged spirally over the whole surface of the receptacle.

SAGITTARIA LATIFOLIA. In this plant, as in Myosurus, the pistils are developed acropetally. Each pistil makes its appearance as a papilla on the side or summit of the spherical receptacle. As this papilla enlarges it grows so as to leave a hollow on the upper side. In its axil there now appears a second papilla, which grows out into the space between the laminae of the pistil, which has now become somewhat curved. As these laminae increase in width they surround the ovule entirely except the very slightly developed "axillary placenta." As a result of this the ovule appears to arise from the floor of the pistil, as indeed some descriptions aver (*figs. 33–35*). While the pistil has been thus developing, the ovule has not remained unchanged. It has increased in length, and about half way from base to apex makes a sudden turn, at which place the two integuments arise. The ovule continues to bend upon the funiculus until by the time that the integuments have reached the apex of the nucellus the latter lies parallel to the surface of the receptacle, with its apex pointed away from the apex of the receptacle (*fig.*

36). Within a very short time the position of the ovule becomes permanent, with the apex of the nucellus directed towards the receptacle (*fig. 37*). Subsequent changes are mostly those in size and such modifications of shape as are caused by the pressure of the surrounding pistils.

ALISMA PLANTAGO AQUATICA. In the very young flowers of this species the receptacle is much broader above than below, and has a rounded top. It is from the narrower basal part that the stamens arise, while the pistils are produced at the edge where the receptacle is widest. They appear as projections, at first small, later larger (*fig. 38*). This gives the receptacle, viewed from above, the appearance of a toothed wheel. The receptacle grows rapidly in height, as do the apex and sides of each pistil, thus forming a hollow in the upper side of each (*fig. 39*). Into this rapidly deepening cavity, there pushes out from the receptacle a rounded mass of cells (*fig. 40*). The apical part of the pistil grows very rapidly until the laminae connecting it with the receptacle at each side of the ovular outgrowth are in such a position that their edges are nearly vertical. The ovule continues to elongate and curve towards the bottom of the pistil, eventually gaining a position in which its apex is directed downwards. During this process the nucellus has become differentiated and the two integuments have appeared. The funiculus has also been clearly distinguished (*figs. 41, 42, 43*). Up to the time of fertilization there has been no organic connection between the edges of the two laminae, although for a little while they have been in contact for a part of their distance. At the time of pollination there is still an opening between the laminae at the bottom of the line of meeting. This is due to the fact that the laminae arise with enough distance between them to allow for the formation of the ovule. Now, when their margins approach each other they are separated furthest at the bottom and require a longer time to come fully together (*fig. 44*). In the mature pistil the funiculus is long and ascending, carrying the ovule well up into the cavity of the pistil. In the young pistil the funiculus is short, and it is only as the pistil grows that the funiculus also increases in length.

ROSACEÆ.

This family contains representatives of many types of flower-structure. Of these types the Potentilleæ have been regarded hitherto as the simplest. In this tribe the pistils are very numerous, on a rounded receptacle, which is expanded below into a shallow cup, on whose edge are borne the numerous free stamens, the petals and the sepals. In Fragaria and Potentilla each pistil is uniovulate, while in Geum it is biovulate. As a rule throughout the family the pistils are biovulate, and in some genera even multiovulate. The only genera studied as representatives of this family were Potentilla and Fragaria, it being the aim to determine whether the remarkable similarity that these show to Ranunculus is also found in the processes of development of the parts of the flower.

POTENTILLA MONSPELIENSIS L. The pistils first appear, as in Ranunculus, as small papillae on the surface of the pistil-bearing part of the receptacle. The first to appear are at the base and the others arise successively towards the top of the receptacle (*fig. 45*). As the pistils enlarge they become hollowed out above. A comparatively small opening is produced on the upper side of the pistil (*fig. 46*), which is made still narrower by the thickening of the edges of the laminae for about half the distance from base to apex. This thickening is sometimes accompanied by a more active growth in width of that part of each lamina, so that viewed from the side it appears as a rounded lobe, as shown in *fig. 47*, where the dotted line shows the more usual form. From one of these thickened edges or lobes a small papilla begins to grow inward and downward, later turning upward again. This is the ovule. It is at first lateral in its position, but the lamina to which it is attached grows more rapidly than the part opposite, so that the ovule finally occupies a median position (*fig. 48*). The ovule, when the pistil is ready for pollination, is anatropous, with the funiculus on the ventral side of the pistil, instead of on the dorsal as in Myosurus. The ovule has but a single integument, and in the large size of its nucellus, as well as in its position in the pistil, much resembles that of Ranunculus (*fig. 50*).

FRAGARIA VIRGINIANA. The development of the pistil in this species is practically identical with that in the preceding. The only important difference is that the line in which the laminae meet is shorter, so that the style arises from well down on the front of the pistil. In this species is also found what probably indicates an advance in development beyond that shown in Potentilla, namely, quite often a pistil contains two ovules instead of one. This doubling is acomplished by the formation of one ovule on each of the thickened laminae, instead of on one only. Possibly this is the way in which the uniovulate genera, like Potentilla, have developed into the typical biovulate genera of the family (*figs. 51–53*).

GENERAL DISCUSSION.

A comparison of the structures exhibited by the pistil in these three families shows that each family includes genera with uniovulate as well as those with multiovulate pistils, and that the course of development of the uniovulate pistils is very similar in the three families, although in Potentilla and Fragaria it has been somewhat modified.

It has been shown above that in Ranunculus the first sign of the ovule is the growth of a mass of cells in the axil of the developing carpel. The carpel elongates and becomes hollowed above by the upward growth of the laminae, which do not grow up over the axillary mass of cells, but rather extend from it on each side to the apex of the carpel. By the elongation of the distal part of the axillary body the ovule is formed, and curves down into the cavity of the pistil, while the proximal part remains in its original position, growing only in height and thickness. The laminae which extend from this body (called above the "axillary placenta") to the apex of the carpel, now approach each other at their edges, and meet in the median line, thus completely closing the cavity of the pistil. The suture along which the laminae meet is like an inverted Y, for before they close they are separated at the bottom by the axillary placenta (see *fig. 19, R. eremogenes*).

If we now compare with this the conditions found in Potentilla and Fragaria, we see the following modifications. There is no axillary mass of cells developed, for the ovules have their origin on the edge of one or the other lamina. Probably this originated as follows: in some plant whose ovules were borne as in Ranunculus, and in which the suture along which the laminae met formed an inverted Y, a variation appeared by which the axillary placenta lost its median position, one arm of the suture becoming elongated and the other shortened. This resulted in a placenta attached to one lamina and free from the other, which is precisely what we find in Potentilla. Even in Ranunculus it occasionally occurs that the axillary placenta is not strictly median but slightly shifted to one side or the other. This suggests that the mode of origin indicated above is not improbable.

In the uniovulate pistils of Fragaria as well as of Potentilla the ovule is borne sometimes on one lamina and sometimes on the other, being very variable in this respect. Under such conditions when neither lamina is especially modified for the production of ovules it is probable that sometimes an ovule might be borne on each lamina, as happens in Fragaria. It seems probable that it was by such a variation that the majority of the genera of the Rosaceæ became biovulate. When once each lamina began to be ovuliferous it would be but a short step to the condition in which several ovules are borne, instead of only one. In this way the multiovulate pistils may have arisen. Probably in this way, too, the multiovulate Ranunculaceæ were developed from the uniovulate Ranunculus, possibly through a biovulate form close to Callianthemum, or even Hydrastis.

From the description of their development as given above it must be evident that Sagittaria and Alisma are quite similar to Ranunculus. Of these two genera, however, Alisma is much less like Ranunculus than is Sagittaria, for the ovule is hardly axillary with respect to the carpel, but arises from the receptacle, in this respect much resembling the origin of the sporangium of Selaginella. The condition found in Sagittaria is one about midway between that in Alisma and that in Ranunculus. In the latter the axillary placenta is in reality only an outgrowth from the receptacle, and this prepares us to find (as in the Alismaceæ) the ovule developed directly from the receptacle. In other cases, as in Potentilla, this axillary placenta loses its individuality by fusion with one of the laminæ of the carpel.

The presence of the accessory ovules in Anemone, Pulsatilla, Clematis, and other genera is difficult to explain. If it were not for the peculiar origin of the one ovule which reaches maturity, it might naturally be supposed that Anemone is descended from plants with multiovulate pistils. However, if this were the case it would be necessary to consider also that Ranunculus and Myosurus had a similar origin, which seems highly improbable in consideration of their close resemblance to the Alismaceæ, which show in other characters no signs of having had Anemone-like ancestors. Furthermore, there are no existing multiovulate Ranunculaceæ that seem to be as simple in other respects as Ranunculus, for their pistils are fewer in number and close much earlier, an evident unsimilarity to the theoretical pteridophytic ancestors of the angiosperms. Perhaps the best solution of the problem is the supposition that some plant of the Ranunculus or Myosurus type after the development of its first ovule varied so as to develop in the space above the ovule one or more accessory ovules which were unable to reach maturity. These accessory ovules being in the unoccupied upper part of the pistil out of the way of the large ovule, and yet protected by the carpel wall, would have no part in the struggle of the plant for existence, and so might persist. This would be the more likely to be true if this modification happened to occur in a plant which, owing to other modifications, was enabled to maintain itself against all enemies, and to be well distributed. This seems to have been the case here, for these accessory ovules are found in those genera in which the ripe achenes are furnished with hairs to aid in their distribution. Evidently under such circumstances, where they occupy a neutral position they would persist although not yet functional.

The uniovulate types might be summed up as follows. These all represent a type of pistil in which an axillary structure appears, developing directly into the ovule in some cases, or in others forming an axillary placenta on which the ovule is borne, or in still others uniting with one lamina of the pistil and bearing at its summit an ovule.

The multiovulate types are not sufficiently different to require discussion beyond the statement that they are probably developed from a modification of the last mentioned case among the uniovulate pistils.

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EXPLANATION OF PLATE XXV.

NOTE.— All the figures were drawn by the author, by means of the camera lucida, with one or two exceptions, from sections 7 to 18μ in thickness, cut upon a Reinhold-Giltay microtome. Some of the material was fixed with 1 per cent. chromic acid solution, some in various platinic chloride mixtures, and the remainder in various osmic acid mixtures, imbedded in paraffin, sectioned, and mounted in Canada balsam. All sections were stained on the slide, many different stains being used. The sections were examined by means of Reichert's objective 8, and oculars 2 and 4. In making the drawings only the outer layer of cells or merely the outline is given.

When not otherwise stated all sections called "longitudinal" are median longitudinal sections.

The magnifications given are those of the drawings, which were reduced one-half in engraving.

Ranunculus abortivus L.

FIG. 1. Longitudinal section of a very young pistil. × 565.

FIG. 2. Cross section of a slightly older pistil. × 565.

FIG. 3. Longitudinal section of a pistil showing the axillary mass of cells. × 565.

FIG. 4. Cross section of a pistil from the same flower as *fig. 3*, in the line *a–a*. × 565.

FIG. 5. Longitudinal section of a pistil at the time of formation of the archesporium. × 565.

FIG. 6. Cross section of a pistil in the same flower as *fig. 5*, in the line *b–b*. × 565.

FIG. 7. Longitudinal section of a pistil at the time of formation of the four megaspores. × 224.

FIG. 8. Longitudinal section of fully developed pistil. × 250.

Ranunculus eremogenes Greene.

FIG. 9. Longitudinal section of two very young pistils. × 565.

FIG. 10. Longitudinal section of the ovule during the formation of the four megaspores. × 565.

Myosurus minimus L.

FIG. 11. Longitudinal section of a very young pistil. × 565.

FIG. 12. Cross section of apical part of a pistil from the same flower as *fig. 11*. × 565.

FIG. 13. Cross section of the basal part of a pistil from the same flower. × 565.

FIG. 14. Longitudinal section of a pistil at the time of the appearance of the archesporium. × 565.

FIG. 15. Longitudinal section of a pistil at a later stage than in the preceding figure. × 265.

FIG. 16. Longitudinal section of a pistil approaching maturity, but with the embryo-sac not far developed as yet. × 250.

FIG. 17. Longitudinal section of a pistil a little older. × 205.

FIG. 18. Longitudinal section of a mature pistil. × 125.

Ranunculus eremogenes Greene.

FIG. 19. Longitudinal ventral section of a pistil showing the formation of the suture shaped like an inverted Y. × 250.

Anemone cylindrica Gray.

FIG. 20. Longitudinal section of a young pistil, showing the beginning of the formation of the axillary body. × 540.

FIG. 21. Longitudinal section of the pistil at the time of the formation of the archesporium. × 535.

Anemone Caroliniana Walt.

FIG. 22. Longitudinal section of a pistil at the time of formation of the archesporium. × 250.

FIG. 23. Longitudinal section of a pistil with the embryo sac developed about halfway. × 120.

FIG. 24. Section of a pistil from the same flower as the preceding, in the line *c–c*. × 122.

Clematis ligusticifolia Nutt.

FIG. 25. Longitudinal section of a mature pistil, showing the accessory ovules. × 75.

Anemone Caroliniana Walt.

FIG. 26. Longitudinal ventral section showing the formation of the inverted Y-shaped suture. × 120.

Delphinium Carolinianum Walt..

FIG. 27. Longitudinal ventral section of a pistil before the appearance of the ovules. × 125.

FIG. 28. Cross section, in the line *d–d*, of a slightly older pistil, but with as yet no ovules. × 125.

FIG. 29. Cross section of a pistil showing ovules. × 75.

FIG. 30. Longitudinal ventral section of a pistil. × 75.

Caltha leptosepala DC.

FIG. 31. Cross section of a pistil ready for pollination. × 75.

Sagittaria latifolia Willd.

FIG. 32. Longitudinal section of an ovule with two archesporial cells. × 520.

FIG. 33. Longitudinal section of a pistil showing a single archesporial cell. × 540.

FIG. 34. Cross section of a pistil in the line *e–e* of *fig. 33*. × 525.

FIG. 35. Longitudinal section of a pistil a little further developed than the preceding. × 410.

FIG. 36. Longitudinal section of a pistil with an embryo sac containing two nuclei. × 155.

FIG. 37. Longitudinal section of a pistil ready for pollination. × 75.

Alisma Plantago aquatica L.

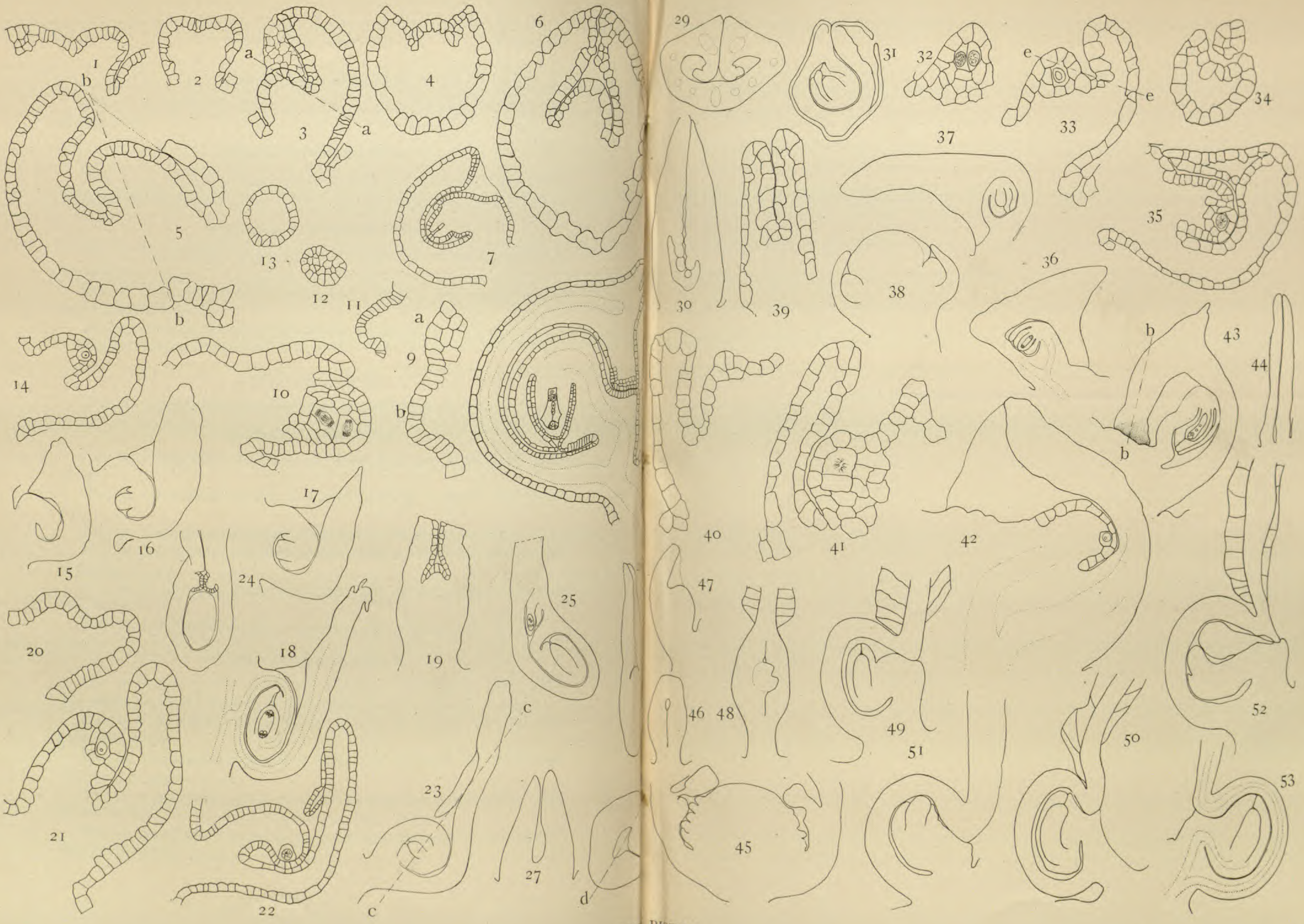
FIG. 38. Longitudinal section of a young flower showing the young pistil. The dotted line shows the level of the surface of the receptacle. × 155.

FIG. 39. Longitudinal ventral section of a pistil slightly older than the preceding. × 555.

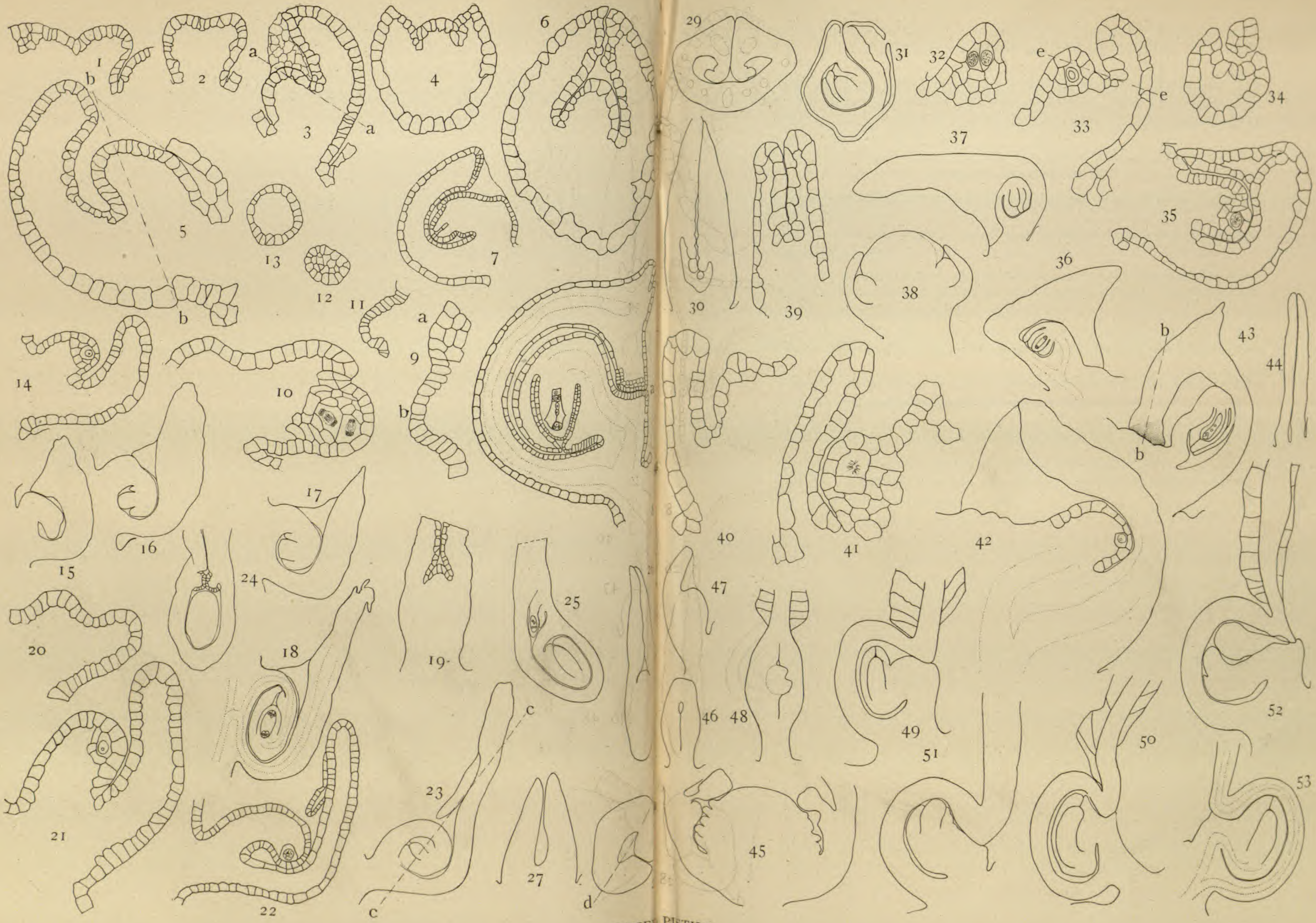
FIG. 40. Longitudinal section of a young pistil in which the ovule is just beginning to appear. × 545.

FIG. 41. Longitudinal section of a pistil showing the archesporium. The section is slightly to one side of the median plane. × 555.

FIG. 42. Longitudinal section of a pistil at a further stage of development than the preceding. × 400.



BESS PISTILS



BESSEY PISTILS

FIG. 43. Longitudinal section of a pistil at the time of pollination. The shaded portion represents the part where the laminae have not yet met. × 75.

FIG. 44. Longitudinal ventral section of a pistil from the same flower as *fig. 43*, in the line *b–b*. × 125.

Potentilla Monspeliensis L.

FIG. 45. Longitudinal section through a young flower showing the developing pistils. × 145.

FIG. 46. Ventral view of a pistil from the flower shown in *fig. 45*, showing the opening. × 330.

FIG. 47. Lateral view of a pistil from the same flower, showing the lobe-like growth of the part of the lamina which bears the ovule. The dotted line shows the normal development. × 445.

FIG. 48. Ventral view of a pistil showing the excessive growth of the lamina which bears the ovule. The dotted line outlines the attachment of the ovule. × 255.

FIG. 49. Longitudinal section of a pistil shortly before pollination. × 255.

FIG. 50. Longitudinal section of a mature pistil. × 150.

Fragaria Virginiana Duchesne.

FIG. 51. Longitudinal section of a half-grown pistil. × 210.

FIG. 52. Longitudinal section of a pistil of about the same age as the preceding, but showing two ovules. × 295.

FIG. 53. Longitudinal section of a pistil ready for pollination. × 175.

THE EMBRYOLOGY OF ALYSSUM.[1]

LUMINA COTTON RIDDLE.

13

(WITH PLATES XXVI–XXVIII)

THE following study of *Alyssum macrocarpum* was begun late in October when a large and thrifty plant was brought into the greenhouse. Cuttings were made which began blooming about the holidays and a constant supply of material was thus furnished.

My original intention was to study *Capsella bursa-pastoris* and to verify or modify the account of its embryonic development, since Capsella has usually been taken as a type for the dicotyls. While Hanstein's method of studying the embryo by squeezing it from the ovule and staining with iodine might appear incapable of yielding any results of a detailed character, it seems nevertheless in his hands to have given rather accurate results.

The close relationship of Alyssum to Capsella, and the resemblance in embryonic development, which was evident from the first comparison with Hanstein's familiar figures, became a constant stimulus to careful and accurate investigation. While I am not wholly positive as to the invariability in the formation of certain portions of the young embryo plant, the most of my work points to a certain definite course of development, though there are sometimes remarkable variations.

My sincere thanks are due to Professor W. A. Kellerman and Mr. J. H. Schaffner for their continued encouragement and valuable suggestions.

METHODS.

Greenhouse plants did not seed profusely, probably because there were no insects present to assist in pollination. Before killing the material, the sepals, petals and stamens were removed,

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[1] Contributions from the Botanical Laboratory of Ohio State University. V.

except from very young buds, to insure rapid penetration. Chrom-acetic acid, and a solution of corrosive sublimate, acetic acid, and 70 per cent. alcohol were the two fluids used. For general purposes the first seemed preferable, though satisfactory results were obtained from both.

The material was imbedded in paraffin and cut into sections 12 μ thick. It was difficult to orient the ovaries so as to get sections parallel to the plane of the embryo sac, since the ovule of Alyssum is campylotropous and the embryo sac soon becomes curved like a horseshoe nearly parallel to the septum of the silicle.

Anilin-safranin, alone or in combination with gentian violet, and sometimes with a third, orange gentian, was used in staining. Acid fuchsin and iron-alum-hæmatoxylin were also employed. The latter was very useful in bringing out early stages of the embryo sac, but it was not so good after endosperm was present. Combinations with anilin-safranin were most satisfactory for general purposes.

A Bausch & Lomb microscope with $\frac{2}{3}$, $\frac{1}{8}$ and $\frac{1}{12}$ objectives, and 2 and 1 inch oculars, was used, and drawings were made with the aid of a Bausch & Lomb camera.

DEVELOPMENT OF MACROSPORES AND EMBRYO SAC.

The archesporial cell (*fig. 1*) is hypodermal in origin and can be recognized in the nucellus before the two outer integuments have entirely surrounded it. The nucleus of the archesporial cell is larger than those in other cells and the contents are more granular. By a transverse division a tapetal cell (*fig. 2, t*) is cut off, and this apparently undergoes no further division. The macrospore mother cell, however, divides into four cells, three potential macrospores (*fig. 2, p*) and a vital macrospore (*fig. 2, m*), which is the lowest of the series and develops into the embryo sac, destroying the entire nucellus in its growth (*figs. 2–12*).

The two-celled embryo sac (*fig. 3*) is nearly straight, with nuclei at opposite extremities and a well marked vacuole in the center. The embryo sac increases in width in the four-celled stage (*figs. 4, 5*), and when it has reached the eight-celled stage it has a decided curvature (*fig. 6*). Many of the eight-celled embryo-sacs were destroyed or rendered worthless for camera drawings because they were cut and scattered through too many sections. The one figured has been sectioned so as to cut off the antipodals. It is probable that one is looking at them from above rather than in side view, as the rest of the figure appears. During the last divisions of the embryo sac the tapetal cell disappears (*figs. 5, 6*).

Up to this point the nuclei are uniform in size, but after the conjugation of the polar nuclei the definitive nucleus is easily distinguished by reason of its superior size, the presence of numerous refractive particles in its large nucleolus, and the readiness with which it stains. The presence of refractive bodies is not peculiar to the nucleolus of the definitive nucleus alone, but is found in less degree in the endosperm nuclei and in the large nucleus of the basal suspensor cell. It may also be true of other nuclei, but is not noticeable on account of the diminutive size.

After the definitive nucleus is formed, the egg apparatus (*figs. 7–9*) is readily distinguished, but in the majority of cases the antipodals have entirely disappeared. They are either absorbed or destroyed by the progress of the embryo sac in its encroachment upon the lower part of the nucellus, crushing and crumpling them out of shape. In many cases the lower part of the nucellus is contorted and pushed aside by the advance of the embryo sac, indicating a remarkable degree of force exerted from within (*fig. 12*). Where remains of antipodals were found, that end of the embryo sac had evidently slipped between the nucellus and its integuments and had not been subjected to the usual ordeal (*figs. 35–36*).

The oosphere is well concealed by the synergids (*figs. 8, 9*) until after fertilization, when its nucleus descends into the lower part and the oospore (*fig. 10*) begins to elongate rapidly (*figs. 11, 12*). Up to this time the definitive nucleus remains undivided, but after fertilization takes place endosperm is formed very rapidly and is especially abundant around the proembryo, obscuring it and making it difficult to distinguish the early stages of embryonic development if the section was cut diagonally.

DEVELOPMENT OF THE EMBRYO.

The first division in the proembryo is transverse and cuts off a basal suspensor cell which does not divide again (*fig. 13, a*). The cell at the end divides very soon into a terminal cell, a true embryo cell (*figs. 13, 14, c*) and an intermediate cell (*figs. 13, 14, b*). The terminal embryo cell divides by a longitudinal wall into two cells (*fig. 15, c*), and the two following longitudinal divisions at right angles to the first cut it into quadrants (*fig. 16, c*). The third division is a series of transverse walls in the cells of the quadrant and produces an octant (*fig. 17, c*).

The dermatogen is the first tissue to be differentiated and is cut off from the octant by a series of periclinal and anticlinal walls (*figs. 18, 19*). Division in the cells of the octant is evidently almost simultaneous, for I could find no instance where any one seemed to have priority in the process. The terminal embryo cell is now represented by two well developed tiers of cells (*figs. 19, 20, c, d*). In each tier, while the dermatogen divides radially, the inner cells undergo a longitudinal division.

Meanwhile the intermediate cell (*fig. 14, b*) has been dividing by a series of transverse walls, and in the cell next those derived from the terminal embryo cell (*fig. 19, e*), the wall has become somewhat rounded. This cell divides, first into two and then into four cells by longitudinal walls, making a quadrant. These divisions and the transverse divisions which follow and form the octant correspond to those which take place in the terminal embryo cell, and, since this cell develops into the lower part of the embryo, I shall henceforth refer to it as the basal embryo cell. The whole embryo is therefore developed from two original cells, a terminal embryo cell and a basal embryo cell, both of which first form quadrants by longitudinal walls, and subsequently octants by a series of transverse walls in each of the quadrants. *Fig. 27* represents a peculiar variation or abnormality in the development of the region of the basal embryo cell.

To the inner cells of the tier *d*, *fig. 20*, one can refer the origin of plerome and periblem, the central cells forming the plerome and the single layer between this and the dermatogen giving rise to the periblem.

The transverse division begun in the dermatogen has extended throughout this tier *d* (*fig. 21*), and is followed by another radial division in the dermatogen, while a longitudinal division occurs in the innermost cells of tier *c* (*fig. 24*). A series of longitudinal walls also begins to appear in tier *d*, followed by irregular transverse divisions (*fig. 25*). The entire embryo is now developing rapidly. The basal embryo cell has undergone the third and transverse division, forming two tiers of four cells each next the suspensor (*fig. 25*, *f* and *g*).. In the region where the cotyledons arise, diagonal division has occurred, while in the region of the stem tip it has been longitudinal. The plerome is quite distinct and is shaded in the figure.

A more advanced stage is shown in *fig. 28*. The cotyledons develop more rapidly and the embryo becomes obcordate (*figs. 29–31*). The plate of cells nearest the suspensor undergoes a series of transverse divisions as well as longitudinal ones. This division extends to some of the adjoining dermatogen cells (*fig. 30*), and gives rise to the calyptrogen, which becomes continuous with the dermatogen and by successive transverse divisions cuts off the root cap. The inner plate, by longitudinal divisions, contributes to that part of the root tip from which the periblem of the radicle is developed (*fig. 33*, *f*, *g*). Beyond this stage it is impossible to get central sections through the entire embryo. The cotyledons fold together and curve upward toward the antipodal region (*fig. 34*), and in the mature state the embryo fills the entire cavity of the embryo sac.

THE SUSPENSOR.

The basal suspensor cell never divides after the first transverse division of the oospore. The intermediate cell contributes toward the suspensor by a series of transverse divisions, which at first apparently occur in acropetal order (*fig. 15*), but later stages seem to indicate intercalary division (*figs. 22, 23*). The number of cells is variable, some large embryos having only eight- or nine-celled suspensors, while in others the number of cells reaches fifteen. In a few cases, instead of the normal transverse division in the suspensor cells, a longitudinal division occurs, giving a peculiar abnormal appearance (*figs. 22, 26*, and *27*).

The function of the suspensor seems to be that of an absorbing organ, supplying nourishment to the rapidly growing embryo and serving the purpose of the root in mature plants. When stained with anilin-safranin or its combinations, the suspensor and the cells arising from the basal embryo cell stained much less deeply than those derived from the terminal embryo cell. This was of great advantage in clearly determining the origin of calyptrogen, root cap, and root tip.

The suspensor persists until the embryo is mature, although it becomes shriveled and apparently functionless some time before the resting period of the embryo is attained.

ENDOSPERM.

The definitive nucleus divides immediately after the formation of the oospore. The endosperm accumulates very rapidly in the region of the proembryo and often obscures it, especially in the early stages. Early in my work I concluded that endosperm was formed previous to fertilization, because I frequently found it when I could not distinguish any embryo. But later research showed that endosperm was not present until after the proembryo appeared; and, whenever found, remains of a badly sectioned embryo were evident. Several instances in which unfertilized oospheres were found in the same silicle with well developed embryos showed the definitive nucleus distinct and undivided in the shriveled embryo sac, and an entire absence of endosperm.

The endosperm forms a complete lining for the embryo sac (*fig. 12*), and then, passing through the well-known radiations, forms cell walls. Some of the free cells accumulate in the antipodal region and form a peculiar thallus-like mass, which further assists in obscuring whatever remains of the antipodals might otherwise be found (*figs. 35–39*). This growth was for some time a puzzle as to its origin, whether the result of division of the antipodals, or a growth of endosperm arising from the first division of the definitive nucleus and cut off by a cell wall from other endosperm, as is the case in Sagittaria.[2] All doubt was dispelled when the remains of the antipodals were found (*figs. 35, 36*) while this thallus-like growth was in early stages of development. In many cases the appearance was so peculiar and the connection with all other endosperm so obscured, while the entire mass stained so similarly to the embryo, that it might easily deceive one as to its nature. Its function is not clearly evident, unless it may be considered as a reserve of food material after the suspensor ceases to supply nourishment.

COMPARISON WITH OTHER DICOTYLS.

Chamberlain[3] says the archesporial cell in Salix divides into a tapetal cell which sometimes gives rise to a tier of five or six cells but occasionally does not divide; and a macrospore mother cell which may or may not divide. If it does there is a potential macrospore which sometimes divides and a vital macrospore which develops without further preliminary division into the embryo sac.

In *Aster Novae Angliae*[4] he reports that after the expected division resulting in four cells, the lowest usually develops into the embryo sac.

Coulter[5] says of *Ranunculus multifidus:* "In no case was a primary tapetal cell cut off, the archesporial cell dividing directly into mother cells." Alyssum might therefore be considered more primitive in this respect than any of these except Salix, which shows a very unsettled state of affairs.

In the development of the embryo of Alyssum there is much

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[2] Schaffner, Bot. Gaz. 23: 252–273. 1897.

[3] Bot. Gaz. 23: 147–179. 1897.

[4] Bot. Gaz. 20: 205–212. 1895.

[5] Bot. Gaz. 25: 73–88. 1898.

more regularity than in that of any other dicotyledonous embryo yet studied. Capsella is undoubtedly quite symmetrical and Alyssum comes very close to it in many respects. I regret that it was not possible for me to make comparisons directly with Hanstein's text and figures, as there is so much variation in the illustrations and reprints given in text-books.

In Vines's *Text-book of Botany*, p. 443, the terminal embryo cell is figured as dividing first transversely, then longitudinally, while the text reverses this. In Goebel's *Outlines*, p. 397, the figures represent the first division as longitudinal, the second as transverse, while the text gives the first and second as longitudinal and the transverse divisions as a third series. This corresponds to Alyssum. In Sachs's *Text-book*, p. 516, 1875, the figure is the same as in Goebel's, but in the text the third series of divisions is given as tangential and cutting off the dermatogen from the quadrants. Whether this statement is due to faulty translation or is so in the original German edition, I cannot say. It does not agree, however, with the German edition of 1882, for there it is distinctly stated in the text that the first three series of divisions are in three directions at right angles to each other, although in the explanation of *fig. 446, I–IV*, he gives the second series of divisions as transverse, and does not figure or mention the second longitudinal division.

Confusion likewise exists with regard to that portion of the embryo of Capsella which Hanstein designates as the "hypophysis." Its origin is uncertain. It is thought to arise from the last division of the suspensor cell; *i. e.*, the cell which gives rise to the greater part of the embryo remains dormant after the first division in the proembryo, while the suspensor cell continues to divide. The last cell arising thus contributes to the embryo. Chamberlain[6] doubts the accuracy of this theory, but thinks it probable that the terminal cell in which the first longitudinal division appears is wholly embryonic, while there may be a varying number of cells in the suspensors formed before this division occurs. This agrees with Alyssum. Hanstein's

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[6] BOT. GAZ. 23: 147–179. 1897.

"hypophysis," whatever its origin, has fallen into much the same confusion as the terminal embryo cell. While the majority of text-books give its first division as transverse, followed by longitudinal divisions, the figures and texts disagree as to the subsequent development of its tissue. In Goebel's *Outlines*, while the text describes the plate of cells, *h*, of *fig. 326*, as dividing to form calyptrogen and root cap, in the figure itself *h'* is divided instead of *h*. In Sach's *Text-book, h'* is so figured and the text corresponds.

It is unfortunate that such confusion exists in the embryology of Capsella, and however careful and accurate Hanstein's original work may have been, he is either ambiguous in his statements or he has been mistranslated. It seems quite probable that Capsella is very close to Alyssum in its embryonic development and the many resemblances existing between some of the stages shown in my drawings and those of Hanstein seem to lead one to the conclusion that their embryology is very similar. Perhaps a re-investigation of Capsella would show its development to be the same.

SUMMARY.

1. The hypodermal archesporial cell divides into a tapetal cell and a macrospore mother cell which gives rise to four macrospores, three potential macrospores and a vital macrospore, the lowest of the series, which develops into the embryo sac.

2. The embryo sac passes through the usual cell divisions, increasing in size and becoming much curved, until the entire nucellus is destroyed.

3. The antipodals are ephemeral, disappearing during the early stages of embryonic development.

4. The endosperm appears soon after the fertilization of the oosphere.

5. The first division of the proembryo is transverse and the basal suspensor cell never divides afterward.

6. The end cell divides into the intermediate cell which contributes both to suspensor and embryo, and a terminal embryo cell.

7. The first and second series of divisions in the terminal embryo cell are longitudinal and form a quadrant. The octant is formed by a series of transverse divisions.

8. The first three series of divisions in the basal embryo cell correspond to those of the terminal embryo cell, also giving rise to an octant.

9. The dermatogen is the first tissue which is differentiated and is cut off by tangential walls in the cells of the octants.

10. The plerome and periblem arise in the basal hemisphere of the terminal embryo cells; the cotyledons and stem tip from the terminal hemisphere.

11. The calyptrogen and root cap are formed from the basal hemisphere of the basal suspensor cell, while that part of the root tip which forms the periblem of the radicle arises from the hemisphere lying next to the terminal embryo cells.

12. The number of cells in the suspensor varies from six to fifteen. The number beyond six apparently depends upon the number of intercalary divisions, some of which may be longitudinal.

13. The endosperm lines the entire embryo sac with a single layer of cells, but is more abundant around the young embryo and forms a peculiar growth in the antipodal region.

COLUMBUS, OHIO.

EXPLANATION OF PLATES XXVI–XXVIII.

Drawings reduced to three-eighths; the magnification given with each figure refers to the original magnification before reduction.

PLATE XXVI.

FIG. 1. Nucellus and integuments; archesporial cells. ×1060.

FIG. 2. Nucellus with tapetal cell, *t;* potential macrospores, *p;* and vital macrospore, *m.* ×1060.

FIG. 3. Two-celled embryo sac; tapetal cell, *t.* ×1060.

FIGS. 4–5. Four-celled embryo sac. ×1060.

FIG. 6. Eight-celled embryo sac. ×1060.

FIG. 7. Seven-celled embryo sac. ×1060.

FIG. 8. Egg apparatus and definitive nucleus. ×580.

FIGS. 9 and 9a. Embryo sac before fertilization; antipodals, *a.* ×1060.

FIG. 10. Embryo sac after fertilization; oospore, *o*; synergids, *s*. ×1060.

FIG. 11. One-celled proembryo; pollen tube, *p t;* synergid, *s;* a peculiar endosperm nucleus, *end. nu.* ×1060.

FIG. 12. Embyo sac showing relative size of proembryo and the distribution of endosperm. ×1060.

PLATE XXVII.

FIG. 13. Three-celled proembryo; basal suspensor cell, *a;* intermediate cell, *b;* terminal embryo cell, *c*. ×1060.

FIG. 14. Same, farther advanced. ×1060.

FIG. 15. First longitudinal division of the terminal embryo cell, *c*. ×1060.

FIG. 16. Second longitudinal division of *c*. ×1060.

FIG. 17. Octant stage, two nuclei cut away in sectioning; intermediate cell, *b* much divided. ×580.

FIG. 18. Embryo with dermatogen. ×580.

FIG. 19. Same, with more cells in suspensor. ×580.

FIG. 20. Embryo showing remains of pollen tube, *p t;* basal embryo cell, *e;* the terminal embryo cell is divided into two distinct tiers, *c* and *d*. ×580.

FIG. 21. Embryo showing a series of transverse divisions in tier *d*, and two longitudinal divisions in basal embryo cell, *e*. ×580.

FIG. 22. Suspensor which seems to indicate intercalary division. ×1060.

FIG. 23. Abnormal suspensor in which intercalary division has been longitudinal instead of transverse; plerome shaded. ×1060.

FIG. 24. More advanced embryo showing longitudinal division in plerome. ×1060.

FIG. 25. Transverse division following the longitudinal; basal embryo cell divided into two tiers, *f* and *g*. ×580.

FIGS. 26 and 27. Embryos from same silicle, showing abnormal suspensor and basal embryo cell. Shaded and light areas show difference in staining where triple staining was used. ×1060.

FIG. 28. Embryo having four tiers in plerome and two in the region where the stem tip and cotyledons originate. ×580.

PLATE XXVIII.

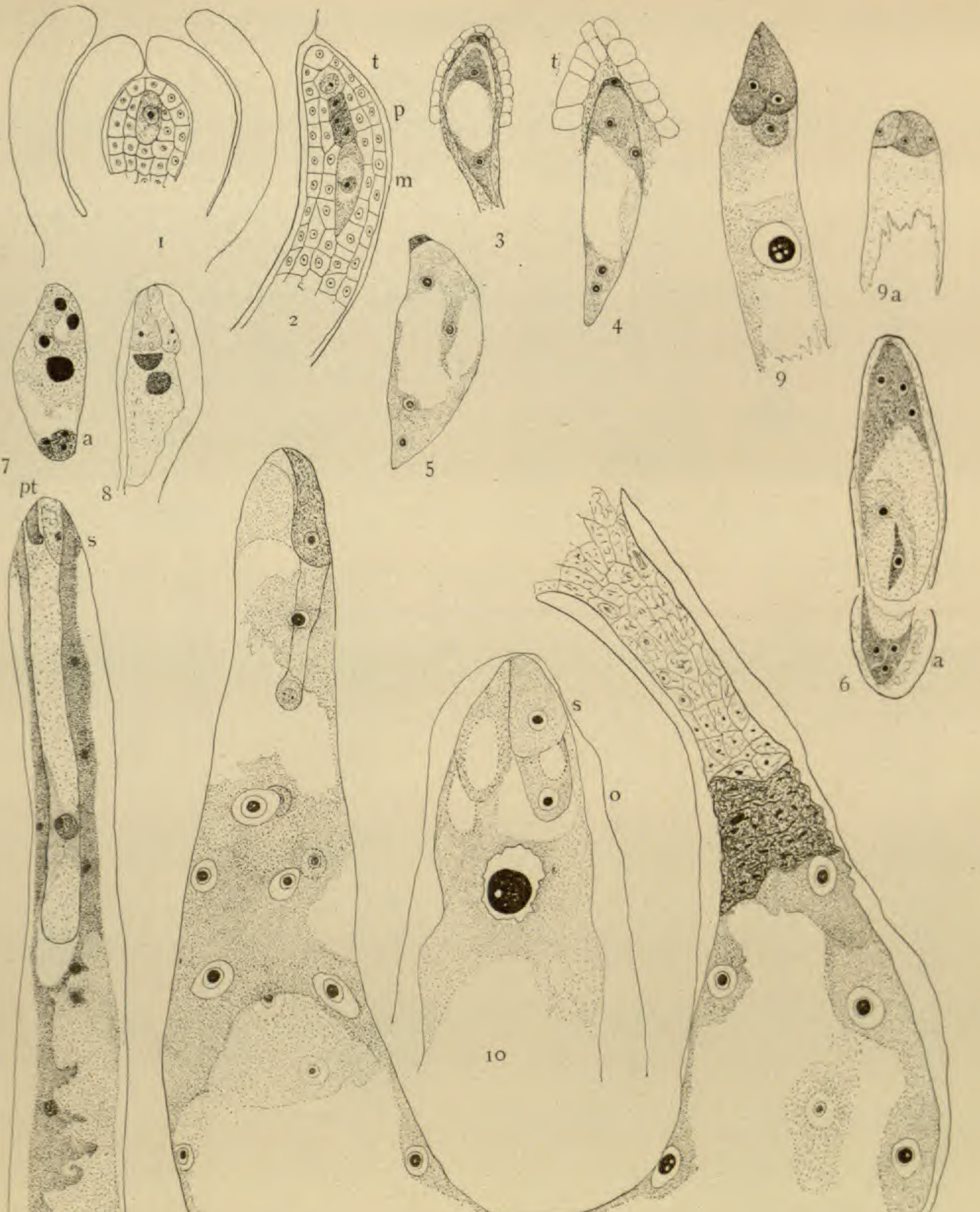
FIG. 29. Embryo with four tiers in plerome; a series of longitudinal walls appearing in the inner tier; three rows in region of cotyledons. ×1060.

FIGS. 30–32. Large embryos showing development of calyptrogen, root cap and root tip. ×580.

FIG. 33. Section through root tip, showing plerome, periblem, dermatogen, calyptrogen, and root cap. ×590.

FIG. 34. Nearly mature embryo showing suspensor still persisting. ×90.

FIGS. 35–39. Antipodal end of embryo sac, showing antipodals disappearing and endosperm forming thallus-like growth. *Figs. 35–38*, × 1060; *fig. 39*. × 590.



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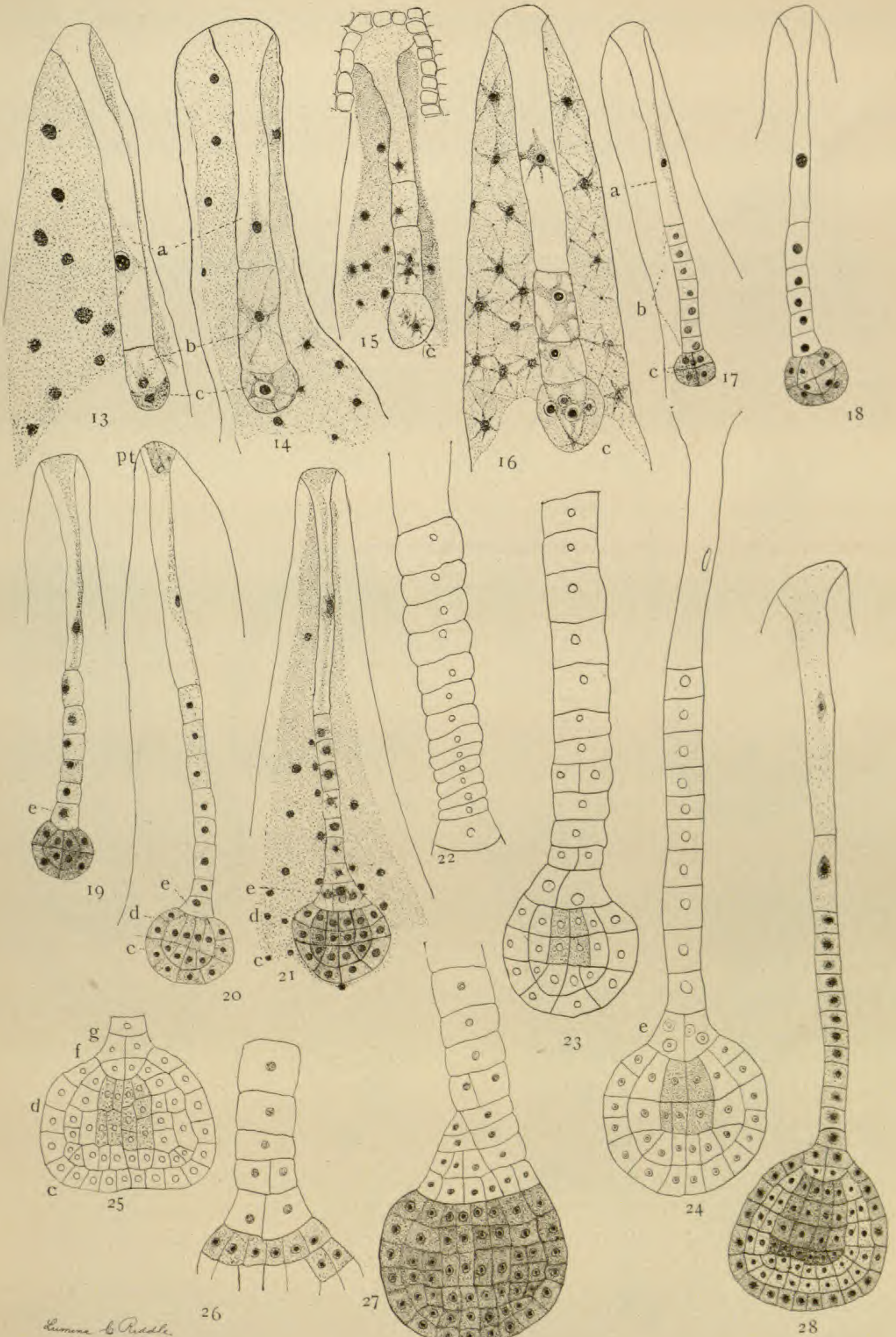
RIDDLE on ALYSSUM



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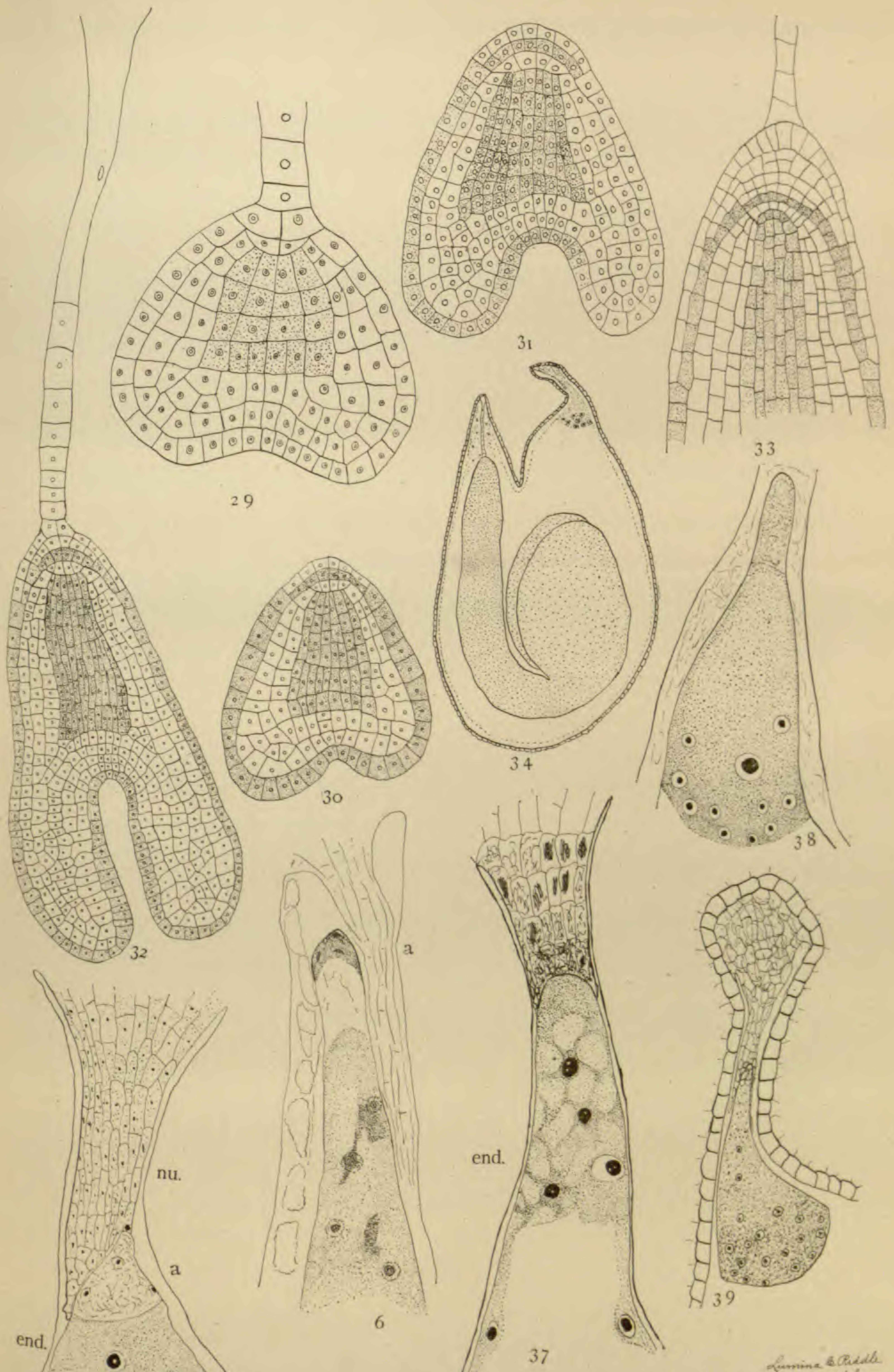

RIDDLE on ALYSSUM

FURTHER OBSERVATIONS ON THE EASTERN ACAULESCENT VIOLETS.[1]

CHARLES LOUIS POLLARD.

IN a paper published two years ago in the *Proceedings* of the Biological Society of Washington,[2] I presented a tentative revision of the purple-flowered, stemless violets found in the northeastern United States. Since that time I have been engaged in field study of the genus in New Jersey, Pennsylvania, the District of Columbia, and Virginia, a territory from which the larger proportion of early types was obtained. The excellent library of Professor E. L. Greene, of the Catholic University, has been kindly placed at my disposal, and the opportunity thus afforded of studying the unpublished colored drawings of Le Conte, illustrative of the latter's well-known monograph of the genus, has been of great value in clearing up doubtful determinations. The herbarium of the Philadelphia Academy of Sciences, containing specimens ticketed by Nuttall, Schweinitz, and Darlington, has also afforded material assistance. Many friends and correspondents, to whom I am deeply indebted, have aided me with living and dried plants.

In the paper above referred to nine species and one variety were enumerated among the purple-flowered, acaulescent class. As a result of subsequent study this number must be increased at least twofold, and Professor Greene's investigations have shown that the violets of Canada and the Great Lake region are as yet but imperfectly understood. Mr. Macoun's observations during the past season, communicated to Professor Greene, have enriched the genus by five species, all natives of Canada; and I doubt not that similar results would follow an exploration of the southern portions of British Columbia.

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[1] Published by permission of the Secretary of the Smithsonian Institution.

[2] 10: 85–92. 1896.

Before discussing certain species in detail it may be well to outline briefly the characters upon which we must depend for any thorough understanding of this genus. At the outset I wish to emphasize the importance of unremitting field work, and the absolute uselessness of herbarium material unless one is fortified by previous familiarity with the growing plant. It should not be forgotten that the value of a herbarium for purposes of systematic research lies in the advantage thereby gained of having material convenient for morphological and histological study, and not in that it provides in any sense a proper substitute for the living individuals. Habit as well as habitat, the texture of the herbage, color of the flowers, position of the cleistogenes, nervation, shape and degrees of pubescence of the leaves, nature of the surrounding vegetation; all these will be taken into consideration by the careful ionologist, and they are each best derived from outdoor investigation. Moreover we should not be content with superficial glances at occasional plants. A large number of individuals should be observed, and every feature of their environment noted; then it will be impossible for any discriminating botanist to make a comment such as I recently heard, that *Viola ovata* is "nothing but a hairy *sagittata* with ovate leaves, growing in dry ground."

In recognizing the variability of leaf-outline often presented by a single individual, there is a tendency to misapprehend or to overlook the fact that in all of the heterophyllous violets the earliest leaves are practically uniform and similar in all the species, and as they are immediately succeeded by others of a totally different type, should never be taken into account in critical diagnoses. Thus the first leaf of *V. sagittata* is cordate-reniform, obtuse and crenate, exactly like the corresponding organ of *V. palmata;* yet in the one case the characteristic foliage has lanceolate, sagittate and glabrous blades, and in the other broadly cordate, pubescent and more or less lobed blades. I am not aware that anyone has ever proposed to unite these two species on account of the similarity of their primitive leaves, and yet my attention has frequently been called to these example of early vernal foliage as an illustration of so-called "intergrading characters." Indeed in a recent important volume dealing with systematic botany in this country the statement is made in a footnote that "the contour of the leaf, varying upon the same individual from reniform to ovate and acute, affords no satisfactory distinction." Such a remarkable variation can scarcely be manifest to the ordinary observer unless the characterless primitive foliage is taken into consideration. With equal consistency and discrimination we might attempt to compare the various species of Ipomoea upon the basis of their remarkably uniform bilobed cotyledons. In two or three of our eastern violets leaf-contour, with respect to the mature foliage, plays an important part in differentiating the species. If it were not for the trigonous outline of the leaf of *V. emarginata*, for example, that species might by those unfamiliar with the habits of violets be confused with *V. sagittata;* but the elongated lanceolate blade of the latter cannot fail to render it distinct to any observer.

In the subjoined key I have followed the primary division of Dr. Gray and other authorities, separating *V. pedata* as a distinct class on account of the characters found in the rootstock and stigma. The remaining divisions are somewhat arbitrary, as I fully realize the futility of constructing any key in the hope that it will afford conclusive determinations of every unusual form. To the larger divisions have been given group names, partly for the sake of convenience, and partly in order to make clear the affinities of each species. A knowledge of these primary groups is often indispensable in determining a violet of doubtful relationship. The key includes all the acaulescent species east of the Mississippi now known to me, with the exception of the Canadian forms recently described by Professor Greene.[3] In the notes following the key are mentioned only those species deserving special comment.

SECTION I.

Leaves and flowering scapes directly from a short, erect caudex; plants not stoloniferous; cleistogamous apetalous flowers apparently wanting; petals beardless, blue; stigma large, not rostrate.

CLASS 1. **Pedatæ.** . 1. *V. pedata*

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[3] Pitt. 3:333 *et seq.*

SECTION II.

Leaves and scapes from a horizontal or ascending, often multicipital rootstock; plants not stoloniferous (except in CLASS 5), but bearing numerous cleistogamous apetalous flowers; petals more or less bearded, purple; stigma small, rostrate.

CLASS 2. **Heterophyllæ.** Leaves on the same individual entire or variously lobed, from cordate-ovate to reniform in general outline; scapes of the cleistogamous flowers deflexed or ascending, not erect (except in *V. Brittoniana*).

- Plants always more or less pubescent 4. *V. palmata* and *vars.*
- Plants comparatively glabrous, or at most with pubescent petiole.
  - Western campestrine species.
    - Leaves divided almost to base with narrowly linear lobes 2. *V. pedatifida*
    - Leaves parted scarcely to the middle with rather broad lobes 3. *V. Bernardi*
  - Eastern coastal plain species.
    - Southern; leaves very irregularly lobed and incised.
      - Plant succulent 7. *V. esculenta*
      - Plant not succulent 8. *V. insignis*
    - Northern; leaves symmetrically lobed.
      - Leaves large, pedately 5-7-parted to base 6. *V. septemloba*
      - Leaves with a large median lobe and pinnately arranged lateral lobes 5. *V. Brittoniana*

CLASS 3. **Communes.** Leaves on the same individual similar or nearly so, rarely pubescent (except in *villosa*), in general outline cordate-ovate; scapes of the cleistogamous flowers either erect or deflexed.

- Woodland species;[4] peduncles of the cleistogenes deflexed.
  - Plants small (less than 1^{dm} high).
    - Leaves reniform-orbicular, silvery-hirsute above 15. *V. villosa*
    - Leaves deltoid-triangular, apparently glabrous above 16. *V. Langloisii*
  - Plants large (more than 1^{dm} high).
    - Leaves broadly asariform; cleistogenes hypogaeous in fruit 10. *V. domestica*
    - Leaves usually broadly cordate; cleistogenes not hypogaeous.
      - Keel-petal cuspidate; leaves hirsutulous 11. *V. cuspidata*
      - Keel-petal not cuspidate; leaves glabrate 9. *V. communis*
- Bog-meadow species; peduncles of the cleistogenes strictly erect.
  - Leaves markedly cucullate 13. *V. cucullata*

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[4] By this expression is meant all dry or merely moist shaded localities as distinguished from open, sunny bog-meadows and partially shaded water courses. The position of the cleistogenes in nos. 11, 14, and 16 is uncertain.

- Leaves scarcely at all cucullate.
    - Leaves yellowish-green, prominently veined, obtuse 14. *V. affinis*
    - Leaves bright green, not prominently veined, acute 12. *V. obliqua*

CLASS 4. **Sagittatæ.** Leaves all similar, ovate-sagittate or ovate-lanceolate in general outline; entire or slightly lobed; peduncles of the cleistogamous flowers strictly erect; flowers dark purple.

- Plants distinctly villous-hirsute.
    - Spur of the corolla saccate-dilated; leaves with a deep sinus 21. *V. Carolina*
    - Spur of the corolla not conspicuous; leaves with a shallow sinus or none 20. *V. ovata*
- Plants glabrate or only ciliate.
    - Leaves elongated-oval, of nearly similar diameter throughout; basal lobes conspicuous 17. *V. sagittata*
    - Leaves ovate-triangular, nearly equilateral, the base truncate, not often lobed; petals emarginate 18. *V. emarginata*
    - Leaves elongated-ovate, tapering to apex, slightly dentate at base 19. *V. dentata*

CLASS 5. **Odoratæ.** Plants stoloniferous; leaves reniform-cordate; flowers purple.

- Rootstock thickened, scaly; plant introduced 22. *V. odorata*
- Rootstock filiform; species native, far northern.
    - Leaves hirsute-pubescent, crenate 23. *V. Selkirkii*
    - Leaves glabrous, crenulate 24. *V. palustris*

SECTION III.

Leaves variable in outline; plants mostly stoloniferous from filiform rootstocks; spur short and saccate; stigma short, pointed; petals yellow or white, usually veined with purple; position of the cleistogenes various.

CLASS 6. **Blandæ.** Corolla white.

- Leaves from ovate to orbicular; cleistogenes deflexed.
    - Leaves reniform, pubescent 29. *V. renifolia*
    - Leaves cordate-ovate, glabrate.
        - Petioles red-spotted; leaves pale beneath 30. *V. amoena*
        - Petioles not red-spotted; leaves green beneath 28. *V. blanda*
- Leaves from ovate-lanceolate to narrowly linear; cleistogenes erect.
    - Leaves linear or linear-lanceolate.
        - Blade and petiole coalescent 25. *V. vittata*
        - Blade and petiole distinct, of nearly equal length 26. *V. lanceolata*
    - Leaves ovate-lanceolate, the blade decurrent 27. *V. primulaefolia*

CLASS 7. **Orbiculares.** Corolla yellow ; cleistogenes deflexed
31. *V. rotundifolia*

VIOLA PEDATA L. Sp. Pl. 933. 1753.

V. digitata Pursh, Fl. Am. Sept. 1: 171. 1812.
V. pedata bicolor Bursh, *fide* Raf. in DC. Prodr. 1: 291. 1824.
V. pedata inornata Greene, Pitt. 3: 35. 1896.

This, the common bird's-foot violet, appears, as is well known, in two forms, in one of which the petals are pale blue and concolorous, in the other the uppermost petals deep velvety-purple. It is the latter form, so long known as the variety *bicolor*, which is figured by Plukenet, and on which Linnaeus based his type. Between these two extremes one finds in Maryland and Virginia every possible variation. Professor Greene considered the *pedata* of New England, which is usually the concolorous form, distinct from this variable southern plant, and bestowed on it the varietal name *inornata*. I have not been able to find characters upon which to base such a separation.

VIOLA BERNARDI Greene, Pitt. 3: 260. 1898. As synonym.

V. pedatifida var. *Bernardi* Greene, l. c.

Professor Greene applies this name to a violet very familiar to me from a specimen in my own herbarium, collected in Wisconsin by Professor S. M. Tracy some years ago, which has since passed into the possession of the National Herbarium. The plant was so remarkable that Dr. Britton originally considered it distinct, and gave it a manuscript name. In the states of Michigan, Wisconsin, and northern Illinois it seems to be the prevailing form, and apparently entirely replaces *V. palmata.* Recently specimens have come to me from Chicago collected by Dr. Moffatt, which in addition to Dr. Greene's material show the plant to be a species intermediate between the PEDATÆ and the HETEROPHYLLÆ, having the foliage and aspect of the former, together with the rootstock and variable leaf-contour of the latter. I have been unable to discover cleistogamous flowers upon the material thus far examined.

VIOLA PALMATA L. Sp. Pl. 933, 1753.

V. palmata var. α *vulgaris* Ell. Bot. S. C. & Ga. 1: 300. 1817.
V. palmata var. β *fragrans* Ell., l. c.
V. cucullata var. *palmata* A. Gray, Man. 78. 1867. [Ed. 5.]

Concerning this species there is a substantial agreement among the early authorities. Mr. Edmund G. Baker in a recent issue of the British *Journal of Botany* discusses the Linnæan type, which was based upon a poorly drawn figure of Plukenet; this might indeed stand for any of the HETEROPHYLLÆ, but Mr. Baker points out that both of Plukenet's specimens are pubescent and adds that the figure in Britton and Brown's *Flora* fairly matches the types, although these have leaves slightly less lobed. The true *palmata*, then, is a plant of rich woodlands, usually distinctly pubescent, with rather dark purple flowers, and leaves exhibiting a great diversity of lobation. I recognize in addition two well-known varieties, both of which are referable to older authorities, and abundantly represented in most herbaria.

VIOLA PALMATA DILATATA Ell., l. c.

V. triloba Schwein., Am. Journ. Sci. 5: 57. 1822.
V. congener Le Conte, Ann. N. Y. Lyc. 2: 140. 1828.

The leaves in this variety are uniformly three-lobed, though occasionally some of them will be found nearly entire, as often happens in the type. The lobes vary in shape, and are frequently dentate or incised, but the central one is constantly the largest. In the District of Columbia this is the prevailing form; indeed the range of *palmata* and its varieties is so strongly marked as almost to warrant a separation of *dilatata* and the type as two distinct species. *V. palmata* in its typical form I have not seen south of Harpers Ferry, except in the Blue Ridge mountains. In the lowlands it seems to be entirely replaced by *dilatata*. Schweinitz argues very strongly in favor of the specific identity of *V. triloba*, as he called it, and in all probability he had observed the difference in range between the two. The character of Elliott's description, and the habitat cited for his plant, leave little doubt as to its identity.

VIOLA PALMATA SORORIA (Willd).

V. sororia Willd. Enum. 263. 1809.
V. asarifolia Pursh, Fl. Am. Sept. Suppl. 732. 1814.
V. villosa var. *β cordifolia* Nutt. Gen. 148. 1818.

Dr. Britton has recognized this species in the *Illustrated Flora* and is still inclined to maintain it, but I fail to perceive in *sororia*, if the name be correctly applied, which is somewhat doubtful, anything more than an entire-leaved state of *V. palmata*. This variety seems remarkably distinct in its early vernal stage, but I have seen individuals put forth occasional lobed leaves, and it is not uncommon for specimens of *palmata* in cultivation to develop large, asariform, unlobed leaves late in the season, and in this condition they are absolutely undistinguishable from typical *sororia*. Among the early writers Pursh and Schweinitz were the only two that retained *sororia* in specific rank. Nuttall named it as a variety of *villosa*, which it somewhat suggests in habit.

Viola Brittoniana, nom. nov.

V. Atlantica Britton, Bull. Torr. Club **24**: 92. 1897; not *V. Atlantica* Pomel, Nouv. Mat. Fl. Atlant. 215. 1874.

The specific designation originally assigned to this plant being clearly a homonym under all accepted rules, it is with great pleasure that I have associated Dr. Britton's name with it, the type coming from a region in which he has long lived and worked. It is essentially a maritime species, ranging practically the entire length of the Atlantic seaboard. Although I have not seen specimens from the Atlantic coast below Virginia Beach, it certainly occurs on the Gulf coast near Mobile, and probably at intermediate stations. It is a succulent, glabrous plant, exhibiting a fondness for saline soils. I have often had misgiving as to whether it might not, after all, be the true *septemloba* of Le Conte; but that is both described and figured as having flowers nearly two inches in diameter, and the cut of the leaves is also different. The plant is thriving in cultivation at the New York Botanical Garden, and when examined during the latter part of the past summer was found to possess erect cleistogenes. This furnishes us with a connecting link between the two groups of SAGITTATÆ and HETEROPHYLLÆ. Dr. Robinson has recently kindly communicated to me specimens of a violet discovered near Boston by Mr. H. A. Purdie which I consider undoubtedly referable to this species, although there is astonishing diversity in the lobation of the leaves.

VIOLA SEPTEMLOBA Le Conte, Ann. N. Y. Lyc. **2**: 141. 1828.

I have applied this name, although with some hesitation, to a rather local violet which at once attracts attention on account of its ample, flabelliform, and deeply divided leaves, which attain in late summer an enormous development. Le Conte remarks on the great length of the peduncles and the large size of the flower, features which I have noticed in the plants obtained about Washington. He assigns it to "Carolina and Georgia, in pine barrens only," and this habitat again agrees with my observations. Finally there is a plant in the herbarium of the Philadelphia Academy of Sciences, labeled, I believe, in Darlington's handwriting "*V. septemloba*."

VIOLA ESCULENTA Ell., l. c., as synonym.

V. heterophylla Muhl. Cat. 25. 1813; not Poiret nor Bertol.
V. palmata var. δ *heterophylla* Ell., l. c.

I have not seen Elliott's type of this species, and am dependent upon a colored drawing of Le Conte's, and a specimen from Louisiana which Professor Greene has seen in the herbarium of Dr. Mohr. The leaves are wonderfully diversified in outline and lobation after the manner of the following species, but it is stated by Elliott that the whole plant is extremely succulent, and is used by the negroes as a pot-herb. In the National Herbarium is a specimen from Elmira, New York, which would seem to match these characters, but I should hesitate to call it *V. esculenta* without having seen individuals from intermediate stations. The habitat of this violet is given as swamps, and in this preference it is distinct from all other members of the HETEROPHYLLÆ

Viola insignis, n. sp.

Acaulescent, glabrous, 2–5^{dm} high: stipules linear-acuminate, slightly ciliate; leaves long-petioled, the early ones cordate-ovate, the later broadly trigonous, with truncate base and very obtuse apex, variously 3–5 lobed, the central lobe largest; margins obscurely crenate, denticulate or nearly entire; venation distinctly palmate: flowering peduncle usually bibracteate, not surpassing the foliage: flower very large (4^{cm} in diameter), deep purple, the petals oblong, and of nearly equal size; lateral petals conspicuously bearded with glistening white hairs; spur short; sepals narrowly lanceolate and acuminate: capsule and apetalous flowers not observed.

Dry pine barrens, northern Florida. Types in U. S. National Herbarium, Curtiss no. 4518a, Jacksonville; A. Fredholm no. 425, Duval county. I would also refer here Nash's specimen from Eustis, no. 203, the leaves of which exhibit a form of lobation akin to that in *Brittoniana*, a pinnate arrangement of small lateral lobes on either side of a large central one; in this case, however, the two posterior lateral lobes are decidedly runcinate, as shown in the detached leaf shown in the accompanying figure. The species is the sole representative of the HETEROPHYLLÆ in Florida, so far as I have observed; and although from the illustration it may appear to resemble *palmata* it is most conspicuously distinct from that species.

Apparently all the members of the HETEROPHYLLÆ (with the exception of *V. Brittoniana*) produce their cleistogamous apetalous flowers on horizontal, or at most ascending, peduncles. The tendency of the ripening capsule is to seek the surface of the ground where it sooner or later becomes partially buried. In the matter of pubescence the species are divided, *palmata* exhibiting nearly constant pubescence, while the remaining species are glabrous or only sparsely hairy. The term glabrous must be used in a comparative sense where violets are concerned, since there is rarely a case in which traces of pubescence or ciliation cannot be found. With respect to leaf-variation it will also be noted that the primitive leaves in nearly every species are alike, and differ widely from the mature foliage.

VIOLA INSIGNIS, *n. sp.*

In the species of the next class, the COMMUNES, lobed leaves are rare exceptions. The position of the cleistogamous flowering peduncles is horizontal in the woodland species, and strictly erect in those growing in bogs or swamps. The physiological reasons for this are not clearly understood ; but it is hoped that a series of experiments to be undertaken next season may shed light on the matter.

Viola communis, nom. nov.

V. obliqua and *V. cucullata* of recent authors ; not of Hill nor of Aiton.

This, the commonest of our eastern violets, is separable from the below-mentioned segregates by the following combination of characters : Plant very stout, at flowering time low, but in late summer attaining a height of from eight to twelve inches ; herbage bright dark green : leaves quite glabrous, cordate to reniform, more or less cucullate, very regularly crenate and distinctly obtuse at apex ; nervation pinnate, with several additional primary nerves from base ; stipules broad and foliaceous, laciniate : flowers deep purple, borne on peduncles almost invariably shorter than the petioles ; cleistogamous flowers on horizontal peduncles, the oblong, scarcely angled capsules ripening on or beneath the surface of the ground.—Inhabits various situations, but prefers rich, moist soil in open places. I have emphasized these well-known characters in order that they may be borne in mind in comparison with the species discussed below, and I shall attempt to show that neither the *cucullata* of Aiton nor the *obliqua* of Hill can be regarded as identical with this plant unless we follow the lead of conservative botanists and continue to treat the species as an aggregate.

VIOLA DOMESTICA Bicknell, Britton and Brown, Illust. Fl. **3**: 519. 1898.

This peculiar violet has frequently been the subject of discussion between Dr. Britton, Mr. Bicknell and myself. I had concluded to publish it as a variety when I heard that Mr. Bicknell's specific description was already in type ; and it very probably is better regarded as a species, although the strange habitat, which is invariably rich, cultivated ground in the close vicinity of dwellings, suggests that it originated as a cultivated variety. The range should have included the District of Columbia, for it is not uncommon here in congenial situations. Mr. Bicknell did not call attention to a very conspicuous peculiarity of the cleistogenes, namely, the tendency to bury themselves deep in the ground instead of remaining close to the surface. The leaves attain enormous proportions, frequently attaining a breadth of eight inches.

VIOLA CUSPIDATA Greene, Pitt. 3:314. 1898.

I have seen only young flowering specimens of this plant in cultivation at the Catholic University. Professor Greene considers it allied to *palmata*, but aside from the pubescence, the characters are those of the COMMUNES. It is a native of the Lake region and of Canada.

VIOLA OBLIQUA Hill, Hort. Kew. 316. *pl. 12.* 1769. Not of Aiton nor of Pursh.

In assigning Hill's name and figure to a certain slender plant of wet rills and shaded rocks, with glabrous foliage, narrowly ovate, cordate and acute leaves, I believe we can be certain both of matching the type and finding ourselves in general agreement with the botanists of the early part of this century. It is fully as likely that this little plant may have been discovered by some collector and sent to Kew as the hedgerow species which I have called *communis*, especially since the latter does not properly agree with Hill's figure.

VIOLA CUCULLATA Ait., Hort. Kew. 3:288. 1789.

Professor Greene was the first to separate this species from the *communis-obliqua* aggregate, and additional observations have amply justified his conclusions. Dr. Britton has included the plant in the appendix to the *Illustrated Flora*, and there seems no doubt that it is the original *cucullata*. It is remarkable for the very pale blue flowers and light green foliage, which does not thrive in late summer like that of other members of the COMMUNES, but often collapses so that it is difficult to secure specimens showing thc erect cleistogenes. The leaves are broader than long, with margins only slightly crenate or denticulate, the apex obtuse, and all or most of them cucullate. In *obliqua*, on the other hand, they are rather longer than broad, with sinuate-crenate margins and scarcely at all cucullate. Both species grow in moist soil, and both produce erect cleistogenes, very different, it will be observed, from *V. communis*. I think I have now shown the specific differences existing between the latter and its allies. There remain only two other names which could be possibly taken up for *communis;* one of these is *V. papilionacea* of Pursh, which I have seen figured by Le Conte, and which is totally different from any violet now known to us; the other is *V. affinis* Le Conte, discussed below.

VIOLA AFFINIS Le Conte, l. c. p. 138.

In an issue of *Pittonia*[5] which has just come to hand. Professor Greene makes the following statement concerning *V. affinis:* "This fine species, common enough in most woodlands of the District of Columbia and adjacent Maryland, was identified by me to my own satisfaction by Le Conte's excellent description, nearly two years since." Inasmuch as the description referred to is exceedingly brief and the characterization of the foliage as "foliis ovatis subacuminatis, crenato-dentatis" might be applied with equal propriety to many other violets, it is difficult to understand the grounds for Professor Greene's preemption of the name *affinis* for a species "common in most woodlands of the District of Columbia." It has always seemed to me that Le Conte himself places a very effectual obstacle in the way of our understanding when he observes at the close of his description "Nimis praecedenti affinis; nullos characteres distinctivos praeter pedunculi brevitatem et latiora calycis sepala invenire

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[5] 3:337.

possum." In the light of this declaration I had always considered *V. affinis* a synonym of *V. cucullata*, the "preceding species" referred to by Le Conte. Nevertheless, having since examined the latter's colored drawing of *V. affinis*, I am inclined to agree with Professor Greene that the species is a distinct one, but I would refer to it a plant which to the best of my knowledge does not grow in the District of Columbia, but is of northward distribution. It is an inhabitant of shaded wet rocks, and has pale bluish-purple flowers ("basi albidis" as Le Conte says), and yellowish-green leaves shaped more like those of *ovata* ("foliis ovatis cordatis") than like those of most violets belonging to the COMMUNES.

VIOLA VILLOSA Walt. Fl. Car. 219. 1788.

V. cucullata var. *cordata* Gray, Man. 78. 1867. [Ed. 5.]
V. palmata var. *villosa* Robinson in Gray, Syn. Fl. N. Am. 1: 196. 1895.

In spite of the undivided foliage of this plant it suggests the HETEROPHYLLÆ more than the COMMUNES. Happily there is no difference of opinion of the applicability of the name, although the latter is not well chosen as the leaves are hirsute rather than villous. The flowers show more of a reddish tinge than those of any other violet with which I am familiar.

VIOLA SAGITTATA Ait. Hort. Kew. 3: 287. 1789.

This species was thoroughly well known and understood until it was made a general receptacle for other species of the same group. It was never characterized as "polymorphous" by either Elliott, Schweinitz or Le Conte, although in recent years it has been a stumbling block for many a student of the Violaceæ. As a matter of fact there is no violet more constant or unvarying either in foliage or habitat. It may be recognized by the very dark purple flowers, distinctly sagittate, narrowly oval, usually glabrous leaves, the petioles of which always exceed the flowering scapes. It chooses wet, springy spots along brooks as its favorite location, although it is frequently found in moist meadows.

VIOLA SAGITTATA SUBSAGITTATA (Greene).

V. subsagittata Greene, Pitt. 3 : 316–317. 1898

Professor Greene thus explains his description : "I here propose, for a new subspecies, what is known throughout a great extent of country west of Lake Michigan, as *V. sagittata*." He further states that the differences consist in the marked pubescence, the larger flowers, and the smaller dimensions of the plant. I infer from his characterization of it as a subspecies that Dr. Greene would agree with my disposal of it as a geographical variety.

VIOLA EMARGINATA (Nutt.) Le Conte, l. c. p. 142, excl. char.

V. sagittata var. *β emarginata* Nutt. Gen. 148. 1818.

It is unnecessary to add anything to the very elaborate description of this plant published, with figures, in Pittonia 3: 255, especially as Dr. Britton has also admitted the species in the Appendix to the third volume of the *Illustrated Flora*. It should be observed that although Le Conte raised Nuttall's variety to specific rank, and hence must be quoted as authority for the name, the plant which he had in mind, as shown by his figure and description was the following:

VIOLA DENTATA Pursh, Fl. Am. Sept. 1: 172. 1812.

V. Porteriana Pollard, Bull. Torr. Club 24: 404. 1897.

Misled by Le Conte's reference of Pursh's *dentata* to *emarginata*, I redescribed this imposing violet last year, after abundant specimens had been secured on an excursion of the Torrey Club to Bushkill, Pa. While its relationship is with *V. ovata*, I do not think the two plants can readily be mistaken for each other, and there is the further fact to be noted that *dentata* is a species of high altitudinal distribution, all the material that I have examined having been collected either in the mountains of eastern Pennsylvania or the Blue ridge in Virginia.

VIOLA OVATA Nutt., l. c. p. 148.

V. primulifolia Pursh, Fl. Am. Sept. 1 : 173. 1812; not *V. primulaefolia* L. 1753.

V. ciliata Muhl. Cat. 26. 1813, without synonymy or description.
V. sagittata var. *β ovata* T. & G. Fl. N. Am. **1** : 138. 1838.

In the typical form, as shown by contemporaneous collections in the herbarium of the Philadelphia Academy of Sciences, the leaves are oval rather than ovate, tapering somewhat at base as well as apex.

VIOLA OVATA HICKSII Pollard, Proc. Biol. Soc. Wash. **10**:92. 1896.

V. sagittata Hicksii Pollard, Bot. Gaz. **20** : 326. 1895.

Leaves distinctly deltoid-ovate, rather truncate at base. The prevailing form in the District of Columbia.

VIOLA CAROLINA Greene, Pitt. **3**:259. 1898.

I have not yet seen material of this species aside from the type sheet in Professor Greene's collection. It is apparently quite distinct from other members of the group in the south.

VIOLA ODORATA L. Sp. Pl. 934. 1753.

V. Thompsonæ Chapm. Fl. S. States 34. 1897. [ed. 3.]

A specimen of this violet was sent to the National Herbarium by Mrs. Thompson at the same time that it was placed in Dr. Chapman's hands, and was immediately recognized as *V. odorata*, a familiar escape in the north, but evidently not hitherto reported from the southern states.

VIOLA VITTATA Greene, Pitt. **3** :258. 1898.

This replaces *lanceolata* throughout the extreme southern states. The leaves are unlike those of any other violet in that they are so short-petioled as to appear almost sessile; hence when they have attained full dimensions they bear a strong resemblance to the fronds of *Vittaria lineata* as the describer of the species has already observed.

VIOLA PRIMULÆFOLIA L. l. c.

A somewhat variable species. I have ventured to segregate as a variety the southern material as follows :

VIOLA PRIMULÆFOLIA **australis,** n. var.

Leaves much larger and thicker, decurrent on the reddish-tinged petiole; flowers larger than in the type ($1-1.5^{cm}$ broad, odorless. Throughout the southern states. Type in the National Herbarium, A. Fredholm, no. 431, Duval county, Florida.

VIOLA AMŒNA Le Conte, l. c. p. 144.

V. blanda var. *palustriformis* A. Gray, Bot. Gaz. 11. 255. 1886.

A much larger and more robust plant than *blanda*, usually more pubescent, with reddish petioles and odorless flowers. It is frequently stoloniferous, which is rarely the case in *blanda*, and prefers moist cliffs and shaded regions rather than the wet, grassy meadows in which *blanda* abounds.

WASHINGTON, D. C.

A NEW SELF-REGISTERING TRANSPIRATION MACHINE.

EDWIN BINGHAM COPELAND.

TRANSPIRATION is so important and conspicuous a function of ordinary land plants that the number of papers dealing with it, as a whole or in part, sufficed already a decade ago to justify the compilation of "the materials for a monograph." No contributor to this literature can have failed to feel the need of some device by which he could record the plant's loss of water, with such ease and accuracy as various auxanometers, for instance, make possible for its growth. Several contrivances for this work have been described, and a few have been put to actual use by their inventors; but none has as yet been well enough adapted to the purpose to bring it into general use, or make it any standard part of laboratory equipment.

Pfeffer[1] refers for such apparatus to papers by Vesque, Eder, Krutizky, Marey, and Anderson. Eder[2] measured only the absorption of water. A tracer fastened to a cork floating in a burette from which the water is drawn makes the absorption self-registering. The apparatus used for investigation by Vesque[3] was not self-registering, but was simply a glass siphon with the shoot being tested in one end, and filled to a given point in the other arm with water, and weighed; after a time it was reweighed, showing the weight of water transpired, and filled to the original level and weighed, showing the weight absorbed. Absorption and transpiration are not necessarily equivalent, for any given time-interval. Krutizky's[4] apparatus consisted of a siphon into

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[1] Pflanzenphysiologie **1** : 224. 1897. [Ed. 2.]

[2] Untersuchungen über die Ausscheidung von Wasserdampf bei den Pflanzen 106. Leipzig. 1875.

[3] L'absorption comparée directement a la transpiration. Ann. Sci. Nat. Bot., VI. **6** : 201.

[4] Beschreibung eines zur Bestimmung der von den Pflanzen aufgenommenen und verdunsteten Wassermenge dienenden Apparates. Bot. Zeit. **36** : 161.

one end of which a leaf or shoot was sealed, while the other was connected with an areometer. The water absorbed by the shoot was drawn from the areometer, which would then rise, and its rise could be recorded by a needle attached to it and traveling on a smoked cylinder. As far as I know, this apparatus has never been used at all. Pfeffer's citation of Marey is "Methode Graphique, 1st ed.," which I have not seen. In the second edition, 1885, pp. 255–258, are brief descriptions of several machines for the automatic registration of changes in weight, used in meteorology to measure rainfall, but equally adapted to use in measuring transpiration, as is illustrated by a curve obtained by Marié-Davy with one of them. Anderson's[5] plan is to collect the transpired water by means of an absorbent on a scale pan. When the balance is sufficiently disturbed, an electric circuit is closed, which drops a weight on the other pan, restores the equilibrium, and makes a record of the time.

Woods[6] has used a rain gauge to measure transpiration, the machine being set up so that the plant's loss of weight opens an electric circuit, this moves the tracing pen and also a counterweight, which closes the circuit again. A sample of the record shows the soundness of the device. Francis Darwin[7] speaks of an attempt to construct a self-registering balance by placing a spring under one pan and prolonging the knife edge as a tracer.

All of these devices except Darwin's, which was never applied to measuring transpiration, are founded on one or the other of two principles: the use of the areometer, as in the apparatus of Rédier and of Salleron, cited by Marey, and of Eder, Krutizky, and Vesque; or the imposition of counterweights at the instant demanded by the change in weight of the subject, as in the apparatus of Ragona, described by Marey, and of Anderson and Woods. They have employed both of the reliable methods of measuring the transpiration, namely, weighing the plant, and collecting and weighing the evaporated water. Eder made a

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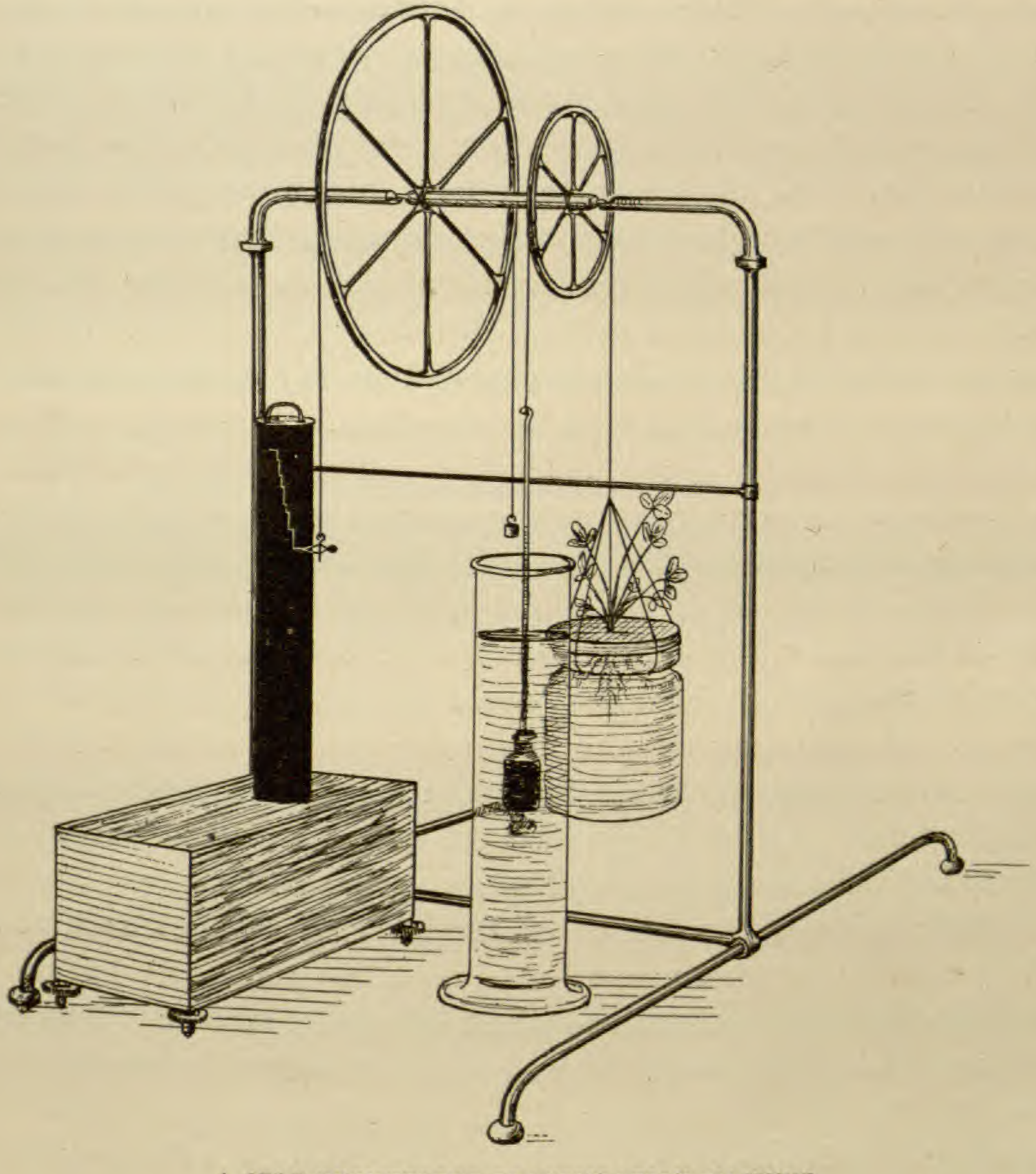
[5] Minnesota Botanical Studies **1** : 177. 1894.

[6] Recording apparatus for the study of the transpiration of plants. BOT. GAZ. **20** : 473.

[7] Annals of Bot. **7** : 461.

mistake in measuring the water absorbed, and Krutizky's apparatus is inapplicable for the same reason.

The apparatus now to be described was made for the Indiana University, from my plan, through the Cambridge Botanical Supply Company, by Professor J. C. Arthur. The cost is about $35. The frame, made of iron tubing, stands twenty-five inches high, and is fifteen inches wide. Each arm bears at the end a piece of plate glass, which must lie with its upper face exactly horizontal. Two wheels of aluminum, cut out so as to



A SELF-REGISTERING TRANSPIRATION MACHINE.

be as light as possible and perfectly centered, have a common axis, whose ends are slender cylinders, rolling on these plate-glass supports. The wheels are six and twelve inches in diameter, and absolutely true; when not loaded they are at rest anywhere on the supports. Over one of the wheels—the smaller one, as I have used the apparatus—runs a thread or string, which carries on one end the plant whose transpiration is to be tested. The other end is fastened to an areometer, weighted until it is partly submerged. For this areometer I use a bottle partly filled with mercury, with a tight-fitting cork, into which is sealed a glass rod or tube. It is convenient to use a tube, so that the load of mercury can be adjusted without disturbing the cork. For the string I used double heavy silk thread, boiled in beeswax, and rubbed until it would not stick to the wheel. It was fastened to the upper end of the glass tube, out of contact with liquid water, and altogether was pretty well protected against hygroscopic changes in length.

Now, as the plant transpires it becomes lighter, and the areömeter sinks, displacing exactly the mass of water at that end of the string which has been lost by evaporation at the other. If, for example, the area of a section of the tube be $1^{\text{sq cm}}$, it will sink 1^{cm} while the plant loses 1^{g} in weight. The larger wheel carries a thread, with a tracer which leaves its record in the same way as that of an auxanometer.

What are the limitations of the working of the machine? When it is used with proper care, there is practically but one, the inertia of the resting load which the wheel carries. Friction is practically eliminated. The axis turns more easily than would be feasible on ball bearings. The only remaining obstacle to perfect ease of movement is the surface tension of the water; but the capillarity is not very considerable even at its theoretical maximum, which is never reached, and if the tube is uniform and clean it will hardly vary as the tube descends. Jars and irregular drafts must of course be avoided.

It has been possible to put the apparatus to an unfortunately brief test. Both potted plants and water cultures were used;

the latter are rather more convenient since there is only the top of the containing vessel from which evaporation must be prevented. Several attempts were necessary before a large enough tube was used on the float; *i. e.*, the apparatus was at first set up so as to be too sensitive. A slender tube is appropriate when the intervals of time are short; but it sank so fast that it reached bottom within a few hours. The results introduced below were obtained by the use of a tube whose cross section was $5/8^{\text{sq cm}}$; one, therefore, which would sink 8^{cm} while the plant lost 5^{g}. in weight. As the areometer sank, the water it floated in rose a very little, but this is not a source of error because the water was in the same vessel when the value of a unit of movement was determined. I did not guard against evaporation from this water, as would be advisable if the clover plant instead of the apparatus were the real subject of experiment. For the same reason, the temperature and relative humidity do not concern us here. The plant was a red clover with about ten leaves, grown in soil, but transferred to water two days before the experiment began.

The data are derived from an experiment on June 15 and 16, and are given in measurements of vertical distances on the smoked cylinder, and in grams of water. Hours in light-face figures are A.M., those in bold-face figures P.M.:

Hour	Record in mm.	Weight in gm.	Hour	Record in mm.	Weight in gm.
9–10	25.6	0.800	1–2	2.9	0.091
10–11	20.3	0.635	2–3	3.7	0.116
11–12	14.6	0.456	3–4	3.5	0.109
12–1	22.3	0.697	4–5	3.9	0.122
1–2	29.5	0.922	5–6	4.6	0.144
2–3	4.0	0.125	6–7	14.2	0.444
3–4	3.8	0.119	7–8	22.9	6.716
4–5	4.0	0.125	8–9	26.6	0.831
5–6	5.9	0.184	9–10	31.1	0.972
6–7	4.2	0.131	10–11	23.0	0.719
7–8	3.9	0.122	11–12	9.9	0.309
8–9	3.7	0.116	**12–1**	8.7	0.272
9–10	3.0	0.094	**1–2**	11.9	0.372
10–11	2.7	0.084	**2–4**	15.2	0.473
11–12	2.3	0.072	**4–5**	6.3	0.197
12–1	3.0	0.094	**5–6**	5.5	0.172

In measuring the distances registered on the smoked cylinder I attempted accuracy to 0.1^{mm}, which is rather finer than is safe. I believe that the real limit to the accuracy of the results to be obtained with this apparatus lies in our ability to measure the trace. The weight on each side of the wheel in this test was only about 700^{gm}, less than would often occur in practical use. It has not been practicable to make a test with a greater load than 3.5^{kg}, with which, under proper conditions, it responds to a change of not more than 50^{mg} in either direction.

It is a merit of this apparatus that it will register equally well a decrease or an increase in weight, without any change in the setting up, except as the areometer will be set deep in the water if a continued increase is anticipated. It can be used to measure the changes in weight of fruits, etc.; and with some modification in details, the plan of the experiment is a good one for delicate and accurate measurements of the pressure of growing roots, the lifting power of prostrated grass stems, etc.

Finally, one comment on the table, introduced only as an illustration, a further discussion being reserved for a future time: the remarkable transpiratory activity during a few hours of both forenoons is not an error, nor does it seem to be an accident; for four different plants of red clover showed the same striking behavior.

MADISON, WIS.

BRIEFER ARTICLES.

THE SEEDS AND SEEDLINGS OF SOME AMENTIFERAE

(WITH PLATE XXIX)

APPARENTLY few observations have been recorded upon the seedlings of this group. Sir John Lubbock[1] briefly describes seedlings of Juglans and Pterocarya, and some representatives of the different genera of the Fagaceæ and Betulaceæ. There has been much confusion regarding the seeds of the Juglandaceæ. De Candolle[2] interpreted the parts of the embryo correctly, as did Kronfeld[3] and Lubbock, but most writers on systematic botany have misunderstood them. The seeds and seedlings studied represented the following genera: Juglans, Hicoria, Fagus, Castanea, and Quercus. Some of the seedlings were grown in moss in the greenhouse and were not subjected to frost action or cracking. Other seedlings of the same species were grown in the garden from seeds planted in the fall. *Juglans nigra* and *J. cinerea* were the only ones that would not grow in the greenhouse. They obviously required the frost action to break their shells.

JUGLANDACEÆ. As is well known, the fruit in this family is a nut, enclosed in a fleshy pericarp, endosperm is absent, and the embryo is straight. The pericarp ruptures into four valves in Hicoria and is normally indehiscent in Juglans. The wall of the nut is bony and splits into two valves on germinating. The embryo is large and fleshy, two large lobes which appear like cotyledons stand erect on a short hypocotyl. De Candolle[4] well describes the condition: "The cotyledons are always opposed to the valves of the nut, each of the chambers in the nut contains the halves of two different cotyledons." In Hicoria, the cotyledons are two-parted and intricately folded, and a lobe of one cotyledon unites with a lobe of the other by a peculiar

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[1] LUBBOCK, SIR JOHN: A contribution to our knowledge of seedlings.

[2] CANDOLLE, C. DE: Mémoire sur la famille des Juglandées.

[3] KRONFELD, M.: Beiträge zur Kenntniss der Walnuss.

[4] DE CANDOLLE, *op. cit.*

turning over of the edges (*figs. 4–8*). The cotyledons are separated for some distance near the tops of the lobes. In Juglans the cotyledons are deeply two-parted (*fig. 1*); the cotyledon in the nut being U-shaped (*fig. 3*) and their lobes united to the summit (*fig. 2*). In Hicoria the shape of the embryo varies greatly in the different species. *Hicoria glabra* and *Hicoria microcarpa*, which in this region are not sharply separated, have the embryos much alike, but in *Hicoria glabra* the division between the cotyledons is twice as deep as in *Hicoria microcarpa.*

In germinating, the seed splits from the micropyle and the tip of the radicle and the two or four basal lobes of the cotyledons push out together. The petioles of the cotyledons lengthen and carry the plumule out of the nut. The cotyledons remain in the nut and do not decrease to any appreciable extent in size, but become very rancid in taste and are filled with a yellowish oil similar to that found in the husks of walnuts and butternuts. The valves of the nut usually remain slightly connected at the hilum but often are split entirely apart, and in one specimen of *Juglans cinerea* where the nut was on the surface of the ground, the two valves had separated and lay one on each side of the stem. The cotyledons, where exposed to the light, were green and could be easily drawn from the nut.

The root of the seedling becomes greatly thickened. In one specimen of *Hicoria glabra*, it was 6^{cm} long and 1.3^{cm} in diameter, and others were nearly as large. The outer portion becomes brown and fissured, the fissures extending to the endodermis. In older seedlings the root becomes very long; in large seedlings of *Juglans nigra* and *J. cinerea* it was over one-third the total length of the plant axis and in Hicoria about two-thirds. In one specimen of *Hicoria alba*, where the main stem had been killed and its place taken by a branch from the axil of one cotyledon, the young stem was 3^{cm} long and the root 20^{cm} long (*fig. 12*). The hypocotyl does not develop. The petioles of the cotyledons attain a length of 0.5 to 1.5^{cm}. The young stem bears four to eight scales before the first leaves appear. In *Juglans cinerea* these scales were two-ranked and in the same plane as the cotyledons, but in all the others they showed the two-fifths arrangement. As the seedlings naturally germinate under trees where the nuts would be buried under leaves, and as the internodes have not the power to lengthen much, Lubbock[5] suggests that the first leaves are

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[5] LUBBOCK, SIR J., *op. cit.*

reduced to scales and only those that would be sure of reaching above the covering expand as true leaves. No stipules are produced. The young stem and leaves are glandular pubescent. In a number of seedlings of *Juglans cinerea* examined, the first two to four leaves were of five leaflets, the next two or three of seven, and the next ones of nine. A few had the first leaf above the scales of three leaflets. Often one leaflet of the uppermost pair of leaflets was obsolete. In *Juglans nigra* the first two to four leaves were of five leaflets, the next two or three of seven, the next two of nine, and where others were present they were of eleven leaflets. In Hicoria the first leaf was often entire or three-lobed and the next three-lobed or of two leaflets, but usually the first four or five leaves were of three leaflets. In the seedlings in the garden three or four leaves developed and then a terminal bud was formed. About the middle of July many of these buds opened and two or three more leaves developed, which were often of five leaflets. In the seed in Hicoria the plumule is made up of ten to twelve leaves. Probably not all of these develop in the first season. In the seedlings of Hicoria in the garden the main stem was often killed in some way near the surface of the ground, and the growth of the axis continued by a bud from the axil of the cotyledon or of one of the scales. In the seedling of *Hicoria ovata* figured (*fig. 12*) the main stem and the branch from the axil of one cotyledon had both died and the bud from the axil of the other cotyledon taken its place. Often in this way two, or even three, stems of about equal vigor arise.

FAGACEÆ. In Fagus the cotyledons are broader than long, notched at the apex and the two folded together into a triangular form completely filling the nut. This folding varies in different nuts. Basal lobes of the cotyledons surround and nearly cover the radicle. In Castanea the cotyledons have two to six basal lobes that nearly cover the radicle and the cotyledons are broadly ovate, thick, and entire. In Quercus the cotyledons are oval to orbicular, very thick, and entire, varying in size and shape in the different species. The basal lobes, two to six, completely cover the radicle.

In Fagus the shell splits in germinating along the three angles and the root pushes out, then the cotyledons expand and enlarge and split the shell more and throw it off. The hypocotyl lengthens considerably and raises the sessile cotyledons well above the ground. In Castanea the cotyledons swell where their petioles join them so as to force the two apart and split the shell. Then the basal lobes push out and spread apart and the radicle grows out. The petioles of the cotyledons elongate and carry the plumule out. In Quercus germination takes place as in Castanea.

In the seedling of Fagus the root does not become greatly thickened as in the Juglandaceæ, but secondary thickening soon occurs. The cotyledons expand and become green but drop off soon after the first leaves expand. The stem and leaves are hairy; the first leaves are of the same form as the mature ones. In Castanea the root soon thickens and has longitudinal fissures extending down to the endodermis. The stem bears several scales, two to six, below the leaves, and the first leaves are of the same form as the mature ones and bear deciduous stipules. In Quercus the seedlings resemble those of Castanea, but there are often more scales on the stem, the uppermost of which bear stipules. The leaves in *Quercus velutina*, *Q. platanoides*, and *Q. macrocarpa* are all serrate and much alike, but the older leaves become more like the mature ones, but are not deeply lobed or cut. The stem and leaves are pubescent.

CONCLUSIONS. The cotyledons in Juglans and Hicoria correspond with the valves of the nut and are deeply two-lobed. The two divisions of the embryo resembling cotyledons are each made up of halves of the cotyledons.

The seeds of Hicoria germinate without frost action; those of Juglans only with frost action.

The tap root is very thick in young seedlings, and very long in older ones.

In Castanea and Quercus the shell is split in germination by a swelling of the cotyledons.

In the species of Quercus studied, the leaves of the seedlings were much alike and not deeply cut or lobed.

Fagus is the only one in which the hypocotyl lengthens, or the cotyledons become aerial.— W. W. ROWLEE and GEORGE T. HASTINGS, *Cornell University.*

EXPLANATION OF PLATE XXIX.

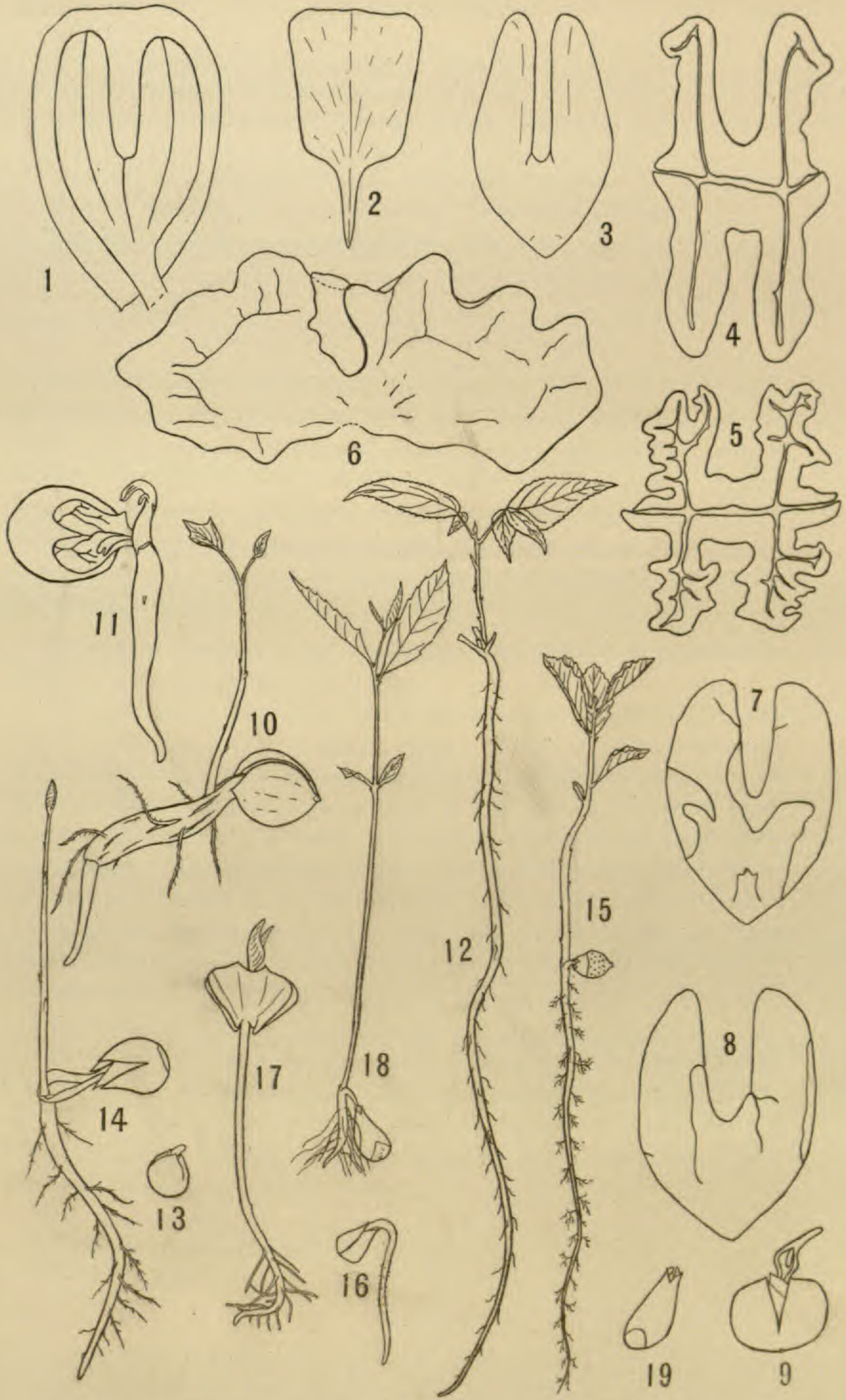
FIGS. 1–3. Cotyledons of *Juglans cinerea.* ×2.

FIG. 4. Cotyledons of *Hicoria laciniosa.* ×5.

FIG. 5. Cotyledons of *Hicoria minima.* ×5.

FIGS. 6–8. Cotyledons of *Hicoria glabra.* ×3.

FIGS. 9, 10. Seedlings of *Hicoria glabra.* Nat. size.



ROWLEE and HASTINGS on AMENTIFERÆ

FIG. 11. Seedling of *Juglans nigra*. Nat. size.
FIG. 12. Seedling of *Hicoria ovata*. Nat. size.
FIGS. 13, 14. Seedlings of *Quercus velutina*. Nat. size.
FIG. 15. Seedling of *Quercus platanoides*. Half nat. size.
FIGS. 16, 17. Seedlings of *Fagus Americana*. Nat. size.
FIG. 18. Seedling of *Castanea dentata*. Three-fifths nat. size.
FIG. 19. Seedling of *Castanea dentata*. Nat. size.

A GRAMINICOLOUS DOASSANSIA.

OF the species of Doassansia enumerated by Setchell in 1892[1] eight are American. Of these four find their host in Sagittaria, two in Potamogeton, one in Alisma, and one in the quite dissimilar Epilobium. In 1894 Setchell described another species on Sagittaria[2]. In 1895 Ellis and Dearness published another, also on Sagittaria,[3] while a Ranunculus was the host of a species described by the writer in the same year[4]. To the list of hosts may now be added one of the Gramineæ.

Doassansia Zizaniæ, n. sp. Subgenus DOASSANSIOPSIS as emended, BOTANICAL GAZETTE **19**:186. 1894.

Sori globose to ellipsoidal, black, the diameter varying nearly 100 μ from the average which is about 200 μ. Cortex of one crowded row of cells which are thick walled, dark brown, nearly opaque, more or less irregularly globose, about 6 μ in diameter. The spore layer beneath the cortex is irregular in thickness but generally about three spores deep. Spores lighter brown, rather thin walled, globose to polyhedral, crowded, 6–10 μ in diameter. Central portion of the sorus composed of pseudoparenchyma, the cells of which are but little larger than the spores. Sori also occur in which the spore layer is bounded within by cells like those of the cortex, the pseudoparenchyma being absent and the central part of the sorus empty.

In the culms of *Zizania aquatica* L., Racine and Kenosha, Wisconsin, September to December. The sori are most common and abundant in the central cavity of the culm, to the walls of which they are loosely attached, but they are often abundant in the looser tissue in the

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[1] Annals of Botany **6**:21.
[2] BOT. GAZ. **19**:185.
[3] Bulletin Torrey Bot. Club **22**:364.
[4] BOT. GAZ. **19**:416.

middle of the culm wall and also in the sheaths. Two or three sori sometimes coalesce to form a large sorus. No spots are produced on the culms, but those containing the fungus are usually weaker and more flaccid. Attempts have been made from time to time during a period of two years to secure the germination of the spores in the moist chamber but without success, and as the species is soon to be distributed in Ellis and Everhart's *Fungi Columbiani* this description is published without the germination characters. The analogue of *D. Zizaniæ* is *D. intermedia* Setchell. The figure accompanying the description of that species[5] shows the same general structure of the sorus. The present species differs especially in the thicker walled and more rounded cells of the cortex, thinner walled spores and smaller parenchymatous cells. — J. J. DAVIS, *Racine, Wisconsin.*

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[5] BOT. GAZ. 19 : *pl. 18. fig. 1.*

OPEN LETTERS.

TWO CORRECTIONS.

THE SOURCE OF WELWITSCHIA.

READERS of the BOTANICAL GAZETTE are requested to correct an inadvertence in the August number, page 152, where it is stated that the inflorescence and dissections of Welwitschia recently given by us were made from a plant growing at Kew. The specimens were sent to me by Mr. Dinter, a German botanist and horticulturist, now settled in German S. W. Africa. The details are given in his letter published in *The Gardeners' Chronicle* 24 : 27. 1898. After making some gross dissections, I handed the material to Professor Farmer for more minute investigation.— MAXWELL T. MASTERS, *London.*

CONFUSED SPECIES OF AGROPYRON.

I am indebted to Mr. Jared G. Smith, of the Division of Agrostology of the Department of Agriculture, for calling my attention to an error in the article "Vegetation Regions of the Prairie Province" in the GAZETTE for June 1898. The grass referred to on page 385, 9th line from the bottom, should be *Agropyron spicatum. A. spicatum* should also be read instead of *A. pseudorepens* on page 394, 4th line from the top. *A. pseudorepens* is a grass of the meadow formation as stated on page 389; the xerophyte of the foothill region is *A. spicatum.* The same correction should be made in the Phytogeography of Nebraska in the discussion of the foothill grass formation.

This removes what seemed to be an anomaly in ecology. That the same species should be a mesophyte of the meadows and wet cañons and also a xerophyte of the table lands of the foothill region, was a puzzle. Confusion of two closely related species, which have commonly passed under the same name of *A. glaucum,* was at the root of the matter. It is very gratifying to have the systematists clear up ecological problems in this manner.— ROSCOE POUND, *Lincoln, Neb.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plant Geography.

THOSE WHO are interested in plant geography are extremely anxious to see new numbers of Engler and Drude's *Vegetation der Erde* as often as possible. The first volume included the results of Willkomm's exhaustive studies in the Spanish peninsula.[1] The second volume deals with the flora of the Carpathians and is from the hands of the well-known botanist, Dr. Ferdinand Pax of Breslau.[2] The area covered by this monograph is much more limited than that which is included in Willkomm's work, comprising the mountain districts in the eastern part of Hungary. Pax began his studies in this region in 1882 and has continued them at short intervals up to the present time. Only a short time ago he published some of the results of his study, a short preliminary sketch dealing with the various elements which make up the Carpathian flora.[3]

The volume under consideration discusses the plant geography of the district in a general way only, while the author contemplates a second volume which will give a more special and detailed account of the smaller areas which make up the Carpathian region.

The introduction gives a very complete history of botanical research in the Carpathians from the sixteenth century to the present time. The historical account is subdivided into the period before Linnaeus, the Linnaean period, the period between Linnaeus and 1850, and the period from 1850 to the present. Among those who deserve especial mention are Winterl, the first professor of botany in Hungary; Kitaibel, a student of Winterl's who published a monographic work on the flora of Hungary; more recently the investigations of Borbás, Hazslinszky, Kanitz, Staub, and others, in addition to the careful work of Pax, have made this interesting region one of the best known to geographic botanists. The bibliography is unusually complete, including more than 1200 titles.

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[1] See BOT. GAZ. **22**: 63. July 1896.

[2] PAX, F.—Grundzuge der Pflanzenverbreitung in den Karpathen (Engler and Drude, Die Vegetation der Erde, II). I. Band. 8vo. pp. 269, *figs. 9*, heliogravures 3, map 1. Leipzig: W. Engelmann. 1898.

[3] PAX, F.—Ueber die Gliederung der Karpathen-flora. Jahresb. Schles. Gesellsch. Vaterl. Kultur. Breslau. 1896.

The physical geography of the Carpathians is the title of the first part of the work, under which head are discussed the geographic features of the area, especially as they are related to the physiognomy of the vegetation. A short treatment of the climatic conditions closes this part of the work.

Part two, the plant formations of the Carpathians, forms the body of the work. The formations are subdivided into three series, those of the lower hills, those of the higher mountains up to the tree line, and those above the tree line. The first two series are subdivided into formations with and without trees. The treeless portions of the lower hills are especially characterized by pastures rich in the beauty of their flowers; these pastures pass lower down into meadows where greener tints predominate. Some pastures (Pusztaweide) are more xerophytic and have a lower more open vegetation. The other treeless formations are those of the rocks and hydrophytic areas. The conifers have a very subordinate display on the lower hills, the dominant forest landscape being made up of mixed deciduous woods, in which the oaks are the most characteristic trees. With the oaks are birches, elms, hornbeams and maples. Besides these forests, there are sometimes pure growths of the beech, and mixed woods along streams, made up of the ash, alder and oak. There are also marginal thickets and xerophilous juniper formations in the hill region. In the mountain region below the tree line there are mountain meadows which pass into swamps in the lower places. The open rock formations assume a more prominent place than lower down and the species present depend upon the chemical nature of the rocks, whether calcareous or not. The mountain forests are largely dominated by the beech in the lower stretches, while higher up the spruce becomes the characteristic tree and ascends to the tree line. There are also mountain woods (Buschwald) where the beech predominates but no longer as a tall tree. Above the tree line appear the subalpine formations, in which there are extensive areas covered by dwarf shrubs, especially the dwarf pines, junipers and alders, and the rhododendrons. There are characteristic mats, meadows, and rock floras in the alpine regions still higher up. At the close of the second part Pax considers the influence of man on the vegetation, especially as it finds expression in the ruderal and culture floras and in injury to the floras.

The third part is entitled "Die Vegetationslinien der Karpathen und ihre Gliederung in Bezirke." These mountains form the east or northeast limits of many European mountain plants and also the south or southeast limits of some eastern and northern plants. The reasons for this are both topographic and climatic, and there results a notable mingling of divergent floral types. Pax finds that the vast majority of the vegetation lines are closely associated with the Kaschau-Eperjeser fault line, which follows in general the trend of the mountains; in fact the close relationship between the vegetation and the geological features is constantly emphasized. After a brief treatment of the species common to the whole Carpathian district, the author goes more in detail into the subject of endemism. A great majority of the endemic forms are isolated, well-marked types and for the most part related to Alpine or Balkan plants. Most of the endemic plants are found east of the fault line, though those of northern origin occur throughout the district. The fault line makes a natural geographic division of the region into the east and west Carpathians and the author makes still further subdivisions of a geographic nature.

In the last part is to be found a discussion of the relations between the Carpathian floras and those of neighboring districts. The closest relationship is to the flora of central Europe, a relationship which is most strikingly shown in the forest trees. The relationship to the flora of Russia and Siberia is quite evident, though of less physiognomic value. A number of other floral elements are represented in the Carpathian flora but to a much less degree. Pax next considers the distribution of the endemic plants, and finds almost complete harmony between the two. The volume closes with a presentation of the historical development of the Carpathian flora from the Tertiary to the present, the discussion of the influence of the ice age on the vegetation having special interest and also the conclusion with regard to the paths along which migrations have occurred.— HENRY C. COWLES.

Flower ecology.

AFTER INDUSTRIOUS work on the pollination and insect relations of the floras of the North Frisian islands, Hallig islands, Helgoland, Rügen, Schleswig-Holstein, Mecklenburg, Pomerania, Westphalia, Nassau, Thüringia, Switzerland and Capri, and the investigation of many special cases, the distinguished anthoecologist of Kiel has undertaken a general review of the fundamental propositions of the subject, the literature and the results of investigations made in all parts of the world.

The first volume gives a historical account of the development of flower ecology, beginning with Kölreuter and Sprengel and including references to all of the investigators who have contributed to the subject. This is followed by an account of the status of the modern flower-theory and a review of the various modes of pollination and correlated phenomena: (1) Modes of pollination and separation of forms of flowers; (2) Autogamy; (3) Geitonogamy; (4) Xenogamy; (5) Heterostyly; (6) Cleistogamy; (7) Parthenogenesis; (8) Flower classes; (9) Flower visiting insects; (10) Methods of investigation. The extent to which these topics are elaborated may be indicated by the note that 262 pages (including index) are devoted to them.[4]

[4] KNUTH, PAUL: Handbuch der Blütenbiologie unter Zugrundelegung von Hermann Müller's Werk "Die Befruchtung der Blumen durch Insekten." Vol. I. pp. 400. Vol. II, part 1. pp. 697. Leipzig: Wilhelm Engelmann. 1898.

The second part of the volume gives a bibliographical list of 2871 titles to April 1, 1898, with a special index. As a frontispiece the volume shows a portrait of Kölreuter. There are 81 figures, most of which are familiar to those who have used Müller's *Befruchtung*. *Fig. 1* is a reproduction of the title-page of Sprengel's *Entdeckte Geheimniss*.

The second volume considers the results of observations made in Europe and in the Arctic regions; of Aurivillius and Ekstam in Nova Zembla; Burkill, Scott-Elliott and Willis in Great Britain; Delpino, Comes, Nicotra and Ricca in Italy; Dalla Torre, Kerner and Schulz in the Tyrol; Heinsius in Belgium; Kirchner at Stuttgart; Loew in the Berlin Gardens; Lindman in Greenland and Scandinavia; MacLeod in Flanders and Pyrenees; Müller in Westphalia, Thüringia and Alps; Verhoeff in the West Frisian island, Norderney; Warming in Greenland and Denmark. The first part includes the families Ranunculaceæ-Compositæ. A contemplated third volume relates to investigations made in other parts of the world. The whole ground is gone over in so thorough a manner that it will not be necessary for contributors to go through so much drudgery in looking up the literature, nor will it leave much excuse for offering contributions which have no relation to the present state of what is called "our knowledge."—CHARLES ROBERTSON.

Fungicides and insecticides.

IT HAS BEEN but a few years, scarcely more than a dozen, since the range of fungicidal agents embraced little more than bluestone for steeping wheat, sulfur for dusting upon foliage, and a somewhat uncertain application of copperas. But in these last years the number of effective fungicides has become exceedingly large, and their specific application is now based upon extensive study of underlying causes and conditions. The history of insecticides and their use is very similar. One has only to consult the excellent treatise by Lodeman on the spraying of plants, published two years ago, to feel that the amount of practical knowledge the scientist now lays before the cultivator in a field where his needs are great is of astonishing proportions. The United States has borne a proud part in the development of this subject, being in fact an acknowledged leader, while France, Italy, Switzerland and Germany have, in the order named, become actively interested in vegetable pathology and prophylactic measures.

Germany, although somewhat tardy in taking up this department of investigation, now puts forth a volume on the methods of combating plant diseases by means of chemical preparations that will prove of interest to all students of the subject, as well as to the cultivators and investigators of Germany for whom it was prepared. It emanates from Halle, that city of experiment stations, and is written by Dr. M. Hollrung,[5] director of the

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[5] HOLLRUNG, M.: Handbuch der chemischen Mittel gegen Pflanzenkrank-

experiment station for plant pathology of the agricultural bureau of Saxony.

The work is compiled from all available sources, American methods being extensively quoted. It devotes three pages to preparations in which the chief ingredients are of animal origin, such as fish oil, lard, soap and glue; twenty pages to those with vegetable substances, such as cotton-seed and other plant oils, resin, tar, pyrethrum, tobacco and hellebore; and the remainder of the work, 141 pages, to those with mineral ingredients. Although primarily a volume of recipes, the metric system of weights and measures being exclusively employed, yet their uses and methods of application are clearly and succinctly set forth, with an estimate of their efficiency, and references to the source of information.

The work is admirably conceived and executed, and as closely up to date as any general work is likely to be. The classification makes it handy for reference, which is further aided by a full index.— J. C. A.

Bryology of Madagascar.

SINCE THE publication in 1879 of Bescherelle's *Florule bryologique de la Réunion et autres îles austro-Africaines de l'Océan Indien*, a number of papers on the mosses of Madagascar and allied regions have been published by Müller, Bescherelle, Brotherus, Wright, Mitten, Warnstorf, Renauld, and Cardot. Collections by French officials, missionaries, and others have accumulated. M. F. Renauld has sought to bring all this scattered information together in a sumptuous volume published by order of Prince Albert of Monaco.[6]

In preparing this work he has had abundant cooperation of bryologists who have been working in this field, or those who have charge of collections from South Africa. A preface on the generic nomenclature and the value of specific characters contains nothing novel. The geology, topography, and climate of the islands are briefly described. The chapter on the distribution of the mosses is very unsatisfactory because knowledge of the region is still much too imperfect to allow adequate treatment. M. Renauld calls the bryological flora south tropical; holds that the islands constitute an independent domain, each island having its own individuality but unequally marked; and sees relations on the one hand with the flora of the Indo-Javanese archipelago through allied species, and on the other with that of the mountains of South Africa both by allied and by identical species.

The flora of the whole group is enumerated as follows: Acrocarpi 413,

heiten; Herstellung und Anwendung in Grossen. 8vo. pp. xii + 178. Berlin: Paul Parey. 1898.

[6] RENAULD, F.— Prodrome de la flore bryologique de Madagascar, des Mascareignes et des Comores, publié par ordre de S. A. S. le Prince Albert I^er^. Ouvrage couronné par l'Institut de France. Small 4to. pp. viii + 300. Monaco. 1897.

Cladocarpi 6, Pleurocarpi 306, Sphagnum 21; total 746 species — not very far short of the enumeration of North American species given by Lesquereux and James in 1884. One is surprised at this large number even when he recalls the tropical climate and the large size of Madagascar. If laid down upon the United States the island would stretch from New York to St. Louis, with an average width equal to the length of the state of Indiana.

The Prodromus contains descriptions of many new species and validates a number of *nomina nuda* by furnishing diagnoses. It is a pity that these new things were not figured. One could have cheerfully forgone the luxurious margins and hand-made deckel-edge paper, if necessary, for the sake of plates.— C. R. B.

Kerner's "Plant Life."

THE FIRST edition of Kerner's *Pflanzenleben* is well known to English and American readers through Professor F. W. Oliver's translation, entitled *The Natural History of Plants.* Kerner issued the first volume of a second edition in 1896, the second volume appearing in 1898, almost simultaneously with the announcement of the author's death.[7] Inasmuch as the second edition follows the same general methods as the first, an extended review seems unnecessary. The divisions and subdivisions are generally the same as in the older edition, although all of the subjects treated have been reconsidered and brought more into harmony with the botany of today. A very attractive addition is the incorporation of a large number of new colored plates, as well as woodcuts and text figures. Kerner's first work has been one of the most satisfactory places to find typical plant habits and landscapes, and this feature has been improved in the second edition. Among some of the new illustrations are red snow, dodder, nullipore banks, luminous moss, reed swamps, Eucalyptus, lianas, lichens, etc. In many chapters considerable additional matter is to be found.

The most noteworthy change is the omission of about 100 pages on the classification of plants. This classification always seemed out of place in a work of this kind. The book closes with an entirely new chapter on the relation between man and plants — economic botany in the broader sense. Those plants which are used in the industrial arts are first discussed, then those which are used as food by man and by domestic animals and those which are employed in medicine, and for ornamental purposes. A historical sketch of gardens follows, beginning with the ancients and ending with the botanical and other gardens of the present day. At the close of the

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[7] KERNER VON MARILAUN, ANTON.— Pflanzenleben, zweite, ganzlich neubearbeitete Auflage. 8vo. Erster Band: Gestalt und Leben der Pflanze. 8vo. pp. xii + 766. *figs. 215. pl. 34* (21 colored). 1896. Zweiter Band: Die Geschichte der Pflanzen. 8vo. pp. xii + 778. *figs. 233. pl. 30* (19 colored). *map 1.* 1898. Leipzig and Vienna: Bibliographisches Institut.

topic, plants as motives in art is discussed, and such unusual botanical subjects are introduced as plants in tapestries, sculpture, painting and poetry. This last chapter is not without its value, even for botanists, especially nowadays when people are laying so much stress on the interrelationships of all subjects.— HENRY C. COWLES.

MINOR NOTICES.

AN EXCELLENT SERVICE has been rendered the collector of fleshy fungi by Mr. C. G. Lloyd[8] in the publication of a twenty-two page pamphlet on the American Volvæ. There are included 38 species of Amanita, 12 of Volvaria and one of Chitonia. The necessity for much field study and close, critical work is evident from the author's statement that in the genus Amanita there are in this country five common species, nine occasionally found and definitely known, and twenty-four that are either doubtful identifications of European species or only recorded by the discoverer, many being described from dried specimens sent to Europe for that purpose.

The author gives concise diagnostic characters for each species, with many helpful notes, and in another place gives the full description for all species not found in Stevenson's *British Fungi*. The author evidently had in mind the encouragement of inexperienced collectors, and such will find that many of their difficulties have been anticipated; but the omission of the authority for the Latin name seems an unnecessary and inconvenient concession.

One is surprised to learn that the author does not approve of the application of the Rochester rules to cryptogams, and thinks that "it would result in an endless confusion in regard to nomenclature, and retard the study fifty years." In a work intended for assistance in field study, where the most familiar names serve best, it is doubtless only necessary to follow the most prominent authorities; but critical monographic study requires the application of the Rochester or similar rules, if reasonable stability is ever to be attained.—J. C. A.

A LIST of the spermatophytes and pteridophytes of the Upper Susquehanna region has been published by Mr. Willard N. Clute.[9] This volume "is part of a general plan for an extended study of the flora about the headwaters of the Susquehanna river." It seems that this is the first compilation of the flora of the region, although a number of well-known botanists have been interested in it at various times. The author promises to record subsequent observations in annual supplements, recognizing the fact that the list

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[8] LLOYD, C. G.—A compilation of the Volvæ of the United States. 8vo. pp. 22. Cincinnati, 1898. 9 ill. from photographs.

[9] CLUTE, WILLARD NELSON: Flora of the Upper Susquehanna and its tributaries. pp. xix + 142 + x. Binghamton, N. Y.: Willard N. Clute & Co. 1898.

is far from complete. An excellent introduction presents the characteristics of the region, in the way of general topography, geology, rivers and streams, lakes and ponds, bogs and swamps, mountains and ravines, altitudes, temperature and rainfall, and general characteristics of the flora. The present volume enumerates 1105 species, the nomenclature of the "Check list" and the sequence of Gray's "Manual" being used. Common names of the region, notes useful to collectors, and a certain amount of synonomy are given. The region includes several counties in southern New York and northern Pennsylvania, and the taking up of a natural area rather than an artificial one cannot be too strongly commended. The book is well printed, and is admirably adapted to its purpose.—J. M. C.

MR. AVEN NELSON has just published[10] an interesting report on the vegetation of the "Red Desert" region of Wyoming. The area referred to extends "from the Platte bluffs on the east to the Green river bluffs on the west, from the northern limit of Sweetwater county to the hills and mountains separating Colorado and Wyoming." This large area is distinctly and strongly halophytic, and although its investigation had primarily in view the economic problem, the results are of interest to ecologists. During the summer the area is practically uninhabitable, but it has proved to afford excellent winter pasturage. The amount of this winter forage is very large, and is of six kinds: "the salt-sages" (various species of Atriplex), "the sage-brushes" (artemisias), "wheat grasses" (species of Agropyron) "Indian millet" (*Eriocoma cuspidata*), "giant rye-grass" (*Elymus condensatus*), and "desert juniper" (*J. Knightii*). The much more abundant vegetation of the hill country, or summer range, is also fully described.—J. M. C.

THE FIRST PARTS of Ascherson and Græbner's flora of the North German Lowlands[11] have appeared. The work was begun as the flora of the Brandenburg province alone, but the urgent need of a new presentation of the entire flora of the North German plains becoming apparent the authors have undertaken the longer work, which is to be published in periodical fashion. Beginning with the pteridophytes, the three parts already received include the pteridophytes, gymnosperms, monocotyls, and almost all of the Archichlamydeæ. A field handbook for popular use is evidently the aim, and to secure it there has been generous cooperation by the taxonomists of the region. The work is sparsely illustrated, and the fact that very few citations are made, and that the names of authors of species are omitted, is

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[10] The Red Desert of Wyoming and its forage resources. U. S. Department of Agriculture, Division of Agrostology, Bulletin 13, Grass and forage plant investigations, 1898.

[11] ASCHERSON, P. and GRÆBNER, P.: Flora des Nordostdeutschen Flachlandes (ausser Ostpreussen). Liefg. 1, 2, 3. Small 8vo., pp. 480. Berlin: Gebrüder Borntraeger.

evidence that nothing is intended beyond a current field manual for work of the most general character.—JOHN GAYLORD COULTER.

DR. CARL HOLTERMANN[12] has just published, with the assistance of the Royal Prussian Academy of Science in Berlin, an elaborate account of his mycological studies in Java and Ceylon. The morphology and in many cases life-histories of some forty forms, chiefly Basidiomycetes, are described and illustrated with a dozen fine plates. Two new genera, *Oscarbrefeldia* and *Conidiascus*, and one new species, *Ascoidea saprolegnioides*, are added to the Hemiasci. The author is not willing to follow strictly Brefeld's views in respect to the derivation of the conidium from the sporangium. His studies upon the tropical forms indicate that the two structures may be phylogenetically quite independent of one another. He believes that each has its own *Anlage*, and that the direct influence of external conditions determines the development of one or the other or both upon the same mycelium.—BRADLEY MOORE DAVIS.

PARTS 175 and 176 of Engler and Prantl's *Die natürlichen Pflanzenfamilien* contain the completion of the Umbelliferæ by Drude, and the Cornaceæ by Harms. This completes the Archichlamydeæ, a cause for congratulation among taxonomists. The parts of this great work have been noticed briefly from time to time, as they appeared, and the general purpose and its execution warmly commended. It is certainly an epochal work, and supplies a much needed compact and illustrated presentation of known genera. The breadth of the plan has not been approached by any other "Genera Plantarum." The necessity of bringing together the work of so many collaborators has made the editorial work onerous, and of course there is great unevenness of presentation. It is impossible to criticise such a work in general. The students of different groups must pass judgment upon the work in their particular fields.— J. M. C.

NOTES FOR STUDENTS.

BY GROWING plants of Indian corn from sterilized seeds in sterile nutrient fluid, to which he had added glucose, Laurent has determined that their roots are capable of absorbing organic matter in this form.[13]—C. R. B.

MR. DAVID WHITE[14] has described and figured a new lepidodendroid genus, *Omphalophloios*, from the Lower Coal Measures of Missouri, founded upon the problematic *Lepidodendron cyclostigma* of Lesquereux.—J. M. C.

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[12] HOLTERMANN, CARL: Mykologische Untersuchungen aus den Tropen. 4to. pp. viii + 122. *pl. 12.* Berlin: Gebrüder Borntraeger. 1898. *M.* 25.

[13] Comptes Rendus —: 887. 1897.

[14] Bull. Geol. Soc. Amer. 9: 329–342. *pls. 20–23.* 1898.

DR. J. WIESNER has published [15] a short paper on *Heliotropism produced by diffuse daylight.* In this paper he lays emphasis upon the fact that although the plant parts possess often an enormous capacity for heliotropic reaction, they always react to the strongest light, although illuminated by diffuse light and, therefore, impinged upon by rays from all sides. It thus comes about that the heliotropic organ places itself so as to divide symmetrically the area from which the light comes. The immediate cause of this is to be found in the fact that the direction is determined by those impulses which are not counteracted by exactly equivalent impulses.—C. R. B.

A PAPER by Hermann Barth has been running for some weeks in the Botanisches Centralblatt entitled *Studies upon the micro-chemical recognition of alkaloids in commercial drugs.* Barth finds the alkaloids in all parts of the drugs ; as for example, in the pericarp of *Conium maculatum;* in the seed coats in *Peganum Harmala* and *Colchicum autumnale;* in endosperm of *Areca Catechu;* in both endosperm and embryo of *Aconitum Napellus,* and in the embryo alone of *Physostigma venenosum.* He concludes from the occurrence of the alkaloids that it is to be expected that their functions must be very various. When they occur in the periphery of the plant organs as excretions it is reasonable to suppose that they are then protective substances against the eating of such parts by animals. Those occurring in the endosperm and embryo serve, according to Heckel, as reserve foods. In most cases, however, it appears to be beyond doubt that the alkaloids are to be considered excretions, as has been commonly believed. Some useful reactions for the recognition of alkaloids are described.—C. R. B.

DR. A. NESTLER has presented to the Imperial Academy of Sciences in Vienna a memoir on "The traumatropic movement of the nucleus and protoplasm." A summary of the results as given in the *Botanisches Centralblatt* **76**: 43. 1898 is as follows: The different orientation of the nucleus and protoplasm produced by wounding is a very common and probably general phenomenon among plants. It has been observed in monocotyledons, dicotyledons, and algæ, and occurs in like fashion in leaves, stems, and roots. The orientation exhibits itself in a few hours after wounding by the movement of the nucleus and protoplasm close to that wall which is nearest the surface of the wound. The maximum stimulation was observed in most cases after two or three days. The return of the nucleus and protoplasm to their normal position is less definite. In some cases it was observed after five or six days, in other cases they appeared to remain fixed even in the intact cells immediately bounding the wound. This transposition, which according to Tangl may be designated as traumatropic, cannot be explained upon mechanical grounds, but seems to be a peculiar stimulation movement, not more exactly definable, which is connected with the living protoplasts. The trans-

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[15] Berichte d. deuts. botan. Gesells. **16**: 158–163. 1898.

mission of the stimulus is observed with diminishing strength to the distance of 0.5 to 0.7^{mm} from the wound. The movement takes place in similar manner in the air and in the water. It is influenced by light and perhaps also by temperature; no influence of gravity could be determined. In the guard cells of the stoma the transposition was never observed. In some cases the effect of the stimulation caused the nuclei to increase considerably in size.—C. R. B.

ITEMS OF TAXONOMIC interest are as follows: Miss Alice Eastwood has published (*Proc. Calif. Acad. Sci.* III. (Botany) **1**:89–146. 1898) a second fascicle of her "Studies in the herbarium and the field." A study of a collection of eighty or more species of plants from San Nicolas island results in the description of nine new species and three varieties, the new species belonging to Abronia, Astragalus, Hosackia, Peucedanum, Amsinckia, Lycium, Plantago, and Malacothrix. Three new species of Cnicus from southern Colorado and Utah are described. Two new species of Synthyris from the alpine region of southwestern Colorado are added to the solitary alpine species heretofore recognized as occurring in the mountains of Colorado. Two new species of Eriodictyon are recognized as having been included heretofore under *E. tomentosum*. New species of Pacific coast plants are described under Campanula, Romneya, Sedum, Cercocarpus, and Calochortus.—In the *Journal of Botany* (**36**: 361–378. 1898) S. Schönland and E. G. Baker describe twenty-six new species of Crassula from South Africa, and R. Schlechter publishes a ninth decade of new plants from the same region. —In the current number of the *Bulletin of the Torrey Botanical Club* (**25**:521–541. 1898) Dr. L. M. Underwood begins a series of papers upon American ferns, the initial number dealing with the ternate species of Botrychium, fifteen of which are recognized, and two described as new, one (*B. Coulteri*) from the Yellowstone National Park, the other (*B. occidentale*) from British Columbia.—J. M. C.

A CAREFUL investigation of the phenomena of fertilization in Onoclea[16] by Mr. W. R. Shaw has brought some interesting facts to light. All previous accounts of fertilization in plants agree in making it consist of the fusion of two germ-nuclei in the resting condition; and similar descriptions are given by zoologists of fertilization in animals. In Onoclea, however, the sperm-nucleus does not pass into a resting condition before uniting with the egg-nucleus, but enters the latter without visible change either of form or structure. Within the egg-nucleus it slowly enlarges and becomes granular before the final building of the nuclear substances. Mr. Shaw was not able to determine with certainty the fate of the cilia and band of cytoplasm, which, together with the nucleus, make up the spermatozoid; though from certain appearances he conjectures they are left outside the egg-nucleus. This con-

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[16] Annals of Botany **12**: 261–285. 1898.

jecture he has confirmed more recently in the case of Marsilia[17] in which the behavior of the sperm-nucleus is as in Onoclea, and the cilia and cytoplasmic band are unmistakably thrown off in the cytoplasm of the egg.

Another result of Mr. Shaw's investigation is well worthy of note. Contrary to what has been seen in many cases and assumed in others, there was no evidence that a membrane is immediately formed about the oosphere after the entrance of the spermatozoid. It is suggested that in Onoclea the exclusion of other spermatozoids is accomplished, not by a membrane but by plasmolysis of the oosphere.

It is highly desirable that further observations should be made on the process of fertilization in zoidogamic plants.—WILSON R. SMITH.

A NEW SPECIES of the genus *Pleodorina* Shaw has been described ana figured by Kofoid in the *Bulletin* of the Illinois State Laboratory 5:273. 1898, and named *Pleodorina Illinoisensis*.[18] The account of the structure and habits of the species is very full and interesting. *P. Illinoisensis* is distinguished chiefly from Shaw's *P. Californica* because the vegetative cells are always four in number at the anterior end of the cœnobium instead of constituting about one-half of the cell colony. The number of cells in the cœnobium is also smaller, usually 32 instead of 64 or 128, and the reproductive cells (gonidia) are two or three times the diameter of the vegetative cells instead of being only slightly larger or twice as large as in the Californian species.

Pleodorina Illinoisensis is found in the back waters that cover submerged lands along the Illinois river. Quantitatively it does not form an important part of the plankton, and is not as abundant as Eudorina. Dr. Kofoid realizes that in the incompleteness of our knowledge of the life history of Pleodorina we cannot be sure that it is not a form of *Eudorina elegans*. There is extensive variation in both species, and such similarity of form and measurements that the younger stages of the two are indistinguishable. The presence of four vegetative cells at one pole of the cœnobium is the characteristic mark of *Pleodorina Illinoisensis*, the remaining 28 cells becoming reproductive. In *Eudorina* the antherozoids are formed in a similar group of four cells at one end of the cell colony, and the remaining 28 cells become oospheres. If *Eudorina* should have a parthenogenetic phase among its polymorphic conditions we should expect those 28 cells to be reproductive (gonidia), and the group of four at the anterior pole might remain vegetative. Such a form, if it existed, would be identical with *Pleodorina Illinoisensis*.—BRADLEY MOORE DAVIS.

THE MOST IMPORTANT series of exsiccati for American mycological students so far issued has come to a close with the thirty-sixth volume of

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[17] Berichte d. deuts. bot. Gesells. **16**:177–184. 1898.

[18] The form of the specific name is barbarous!—EDS.

Ellis and Everhart's *North American Fungi,*[19] which appeared a short time ago. For twenty years the work has been issued with an average regularity and a uniformity in make up and quality rarely attained.

The immediate cause of the discontinuance of the work is the sad illness of one whose name never appears in connection with its publication, but whose untiring zeal and labor have contributed largely to its success. The volumes for the whole series (except the first installment of sixty copies) have been made by Mrs. Ellis, the packets folded and the specimens put in place by her; and we may well believe that without her assistance and encouragement this splendid contribution to American mycology would never have been realized.

The last issue, like each of the preceding ones, contains 100 specimens of dried fungi belonging to various groups, placed loosely in folded packets and provided with printed labels. These are attached to the leaves of a volume containing title page and table of contents. The labels occasionally bear brief critical notes, and still more seldom diagnostic characters. The naming of the specimens has been done with care, and if errors occur, they are few and unavoidable.

The *Fungi Columbiani*, by the same authors, of which thirteen centuries have been issued and which have been, heretofore, a sort of duplicate of the N. Am. Fungi, will hereafter contain species that have not yet appeared in that work, and will thus in a measure be a continuation of it. The packets in this work are not fastened into volumes.—J. C. A.

S. HIRASÉ'S second paper on *Gingko*[20] adds an important contribution to the subject of spermatozoids in gymnosperms. The development of the pollen grain, pollen tube and antherozoid are treated in detail. Three cells are cut off in succession from the main body of the pollen grain. The first of these is soon resorbed; the second persists but does not seem to take any active part in the processes which follow; the third divides into a "stalk cell" and a "body cell." As the body cell increases in size two attractive spheres appear at the poles of its nucleus and somewhat later two larger spherical bodies resembling nucleoli are found between the attractive spheres and the nucleus. These bodies which are surrounded by a dense mass of granules may possibly aid nutrition but further investigation is necessary before anything definite can be said of their physiological or morphological value. The body cell divides parallel to the long axis of the pollen tube, giving rise to two cells in which the antherozoids are organized. A beak put out by the nucleus becomes joined to the centrosome which then makes three spiral

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[19] ELLIS, J. B. and EVERHART, B. M.—North American Fungi. 2d Ser. Cent. 36. Pub. by the editors, Newfield, N. J. 1898. $7.00.

[20] Études sur la fécondation et l'embryogénie du Gingko biloba. Jour. of the Tokyo Coll. of Science **12**: 102–149. 1898.

turns in the cytoplasm, in this process becoming drawn out into a spiral band along the edges of which cilia are developed. The antherozoids escape from the mother cell and swim freely in the liquid contained in the pollen chamber. According to Webber the antherozoids in Zamia are themselves ciliated mother cells and the pollen chamber contains air only.

Antherozoids in gymnosperms have now been described by Hirasé[21] in *Gingko biloba*, by Ikeno[22] in *Cycas revoluta* and by Webber[23] in *Zamia integrifolia*. All three find a pair of spherical bodies in the cell which is to give rise to the two antherozoids. Hirasé and Ikeno agree in calling these bodies centrosomes but Webber not believing that they are centrosomes calls them centrosome-like bodies, and later proposes the term blepharoplast. Bodies probably homologous with these centrosomes or blepharoplasts have recently been described by Belajeff and Shaw in several pteridophytes. While Gingko, Cycas and Zamia resemble each other in the general development of their pollen grain structures they present considerable variation in details, especially in the history of the body cell and the formation of the antherozoid.

These investigations have added so much to the evidence accumulating from other sources, that Engler has removed Gingko from the conifers and put it by itself in the Gingkoales, a group coordinate with cycads, conifers and gnetums.—CHAS. J. CHAMBERLAIN.

NUCLEAR DIVISION IN SPIROGYRA has been studied for a long time and the most contradictory results have been obtained, especially in regard to the chemical nature of the nucleolus and its rôle in karyokinesis. Some claim that the nucleolus is fully analogous with that of the higher plants, while others think it very different both in chemical composition and its rôle in karyokinesis. Some believe that the nuclear plate is formed exclusively at the expense of the chromatic network of the nucleus, others that it comes from the nucleolus and still others that it is formed partly from the nuclear network and partly from the nucleolus. The origin of achromatic parts is also in dispute, some claiming a cytoplasmic origin, others a nuclear origin and still others a mixed origin partly cytoplasmic and partly nuclear.

L. Mitzkewitsch[24] has recently presented a thorough discussion of previous literature and added a most important contribution to the subject. The most modern killing and fixing agents were employed. After washing in water, alcohol was added to the water drop by drop at intervals of a minute or more until the material was dehydrated. The transfer from alcohol to xylol and from xylol to paraffin was equally gradual.

The investigations deal almost exclusively with the nucleolus and the

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[21] *Loc. cit.* and Bot. Cent. **69**: 33–35. 1897.

[22] Flora **85**: 1. 1898 and Bot. Centralbl.

[23] BOT. GAZ. **23**: 451–459 and **24**: 16–22, 225–235. 1897.

[24] Ueber die Kerntheilung bei Spirogyra. Flora **85**: 81–124. 1898.

achromatic parts of the mitotic figure. *Spirogyra subæqua* and *S. jugalis* were the principal forms studied. The sequence in *S. subæqua* is as follows: The resting nucleus has a large nucleolus surrounded by a very evident nucleolar membrane and the threads of the nuclear network are very faint. As division begins the nucleus elongates, the nucleolus loses its membrane and puts out processes which extend to the periphery of the nucleus. At this stage striations are distinctly visible in the plasma heaps at the poles of the nucleus. The nucleolar processes are now withdrawn and the nucleolus shows a differentiation into intensely staining granules and a less deeply staining ground substance. Achromatic threads now appear inside the nucleus and represent a continuation of the achromatic threads outside. The granules continue to stain more deeply and the nuclear membrane disappears, beginning at the poles of the nucleus. The granules, or chromosomes, become arranged in a single layer in the nuclear plate, while the less deeply staining substance takes the form of bows with sides resting on the chromosomes and the apices, to which the achromatic threads are attached, turned toward the poles. The chromosomes split and as the halves of the nuclear plate separate, granular threads connect them for a time.

After the formation of a new nuclear membrane the material of the nuclear plate still shows the intensely staining chromosomes imbedded in a less deeply staining mass from which processes reach to the nuclear membrane. The processes are gradually withdrawn, the chromosomes gradually become indistinguishable from the rest of the mass, the nucleolar membrane appears and the nucleolus assumes the ordinary aspect of the resting condition.

The other species studied differed only in unessential details.—CHAS. J. CHAMBERLAIN.

A MONOGRAPH of the Caulerpaceæ[25] has recently appeared from the *Annales* of the Botanical Garden of Buitenzorg. Madame Weber-Van Bosse presents a complete taxonomic account of these interesting plants, based upon a personal and very extensive examination of the various scattered herbaria. There is perhaps no group of algæ more difficult to handle than the caulerpas, and the skill with which the author has reduced the immense number of described forms and varieties to sixty-four species is admirable. The specific descriptions seem excellent and fifteen fine lithographic plates greatly assist the reader. One must regret, however, the absence of an index to species and synomyms, for an index, although a clerical detail, is indispensable to the complete usefulness of such a work.

It is exceedingly interesting that this genus Caulerpa, immense in the number and diversity of its varieties, and cosmopolitan in its distribution through the warmer waters of the globe, should apparently reproduce itself

[25] WEBER-VAN BOSSE: Monographie der Caulerpes. Ann. d. Jar. Bot. d. Buitenzorg 15:243–401. 1898.

entirely vegetatively. No zoospores have ever been seen, the supposed observations of Montagne and Gardiner apparently having been erroneous.— BRADLEY M. DAVIS.

AT THE MEETING of the Academy of Science of St. Louis on the evening of October 17, 1897, Mr. C. H. Thompson spoke of some interesting stylar movements of certain Marantaceæ connected with their pollination. In the course of his remarks Mr. Thompson said:

"Generally speaking, the flower of Marantaceæ is a more or less evident tube, with the calyx and corolla inconspicuous and the stamens changed into irregular petaloid staminodia, except a single fertile one. My studies of the order have been confined to three genera, Maranta, Calathea, and Thalia, and refer to about eight or ten species. In all of the species, one of the staminodia is developed into a keel-like structure, not unlike the keel of a papilionaceous leguminous flower. At maturity of the flower, this keel holds within its fold the style. On one margin of the keel, about midway between the apex and the base of the staminodium, is developed a tentacle-like body which is extremely irritable. This tentacle, in the open flower, guards the passage to the nectary. If the tentacle is irritated, the impulse is conveyed to the sheathing basal portion of the keel, which holds the style, opening the sheath and allowing the style to escape its embrace. This movement of the style is probably due to the unequal turgescence in the cells between those of the upper side and those of the lower side of the style, the greater turgescence existing in the latter. This, when the style is liberated, causes it to curve upward with considerable force. In Maranta the style forms a semicircle, coming to rest with the stigma firmly pressed against the upper staminodium. In Calathea and Thalia it makes a complete spiral revolution, bringing the stigma, in the former, into firm contact with the style, and in the latter placing it securely in a pocket formed by a fold of the inner wall of the upper staminodium. In each instance, the contact is so secure that the stigma can be reached only by destroying the flower. The sensitive tissues seem to be located in the outer cell structure of the sheathing base of the keel. An irritation from an outside agency directed against the tentacle is conveyed by that organ to the sensitive tissue, causing the sheath to open, and liberating the style, which it has been holding under great tension.

"This complicated differentiation of the flower is undoubtedly an adaptation to insure cross-pollination. To understand this better, a detailed description of the essential organs is desirable. In the flower bud the stamen lies parallel with the pistil, with its one-celled anther placed just back of the stigma and on the style. Immediately preceding the opening of the flower, the anther dehisces, shedding its pollen on a viscid disk which is located on the style at the point of contact. Here the pollen adheres till scraped away in the operation next to be described.

"A bee alights on the platform formed by one or more of the lower staminodia, thursts its beak forward to secure the drop of nectar, and in doing so strikes the sensitive tentacle. The pistil suddenly coils and strikes the bee. First the stigma is brought in contact, and scrapes off any pollen that may have been previously deposited on the bee at that point. Then, as the style continues coiling, it brings the viscid disk in contact with the same point of the bee's body, depositing more pollen, which will be scraped off in another flower visited. In Maranta and Calathea, the visitor is probably a bee of the size of the hive-bee, and the pollen would be deposited on the abdominal surface of its body. The visitors to the Thalia flower are of the larger bumble-bee type, and the individual receives the pollen deposit at the base and on one side of its beak. Previous to the coiling of the style, the stigma is covered by one or more of the lower staminodia; at the end of the operation, in each case, it is again covered securely, so that it has but one chance to become pollinated. After pollination, the flower rapidly withers."—WM. TRELEASE.

NEWS.

Dr. W. F. R. Suringar, Professor of Botany and Director of the Botanical Garden at Leiden since 1862, died on July 11 at the age of 66 years.

Dr. Carl Fritsch has been appointed director of the Botanical Museum of Vienna as the successor of the late Dr. Anton Kerner von Marilaun.

Professor Dr. Karl Goebel, director of the Institute for Plant Physiology in Munich, is absent upon a journey to Australia and New Zealand.

Professor Volney M. Spalding, of the University of Michigan, has been granted a year's leave of absence. Dr. Julia W. Snow has been appointed instructor in botany in the same institution.

Professor L. M. Underwood of Columbia University returned on October 4 from his vacation trip in Europe, where he examined many herbaria for type material of Pteridophyta and Polyporei.

Mr. C. F. Baker of the Alabama Polytechnic Institute sailed from New York on November 5 for an extended collecting tour in South America, beginning at the northern border of Columbia, the region first visited by Jussieu and Bonpland. He will touch at Jamaica on the way.

The important investigations by W. Belajeff upon the male prothallia of the water ferns (Hydropterideæ), published in Russian in 1890, have been made more available to botanists in general by their republication in German. See Bot. Zeit. **56**^{1} : 141–194. *pl. 2.* 1898.

The Lloyd series of photogravures of American Fungi has been increased by the issue last month of two numbers, one of *Polyporus umbellatus* Fr., and the other of *Strobilomyces strobilaceus* Scop. The latter, showing a common species known as black boletus, is from a remarkably perfect photograph.

Professor Dr. Paul Knuth, of Kiel, started in October from Genoa upon a scientific tour of the world. He will be absent from eight to ten months, going through India to Java, where he will remain in Buitenzorg for some time, thence to China and Japan, and finally by way of Honolulu to this country.

Mr. E. W. D. Holway, who spent six weeks in Mexico during September and October, has brought back many new and interesting rusts and other fungi. He collected in the region about the city of Mexico, somewhat at Mt. Orizaba and Vera Cruz, and northward, the last stop being made at San Luis Potosi and vicinity.

PROFESSOR W. F. GANONG, of Smith College, Northampton, Mass., wishes to obtain seeds of Cactaceæ collected in the field by botanists who can vouch for the accuracy of their determinations, particularly from localities outside of the United States. They are wanted for studies upon the embryology of the family in continuation of a work upon the subject now in press. Exchange will be made if desired.

THE NATIONAL HERBARIUM at Washington recently received the entire collection made by Dr. W. H. Forwood in western Wyoming in the years 1881–2. These plants form the basis for two reports published by the War Department, both of which are now quite difficult to obtain. Many of them, also, are reported upon in Mr. Frank Tweedy's *Flora of the Yellowstone.*

THE REPORT of Dr. D. Prain, the Director of the Botanical Survey of India, for the year 1897–8, is largely occupied by a continuation of Professor Woodrow's *Flora of Western India.* He records the botanical explorations which have been made during the year, of portions of Assam and Burma; in the latter of which great assistance was rendered by Lieut. E. Pottinger, R. A.—*Nature.*

A PRIZE OF 4000 MARKS is offered by the Economic Society of Mohrungen, near Königsberg, for the best work on the relations of electricity to living organisms. This work must discuss either fundamentally new phenomena in plant or animal electricity, or, from the point of view of physics, discuss the sources of organic electricity, or its significance for life in general or for certain functions.

UNDER THE AUSPICES of the New York Botanical Garden Mr. A. A Heller will shortly leave for Porto Rico to make collections of the flora of our newly acquired territory. The flora of this island is very imperfectly represented in herbaria either in this country or in Europe. Arrangements will be made for preserving specimens both dried and in formalin. The expenses of the expedition will be borne by Mr. Cornelius Vanderbilt.

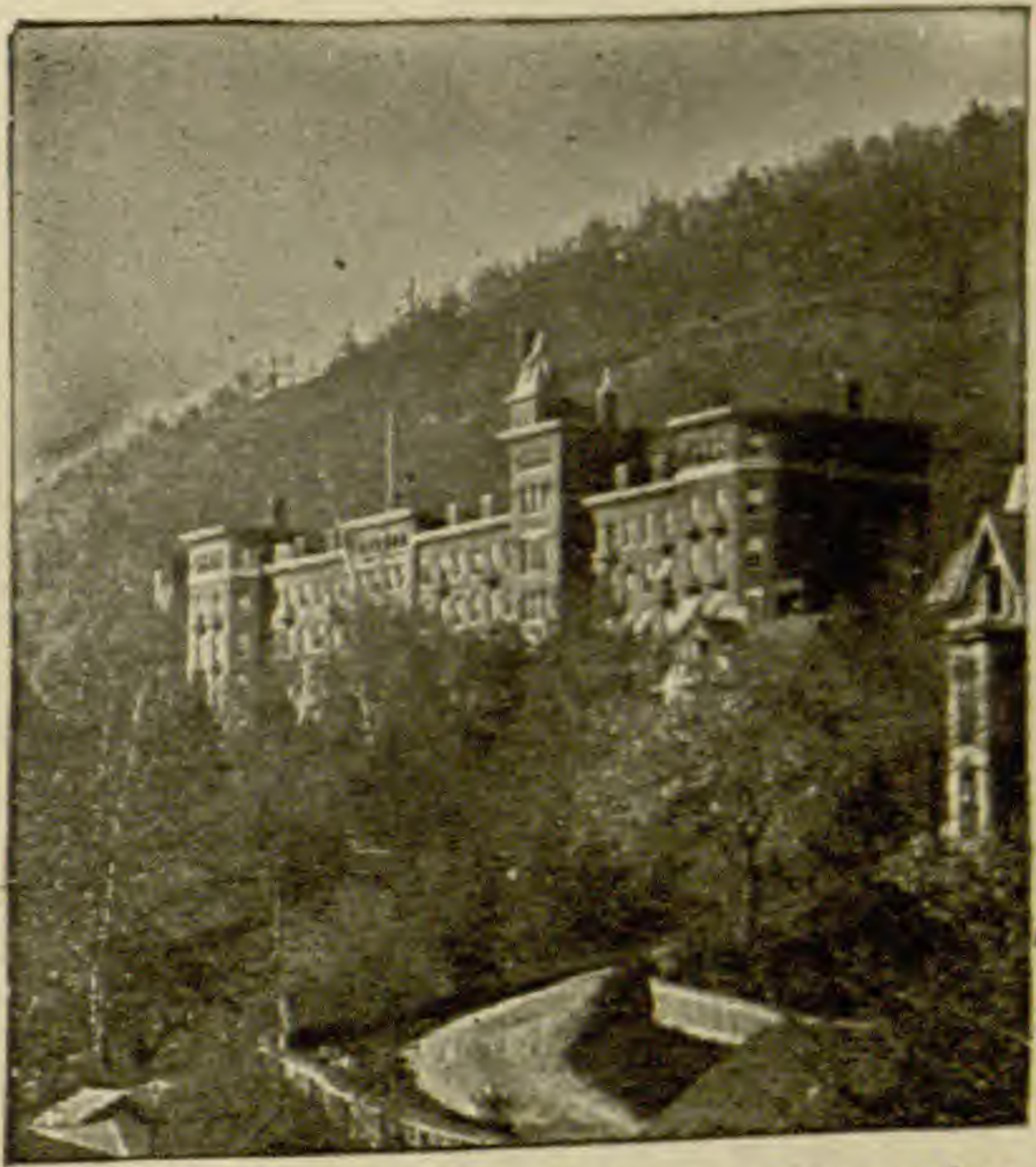
IN HIS ADDRESS before the Section of Botany of the British Association, Professor F. O. Bower, President, discusses the homology of the members of the plant body at large with special reference to the question of homology involved in the alternation of generations in green plants. The paper is one that will be of large interest at the present time. It includes, also, some suggestive remarks upon the methods to be used in terminology. Professor Marshall Ward read a paper upon Penicillium as a wood destroying fungus, in which he showed that this plant, one of our commonest molds, undoubtedly plays an important part in the reduction of plant offal to the vegetable mold which makes up largely the soil of our forests. It was not determined in how far the fungus could initiate the destruction of the wood, if indeed it does not merely follow the attacks of other fungi and bacteria.

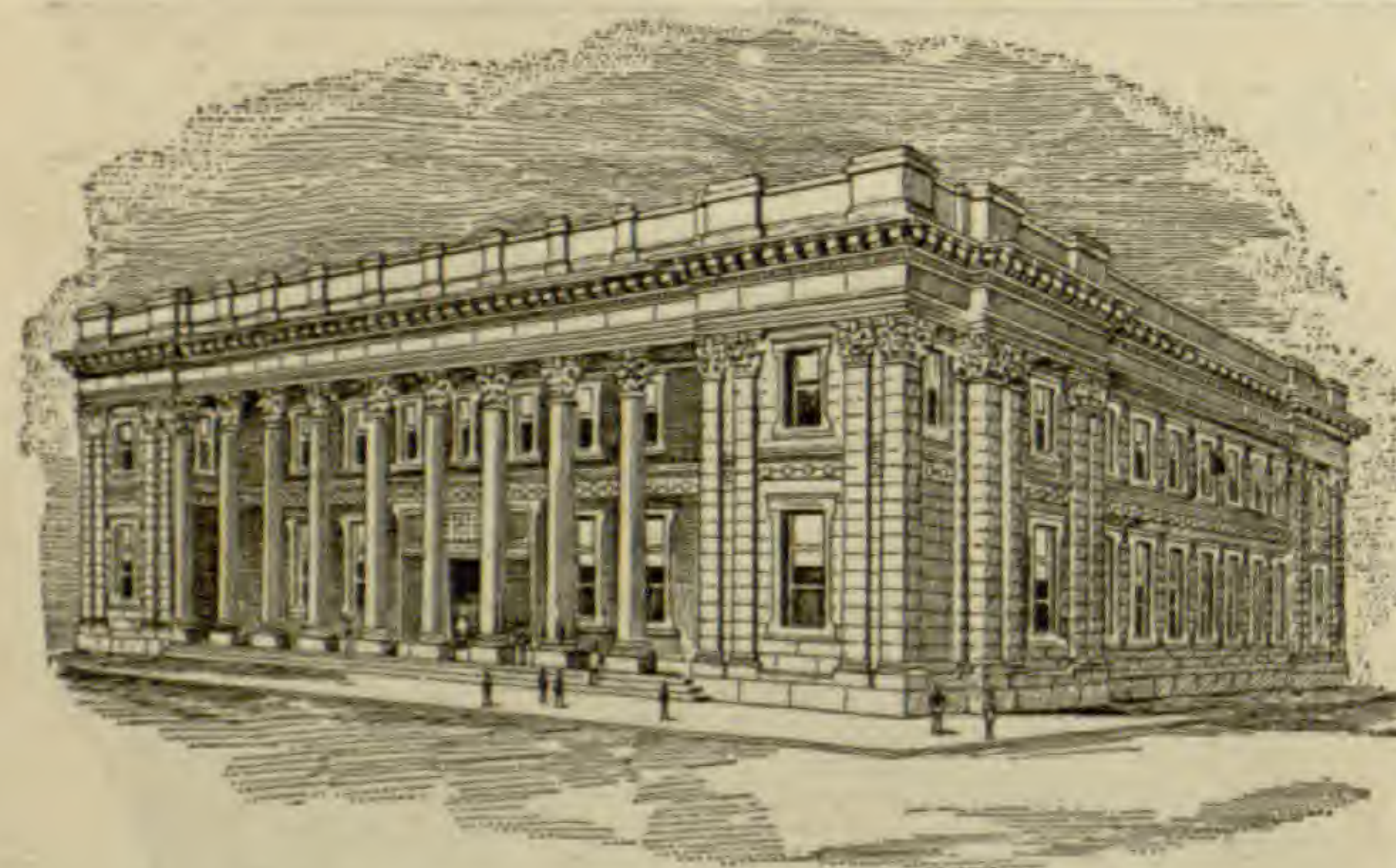
EDWARD TATNALL, one of our best local botanists, died somewhat suddenly at Wilmington, Del., on the 30th of May last in his eightieth year. Almost from childhood he had strong botanical tastes, and, as these increased, they were fostered and appreciated by his association and correspondence with such botanists as Darlington, James, Gray, Engelmann, and many others. He was the author of the "Catalogue of the plants of New Castle county, Delaware," which passed through two editions. Many herbaria in this and foreign lands have been enriched by his collections. He retained his active interest in botany to the last day of his life, and his death was much regretted by all who knew him.

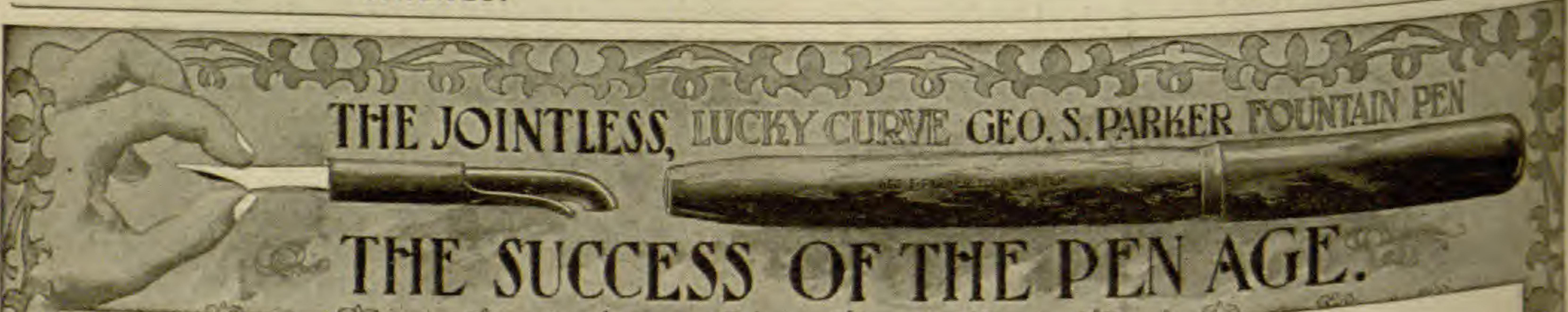
CARD'S *Bush fruits*, one of the "Rural Science Series," is just off the press. It is very full in botanical matter, containing descriptions of all forms of Rubus and Ribes, wild and cultivated, in North America, with very many illustrations, following, in this respect, the precedent of Fuller's *Small fruit culturist*. It also has full lists of fungi which attack blackberries, raspberries, currants, gooseberries, etc. Bailey's *Evolution of our native fruits*, just published, contains a revision, with new names, of American blackberries and dewberries. Two of Professor Bailey's works, the *Forcing book* and *Plant breeding*, are now being translated into French. They are the first American horticultural books to be republished in France.

THE BOTANICAL expedition to the LaPlata and San Juan mountains of Colorado was in the field four weeks last summer, the time being unexpectedly shortened. During that time the three collectors, Professor F. S. Earle, C. F. Baker, and S. M. Tracy, secured about 25,000 specimens. Eighteen uniform sets (all sold in advance) will be distributed shortly, beside which there will be a number of partial sets (a few yet remaining unsold). It is believed that the series is more than usually valuable, both on account of the biological importance of the region, and from the care exercised to secure all available forms and variations. There are also a number of new species, and quite a number of rare ones, including *Ranunculus Macauleyi*, in flower and fruit, *Astragalus Wingatensis*, *Cerastium arvense Fuegianum*, *Fendlera rupicola*, and others. The sets will form the basis for a report upon the season's work, to be issued with the aid of Dr. E. L. Greene.

ACCORDING TO THE *Bulletin of Miscellaneous Information* of the Kew Gardens, the duties of the new department in the West Indies to be administered by the Imperial Commissioner of Agriculture, Dr. Morris, are to induce the people, as far as possible, to substitute other industries for sugar raising, which is the almost universal occupation. Besides this, the department is to deal with all questions concerning economic plants and the botanical stations in all the islands. For the first year a grant of £4500 was made by Parliament with the expectation that the annual charges hereafter for the department will be £17,000. The establishment of this new department is an experiment in the hope of again placing these colonies in a self-supporting condition by diversifying the agriculture. It is intended, also, that the means of communication between the islands and the markets should be greatly improved. The government purposes establishing a line of steamers between the islands and New York, and also to secure, if possible, better communication between Jamaica and London. Fortnightly communication between the different islands is also to be established. The grant for these purposes, however, is to be separate from that intended for experimental and agricultural work.



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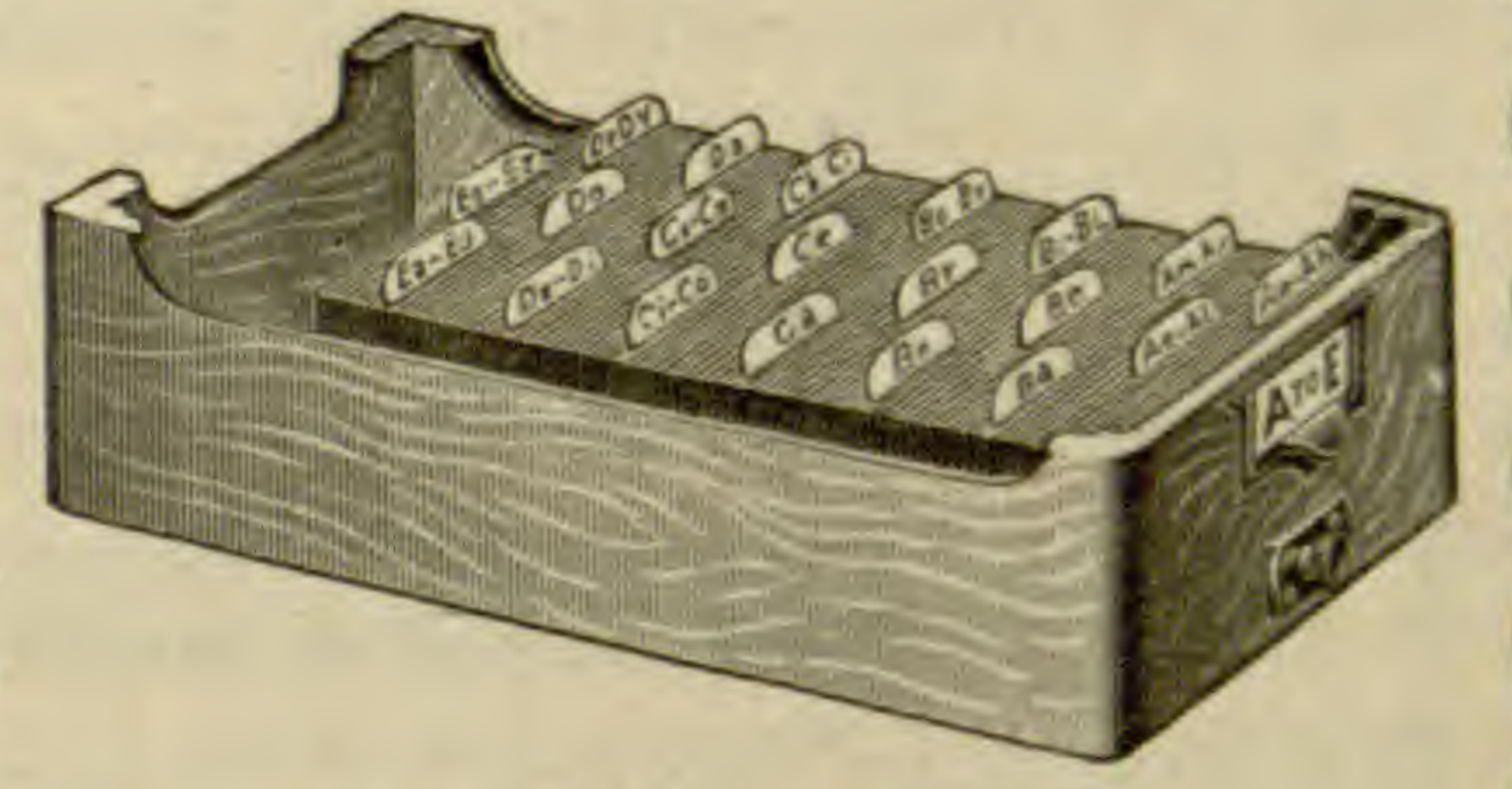

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Vol. XXVI DECEMBER 1898 No. 6

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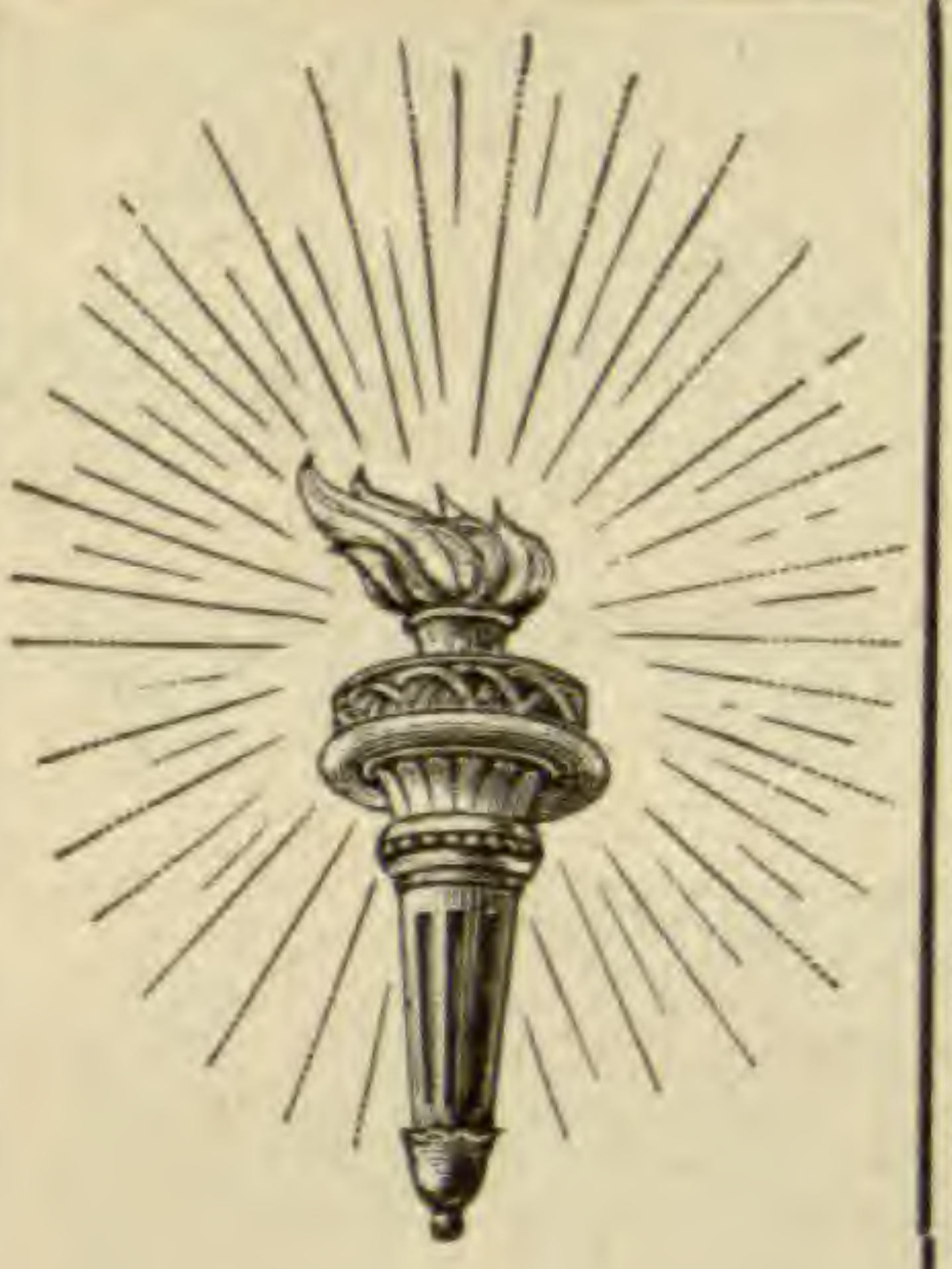

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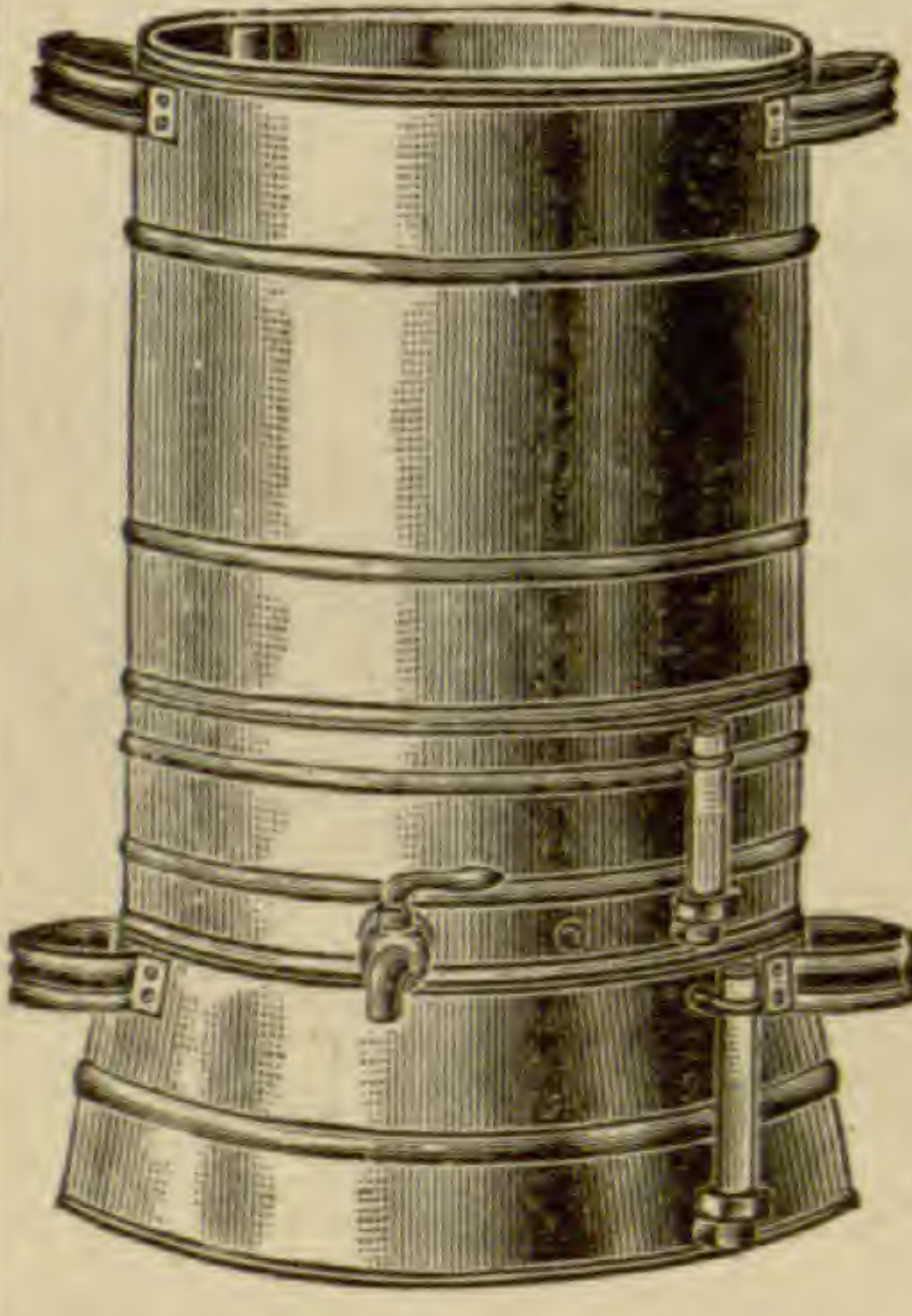

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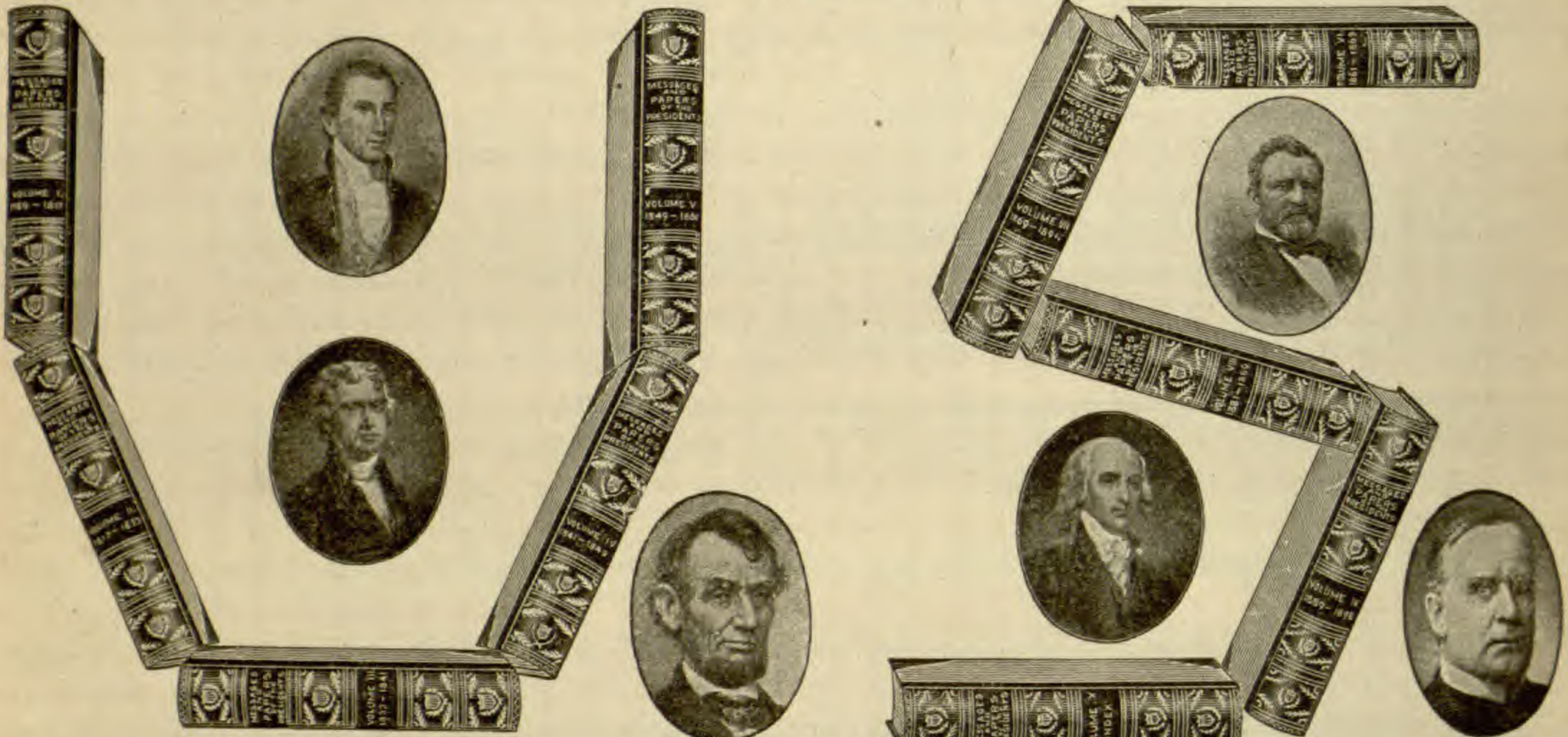

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VOLUME XXVI NUMBER 6

BOTANICAL GAZETTE

DECEMBER 1898

THE EFFECT OF AQUEOUS SOLUTIONS UPON THE GERMINATION OF FUNGUS SPORES.[1]

F. L. STEVENS.

OBJECT.

THE primary object in the work here related was to establish with some degree of accuracy the strengths of various solutions which are necessary to prevent the growth of fungus spores.

The bearing of this question upon the relation of a fungicide to its efficiency is apparent, and from the wide use of these compounds it seems important that all knowledge possible should be gained regarding the principles underlying their action.

Incidentally, new evidence bearing upon the theory of the hydrolytic dissociation of the molecule is adduced; also facts which may throw some light upon the structure of the cell wall

PRELIMINARY.

Before work bearing results could be practically undertaken, it became necessary to select the best manner of working, and the materials to use, and to become familiar with the sources of error most common.

---

[1] Contributions from the Hull Botanical Laboratory. XI.

After various means of culture had been tried, the van Tieghem hanging drop proved the most satisfactory.

In the selection of material such fungi were chosen as could be obtained in abundance, could be easily kept in stock culture, were not liable to become seriously impure, and, of most importance, such as would uniformly grow in the kind of culture medium used.

Botrytis vulgaris Fr., *Macrosporium* (*sp.* ?) from the fruit of *Datura Tatula*, *Glœosporium Musarum* C. & M., and *Uromyces caryophyllinus* (Schrank) Schr., were selected. *Penicillium crustaceum* (Linn.) Fries was useful in tube cultures.

Many other fungi were tried but presented disadvantages which prohibited their use.

Several hundred cultures were made to ascertain whether there was any toxic effect from the cells, cement, or oil used to seal the cell, and to note whether or not nourishing materials were useful in the solution.

METHODS.

The cultures were made in hanging drop in van Tieghem cells used in the usual manner with vaseline as an adhesive. It was not found necessary to place them in a moist chamber, as they did not dry if carefully sealed. Cultures were uniformly examined about twenty-four hours after their preparation and every time that a series of cultures was made, a series of check cultures in distilled water was prepared. In every case where the checks failed to grow, all negative results were discarded The cells themselves were frequently thoroughly cleansed and the cover glasses were carefully wiped each time before using washed in alcohol and wiped again.

In order to facilitate the making of cultures a tube was bent as shown in the figure on opposite page. By slightly raising the long end the liquid rises in the short end and a hanging drop of any desired size is readily placed on the cover glass.

This tube was washed, then rinsed with the solution under observation, then filled with that solution. This and all other tubes and bottles used were, of course, very thoroughly washed before introducing another chemical or one of different strength. The drop being upon the cover glass, a clean teasing needle or platinum needle was touched to the stock culture, and then to the hanging drop. Before using this needle with another chemical it was washed. Sterilization was nowhere necessary, as the culture was to be of such short duration that bacteria or other fungi did not develop.

The cultures of *Penicillium crustaceum* (Linn.) Fries were made otherwise. A small piece of bread $2 \times 1 \times 1^{cm}$ was soaked in the solution under experimentation, then placed in a 15^{cm} test tube where it was about three quarters immersed in the solution. It was then inoculated with the Penicillium, evaporation being prevented by a stopper to the tube.

Readings were made with this fungus when the checks had begun to grow well.

In order to insure that a proper planting had been made, and to be sure that no spores had been germinated previous to being placed in the solution, each slide was microscopically examined before placing away.

The series of cultures being made, the slides bearing them were placed away in a thermostat on a metallic slide holder.

SOLUTIONS.

Inasmuch as the object of the work was to investigate the effect of the salts upon the growth of the fungus, it was deemed advisable to prepare solutions the composition of which should be based upon their molecular weight rather than upon a percentage basis. To do this the molecular weight of the salt, base, or acid was estimated, and this weight taken in grams was dissolved in one liter of water. Such a solution is designated throughout this article as a *normal solution.* Thus, potassium hydrate has the formula KOH. K, O and H have respectively the atomic weights 38.85, 15.88 and 1. Therefore the molecular weight of KOH is 55.73. Then 55.73^{gm} of potassium hydrate dissolved in one liter of water constitutes a normal solution of potassium hydrate.

It will be readily seen then that, the work being accurately done and the molecular formulæ being correct, a normal solution of any substance will contain as many molecules per cubic centimeter as a normal solution of any other substance.

In a few cases solutions of greater than normal strength were used, but generally, if the substance did not prevent growth when in one-tenth of normal strength, the substance was considered non-poisonous and was not experimented with further.

Starting with a normal solution, dilutions were easily made till such strength was reached that the spores would germinate The various strengths used are designated as fractions of normal Thus $\frac{n}{800}$ signifies a solution of one eight-hundredth normal, a strength which could be prepared by taking one cubic centimeter of normal solution and diluting it to 800^{cc}. Ten cubic centimeters of $\frac{n}{800}$ diluted to 80^{cc} would furnish $\frac{n}{6400}$, etc.

The atomic weights used are those given by Roscoe and Schorlemmer.[2]

TABULATION AND DISCUSSION.

In tables I–XVI appears a record of the cultures made, more than 1500 in all, each culture bearing from fifty to a few thousand spores. The fraction shows the strength of solution used, and the figure to the left of the fraction shows the number of times this strength was tried. If the fungus grew, the strength in which it grew appears in the corresponding column. Those strengths in which it failed are to be found in the column headed Failed. Reference to a footnote indicates some peculiarity regarding the culture, which will be found explained in the note. The numbers used in these footnotes are original numbers of the cultures.

---

[2] Treatise on Chemistry 1 : 52. 1895 [ed. 3].

TABLE I.

MERCURIC CHLORID.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
1 $\frac{n}{51200}$ *	4 $\frac{n}{12800}$	3 $\frac{n}{819200}$	1 $\frac{n}{819200}$	2 $\frac{n}{25600}$	2 $\frac{n}{3200}$	2 $\frac{n}{204800}$	6 $\frac{n}{6400}$
3 $\frac{n}{102400}$	5 $\frac{n}{25600}$	5 $\frac{n}{409600}$ †	3 $\frac{n}{409600}$	2 $\frac{n}{12800}$		1 $\frac{n}{51200}$	
8 $\frac{n}{204800}$	2 $\frac{n}{51200}$	4 $\frac{n}{204800}$ ‡	6 $\frac{n}{204800}$	2 $\frac{n}{6400}$		3 $\frac{n}{25600}$	
	1 $\frac{n}{102400}$	1 $\frac{n}{102400}$	3 $\frac{n}{102400}$	6 $\frac{n}{3200}$ §		4 $\frac{n}{12800}$ ¶	
			4 $\frac{n}{51200}$				
			4 $\frac{n}{25600}$				

*No. 436. Growth scattered.

†No. 157. Four cultures normal and one slight but uniform.

‡No. 156. One culture, slight but uniform.

§No. 927. Slight growth; was dry.

¶No. 200. Scattered growth.

Mercuric chlorid.—Thus we see that Botrytis grew in $\frac{n}{204800}$ in eight different cultures, and there is no evidence that this strength injures it. In $\frac{n}{102400}$ three cultures grew normally and one failed to grow. The growth here may be considered as normal. In $\frac{n}{51200}$, twice as strong as the last, growth was poor in one culture, two failed utterly, and the strength necessary to prevent germination is evidently reached. Five cultures of twice this strength or $\frac{n}{25600}$ were tried, but all failed to germinate.

So it can be concluded that the strength which prevents most spores from growing is $\frac{n}{51200}$, and that $\frac{n}{25600}$ is a sure preventive. Then the range from sure prevention of growth to a normal growth is from $\frac{n}{25600}$ to $\frac{n}{102400}$.

With Macrosporium the growth was normal for $\frac{n}{819200}$, while $\frac{n}{409600}$ and $\frac{n}{204800}$ grew but gave evidence of injury, and $\frac{n}{51200}$ proved a sure preventive. With Penicillium, starting with as weak as $\frac{n}{25600}$, the growth was normal, in as strong as $\frac{n}{3200}$ a killing strength was not reached.

Uromyces, from a generalization made in my notebook, grew normally in $\frac{n}{25600}$, not quite as well in $\frac{n}{12800}$, and is prevented by $\frac{n}{6400}$ except in very rare cases, where a single spore grows.

TABLE II.

POTASSIUM CYANID.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
2 $\frac{n}{6400}$	1 $\frac{n}{800}$	2 $\frac{n}{25600}$	1 $\frac{n}{400}$	2 $\frac{n}{12800}$	2 $\frac{n}{100}$	2 $\frac{n}{25600}$	2 $\frac{n}{800}$
2 $\frac{n}{3200}$		2 $\frac{n}{800}$	2 $\frac{n}{50}$	2 $\frac{n}{800}$		2 $\frac{n}{6400}$	3 $\frac{n}{200}$ †
1 $\frac{n}{800}$		1 $\frac{n}{400}$	1 $\frac{n}{50}$ *	2 $\frac{n}{400}$		2 $\frac{n}{3200}$	7 $\frac{n}{100}$
2 $\frac{n}{400}$		2 $\frac{n}{100}$		2 $\frac{\text{n}}{200}$		4 $\frac{n}{800}$	
						1 $\frac{n}{400}$	
						2 $\frac{n}{100}$	

* No. 1369. Some grew poorly.

† No. 1363. Nearly all grew to about half normal size.

Potassium cyanid.—Potassium cyanid was tried upon Glœosporium and other fungi, and, notwithstanding its great toxic action upon animal organisms, proved comparatively harmless to the spores. Starting with $\frac{n}{6400}$ on Glœosporium, successively stronger solutions were tried till $\frac{n}{400}$ was reached without preventing growth. No stronger solutions were tried.

Macrosporium with potassium cyanid was started at $\frac{n}{25600}$, and successively stronger solutions taken till $\frac{n}{50}$ was reached. In this strength one culture grew poorly and two failed, so that the fatal strength was evidently reached. With Penicillium $\frac{n}{100}$ proved fatal. Uromyces grew normally till a strength of $\frac{n}{200}$ was reached. In this the growth was much stunted in one culture, and two failed. In $\frac{n}{100}$ two cultures grew somewhat, while seven failed utterly.

The unexpectedly low toxic action of potassium cyanid is puzzling, especially as other experimenters[3] upon spermatophytes find its toxic action about one-half that of mercuric chlorid.

It is evident that the action of this salt upon fungi is not as vigorously toxic as upon higher plants and animals.

TABLE III.

HYDROCHLORIC ACID.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
3 $\frac{n}{800}$		2 $\frac{n}{6400}$	1 $\frac{n}{200}$	1 $\frac{n}{6400}$	1 $\frac{n}{6400}$	2 $\frac{n}{3200}$	2 $\frac{n}{800}$
2 $\frac{n}{400}$		2 $\frac{n}{400}$	3 $\frac{n}{50}$	2 $\frac{n}{400}$		2 $\frac{n}{800}$	1 $\frac{n}{400}$
1 $\frac{n}{200}$		1 $\frac{n}{200}$		2 $\frac{n}{200}$		1 $\frac{n}{400}$	2 $\frac{n}{200}$
1 $\frac{n}{100}$		4 $\frac{n}{100}$		2 $\frac{n}{100}$		2 $\frac{n}{100}$	2 $\frac{n}{100}$
		2 $\frac{n}{50}$ *		2 $\frac{n}{50}$			4 $\frac{n}{50}$ †

* No. 1376. Not quite normal.

† No. 1358. Stunted.—1359. About 1 in 200 grew.

Hydrochloric and sulfuric acids.—These acids have about an equal status in the results of the work upon Glœosporium. Starting with a solution of $\frac{n}{800}$ the spores grew normally. Gradually stronger solutions were taken till growth was evident in $\frac{n}{100}$ with HCl, but H_2SO_4 of this strength weakened the growth perceptibly. Glœosporium here became irregular in its behavior, and the killing point was not reached. The secondary spores so common in this genus were produced, however, in

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[3] KAHLENBERG and TRUE, On the toxic action of dissolved salts and their electrolytic dissociation. BOT. GAZ. **22**: 81.

F. D. HEALD, On the toxic effect of dilute solutions of acids and salts upon plants. BOT. GAZ. **22**: 125.

unusual abundance in these solutions, and may have been an indication of injurious action. The fact may also be significant that abnormal and distorted mycelium more frequently resulted than in ordinary nutrient solution.

TABLE IV.

SULFURIC ACID.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
3 $\frac{n}{800}$*	1 $\frac{n}{800}$	3 $\frac{n}{800}$	1 $\frac{n}{800}$	2 $\frac{n}{6400}$		2 $\frac{n}{800}$	1 $\frac{n}{800}$
2 $\frac{n}{400}$		2 $\frac{n}{400}$	2 $\frac{n}{100}$	2 $\frac{n}{400}$		1 $\frac{n}{400}$	1 $\frac{n}{400}$
2 $\frac{n}{200}$		2 $\frac{n}{200}$†	2 $\frac{n}{50}$	2 $\frac{n}{200}$		1 $\frac{n}{200}$	1 $\frac{n}{200}$
1 $\frac{n}{100}$		2 $\frac{n}{100}$		2 $\frac{n}{100}$		1 $\frac{n}{100}$	6 $\frac{n}{100}$
		2 $\frac{n}{50}$		2 $\frac{n}{50}$			

*No. 1338. Poorly.

†No. 1094. Stunted.

‡No. 1028. Ten in 100 grew poorly.

With Macrosporium and Penicillium neither acid prevented growth at $\frac{n}{50}$. Uromyces was exceedingly variable in its behavior with these acids, and the results, as far as they can be interpreted, seem to show H_2SO_4 to be a trifle more toxic. The killing point of HCl apparently is $\frac{n}{50}$, while for H_2SO_4 it is $\frac{n}{100}$.

Alcohol.—Glœosporium germinated normally in alcohol of semi-normal strength. Macrosporium even grew in five times normal strength, while Penicillium grew in semi-normal, but failed in normal. Uromyces grew in five times normal. Stronger solutions were not tried, owing to the inability to secure hanging drops in stronger solutions. The low toxic power might be sought here in volatility, but this seems not to be the cause, as it was evident that the Uromyces, Botrytis, and Macrosporium were stimulated by the alcohol. More spores grew, and they grew far more luxuriantly than in water.

TABLE V.

ALCOHOL.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
$2\ \frac{n}{10}$		$2\ \frac{n}{10}$		$2\ \frac{n}{5}$	$4\ \frac{2n}{1}$	$2\ \frac{n}{10}$	
$2\ \frac{n}{1}$		$2\ \frac{n}{1}$		$2\ \frac{n}{2}$	$2\ \frac{n}{1}$	$2\ \frac{n}{1}$ *	
		$2\ \frac{5n}{1}$				$2\ \frac{5n}{1}$	

*No. 480. Much knotted and distorted.

TABLE VI.

COPPER SULFATE.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
$2\ \frac{n}{12800}$	$1\ \frac{n}{6400}$	$1\ \frac{n}{12800}$	$6\ \frac{n}{6400}$	$2\ \frac{n}{6400}$	$1\ \frac{n}{800}$	$2\ \frac{n}{12800}$	$3\ \frac{n}{6400}$
$5\ \frac{n}{6400}$ *	$2\ \frac{n}{3200}$	$2\ \frac{n}{6400}$ †	$2\ \frac{n}{3200}$	$2\ \frac{n}{3200}$	$2\ \frac{n}{200}$	$5\ \frac{n}{6400}$ ‡	$2\ \frac{n}{3200}$ §
	$2\ \frac{n}{100}$		$2\ \frac{n}{100}$	$2\ \frac{n}{1600}$			$1\ \frac{n}{100}$ ¶
				$3\ \frac{n}{800}$			
				$2\ \frac{n}{400}$			

*No. 274. Scattered.
†No. 377. Grew slightly.
‡No. 706. One culture stunted.
§No. 700. One in 300 grew.
¶No. 290. A few grew in one culture.

Copper sulfate.—Botrytis failed in $\frac{n}{3200}$, grew poorly in $\frac{n}{6400}$, and normally in $\frac{n}{12800}$. Macrosporium behaved in a similar manner, but was more injured by $\frac{n}{6400}$.

TABLE VII.

COPPER NITRATE.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
2 $\frac{n}{6400}$	2 $\frac{n}{3200}$	1 $\frac{n}{6400}$	2 $\frac{n}{100}$	2 $\frac{n}{6400}$	2 $\frac{n}{200}$ *	2 $\frac{n}{6400}$	2 $\frac{n}{3200}$
	2 $\frac{n}{100}$	1 $\frac{n}{3200}$		2 $\frac{n}{3200}$			2 $\frac{n}{100}$
				2 $\frac{n}{800}$			
				2 $\frac{n}{400}$			

* No. 956. Grew on dry part only in one culture.

TABLE VIII.

COPPER ACETATE.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
2 $\frac{n}{6400}$	2 $\frac{n}{3200}$	2 $\frac{n}{6400}$	3 $\frac{n}{3200}$	2 $\frac{n}{3200}$	2 $\frac{n}{800}$	2 $\frac{n}{6400}$	6 $\frac{n}{1600}$ *
		1 $\frac{n}{3200}$	2 $\frac{n}{1000}$	2 $\frac{n}{1600}$		4 $\frac{n}{3200}$	3 $\frac{n}{800}$ †
							4 $\frac{n}{400}$ ‡
							4 $\frac{n}{200}$

* No. 524. Twenty per 100 grew.—No. 525. Eighteen in 150 grew.
† No. 551. Five in 100 grew.—No. 552. A few in a bunch grew.
‡ No. 586. Six in 100 grew.—No. 587. Four in 100 grew.

Copper nitrate.—Botrytis grew in $\frac{n}{6400}$ and failed in $\frac{n}{3200}$. Macrosporium grew in $\frac{n}{3200}$. Penicillium grew in $\frac{n}{400}$, and in $\frac{n}{200}$ one culture became dry and grew at the dry portion, but the culture which remained moist showed no growth. Uromyces grew in $\frac{n}{6400}$, but failed in $\frac{n}{3200}$.

Here it first became evident that Uromyces, as the toxic solution becomes stronger, does not diminish in vigor of growth, but does diminish in the number of germinating spores.

Copper acetate.— Botrytis grew in $\frac{n}{6400}$ and failed in $\frac{n}{3200}$. Macrosporium grew in $\frac{n}{6400}$ and failed in $\frac{n}{3200}$. Penicillium grew in $\frac{n}{1600}$ and failed in $\frac{n}{800}$. Uromyces was a practical failure in $\frac{n}{800}$ or stronger, but some spores grew poorly in $\frac{n}{400}$, and, on the other hand, were much injured by $\frac{n}{3200}$. There was no growth it $\frac{n}{200}$, which was tried four times.

TABLE IX.

COPPER CHLORID.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
1 $\frac{n}{12800}$	2 $\frac{n}{6400}$		2 $\frac{n}{3200}$	2 $\frac{n}{6400}$	2 $\frac{n}{200}$	1 $\frac{n}{6400}$	4 $\frac{n}{3200}$ *
	2 $\frac{n}{3200}$			2 $\frac{n}{3200}$			4 $\frac{n}{1600}$ †
	2 $\frac{n}{1600}$			2 $\frac{n}{1600}$			
				2 $\frac{n}{800}$			
				2 $\frac{n}{400}$			

*No. 758. Four in 100 grew.— No. 759. One half usual number grew.

†No. 757. Three in 200 grew.

Copper chlorid.—This was tried upon Glœosporium. In $\frac{n}{12800}$ it grew, while in $\frac{n}{6400}$ it failed. Macrosporium was tried with only one strength, $\frac{n}{3200}$. It failed to grow. Penicillium grew in $\frac{n}{400}$ and weaker, and failed in $\frac{n}{200}$. Uromyces in $\frac{n}{6400}$ grew; in $\frac{n}{3200}$ three grew very poorly and one failed. This is evidently a killing strength.

Potassium permanganate.— The killing strength of this chemical was determined with much accuracy, and in experimentation presented interesting phenomena. In strong solutions, that is $\frac{n}{100}$ or stronger, it stained the protoplasm and prevented growth. With Glœosporium $\frac{n}{800}$ prevented growth and $\frac{n}{1600}$ allowed it. At this strength the protoplasm was barely tinted.

That strong solutions are withstood by Penicillium may be partly explained by the decompositions due to the organic matter present; but this can only slightly reduce the amount of the salt present.

Uromyces grew normally in $\frac{n}{400}$, and there was practically no growth in $\frac{n}{200}$ or stronger, although in culture 749 one spore, standing unprotected in the hanging drop and to all appearances in the same conditions as any of the others in the drop, grew normally, although the protoplasmic contents of its germ tube were colored strongly. This apparently perfectly normal growth, while the surrounding spores remained completely undeveloped, may be taken as almost typical of the behavior of the uredospores of *Uromyces caryophyllinus* when in highly poisonous solutions.

TABLE X.

POTASSIUM PERMANGANATE.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
2 $\frac{n}{1600}$	2 $\frac{n}{800}$			2 $\frac{n}{20}$		4 $\frac{n}{400}$	2 $\frac{n}{200}$
	4 $\frac{n}{400}$			2 $\frac{n}{10}$			2 $\frac{n}{100}$ *
	2 $\frac{n}{200}$						

*No. 749. One spore grew well.

Sodium chlorid.—This proved practically non-toxic. With Botrytis a semi-normal solution did not prevent normal germination. Macrosporium grew in a normal solution. With these two fungi a killing strength was not obtained.

TABLE XI.

SODIUM CHLORID.

Glœosporium		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
4 $\frac{n}{6400}$		4 $\frac{n}{3200}$		3 $\frac{n}{50}$		2 $\frac{n}{3200}$ †	5 $\frac{n}{2}$ ‡
2 $\frac{n}{1600}$ *		2 $\frac{n}{100}$		2 $\frac{n}{2}$		2 $\frac{n}{100}$	2 $\frac{n}{1}$
4 $\frac{n}{100}$		2 $\frac{n}{2}$		2 $\frac{2n}{1}$			4 $\frac{2n}{1}$
2 $\frac{n}{1}$		1 $\frac{n}{1}$					2 $\frac{4n}{1}$

* No. 25. Apparently stimulated. † No. 146. Apparently stimulated.

‡ No. 446. In one culture only 3 per cent. grew.

TABLE XII.

POTASSIUM CHROMATE.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
	1 $\frac{n}{640}$	2 $\frac{n}{640}$ †	1 $\frac{n}{320}$		2 $\frac{n}{640}$	2 $\frac{n}{320}$	3 $\frac{n}{40}$ ¶
	2 $\frac{n}{320}$	1 $\frac{n}{320}$	2 $\frac{n}{10}$		2 $\frac{n}{320}$	4 $\frac{n}{160}$ ‡	2 $\frac{n}{10}$
	2 $\frac{n}{40}$	1 $\frac{n}{40}$ *			2 $\frac{n}{160}$	3 $\frac{n}{80}$ §	
	2 $\frac{n}{10}$				2 $\frac{n}{80}$		
					2 $\frac{n}{10}$		

* No. 539. Growth slight. † No. 652. Growth slight.

‡ No. 611. Many failed, but those which grew were normal.

§ Nos. 602, 604. Nearly every spore grew, but the tubes were about half the usual length, and the protoplasm was granular and finally plasmolyzed.

¶ Nos. 640, 641. One in 200 grew.—No. 642. Two in 200 grew.

Potassium chromate.—Uromyces failed in three cultures $\frac{n}{40}$. One culture in $\frac{n}{40}$ had one spore grow, but this grew with remarkable vigor, producing a tube fully twice the usual length, while in two other cultures of the same strength respectively one in 100 and two in 200 grew. The fatal strength here is thus evidently $\frac{n}{40}$, while $\frac{n}{160}$ has an appreciable toxic action, and $\frac{n}{80}$ is strongly toxic.

TABLE XIII.

POTASSIUM BICHROMATE.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
	2 $\frac{n}{1280}$	2 $\frac{n}{3200}$*	2 $\frac{n}{1280}$		3 $\frac{n}{1600}$	2 $\frac{n}{3200}$†	2 $\frac{n}{1280}$
	2 $\frac{n}{640}$		2 $\frac{n}{640}$		2 $\frac{n}{800}$	3 $\frac{n}{640}$‡	1 $\frac{n}{640}$
	2 $\frac{n}{320}$		2 $\frac{n}{320}$		2 $\frac{n}{160}$		2 $\frac{n}{320}$
	2 $\frac{n}{160}$		2 $\frac{n}{160}$		2 $\frac{n}{10}$		2 $\frac{n}{160}$
	2 $\frac{n}{40}$		2 $\frac{n}{40}$				2 $\frac{n}{40}$
	2 $\frac{n}{10}$		2 $\frac{n}{10}$				4 $\frac{n}{10}$

*No. 715. Grew poorly.

†Nos. 712, 713. One in seventy-five grew normally.

‡No. 634. Two spores grew well.—No. 635. One in eighty grew.—No. 636 Three in seventy-five grew.

Potassium bichromate.—This would not allow the germination of Botrytis spores when of $\frac{n}{1280}$ strength. No weaker was tried. Macrosporium would not grow in $\frac{n}{1280}$, and in the next weaker tried, $\frac{n}{3200}$, it grew poorly. Penicillium failed to grow in $\frac{n}{1600}$, and weaker were not tried. Uromyces spores were nearly all killed by $\frac{n}{640}$, would not grow in stronger, and were injured by even weaker. Penicillium grew in as strong as double normal, and killing strength was not reached. Uromyces was prevented almost completely by $\frac{n}{2}$, and stronger solutions absolutely prohibited germination. Weak solutions, such as $\frac{n}{3200}$, seemed to stimulate the early growth somewhat.

TABLE XIV.

AMMONIUM NITRATE.

Botrytis		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed
2 $\frac{n}{4}$ *	2 $\frac{n}{2}$	2 $\frac{n}{2}$		1 $\frac{n}{4}$	2 $\frac{n}{2}$

* No. 654. Growth slight.

TABLE XV.

POTASSIUM HYDROXID.

Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed
4 $\frac{n}{200}$		2 $\frac{n}{50}$	1 $\frac{n}{20}$ *	2 $\frac{n}{200}$	2 $\frac{n}{200}$
2 $\frac{n}{100}$		1 $\frac{n}{20}$ †	2 $\frac{n}{40}$	1 $\frac{n}{100}$	

SODIUM HYDROXID.

2 $\frac{n}{200}$		2 $\frac{n}{50}$	2 $\frac{n}{40}$	1 $\frac{n}{200}$	
2 $\frac{n}{100}$			2 $\frac{n}{20}$	2 $\frac{n}{100}$	

AMMONIUM HYDROXID.

		1 $\frac{n}{28}$	2 $\frac{n}{2.78}$		
			2 $\frac{n}{5.56}$		
			2 $\frac{n}{13.7}$		
			1 $\frac{n}{28}$		

* No. 825. Grew not at all.

† No. 824. Grew luxuriantly.

Ammonium nitrate.—This permitted the growth of Botrytis in $\frac{n}{4}$ but not in $\frac{n}{2}$. Penicillium grew in $\frac{n}{2}$. Uromyces was prevented by $\frac{n}{2}$, but grew in $\frac{n}{4}$.

Potassium, sodium, and ammonium hydroxids.— Macrosporium gave identical results with the first two of these chemicals and a killing strength was not reached at $\frac{n}{100}$. Stronger solutions could not be tried in drop culture. With Penicillium the fatal strength may be considered as $\frac{n}{40}$ for sodium and potassium hydroxids. There is an apparent anomaly in the fact that in one tube the fungus grew finely in KOH $\frac{n}{20}$, while its mate failed utterly. This can be explained on the assumption that one spore or more found a lodging place in a fragment of unsaturated bread, and thus attained a sufficient protection and

TABLE XVI.

POTASSIUM IODID.

Botrytis		Macrosporium		Penicillium		Uromyces	
Grew	Failed	Grew	Failed	Grew	Failed	Grew	Failed
1 $\frac{n}{20}$		2 $\frac{n}{50}$		2 $\frac{n}{10}$		2 $\frac{n}{50}$	
2 $\frac{n}{50}$		1 $\frac{n}{40}$				2 $\frac{n}{20}$	
		1 $\frac{n}{20}$					

POTASSIUM BROMID.

2 $\frac{n}{20}$		2 $\frac{n}{20}$		2 $\frac{n}{10}$		2 $\frac{n}{20}$	

SODIUM ACETATE.

2 $\frac{n}{4}$	2 $\frac{n}{2}$	2 $\frac{n}{4}$ *		1 $\frac{n}{1}$		2 $\frac{n}{4}$ †	2 $\frac{n}{2}$

* No. 647. Some injured.

† No. 645. Very few grew.

start to resist the further action of the toxic solution. With Uromyces results were somewhat variable, but undeniable proof was obtained that growth is not prevented by $\frac{n}{100}$.

Ammonium hydroxid was tried only with Penicillium, and $\frac{n}{14}$ prevented growth.

Potassium iodid and bromid.—These agree in being non-toxic toward Botrytis, Macrosporium, and Uromyces at $\frac{n}{20}$, and to Penicillium at $\frac{n}{10}$.

Sodium acetate.—This allowed growth of Botrytis, Macrosporium, and Uromyces at $\frac{n}{4}$, and of Penicillium at normal, while $\frac{n}{2}$ prevented Botrytis and Uromyces from growing.

Magnesium sulfate, barium chlorid, ammonium chlorid, magnesium chlorid.— By two tests each, these all proved harmless to Penicillium at $\frac{n}{10}$ strength.

A general tabulation of these results is presented in table XVII which will be readily comprehended. The strength expressed represents the dilution of normal solution required to prevent most of the spores from germinating. If any growth occurred, there would be only a few isolated cases of germination. In table XVIII the strength is indicated in parts per million.

The signs $>$ and $<$ are the common mathematical signs for "greater than" and "less than." For example, the killing strength of KCN for Glœosporium is greater than $\frac{n}{400}$, while that of potassium bichromate for Botrytis is less than $\frac{n}{640}$. The molecular weight of the salt as used in making up the solutions is given, with formula of each substance.

From the more interesting and important generalizations of this table a few may be indicated.

Mercuric chlorid is by far the most poisonous substance used, while potassium cyanid has low toxic power. This may be partially explained by the evaporation of the potassium cyanid from the drop, but this explanation surely cannot apply in the

TABLE XVII

STRENGTH REQUIRED TO PREVENT GERMINATION

[Expressed as parts of normal solution]

Substance	Botrytis	Macrosporium	Glœosporium	Penicillium	Uromyces
$HgCl_2$ 239.2	$\frac{n}{51200}$	$\frac{n}{102400}$		$> \frac{n}{3200}$	$\frac{n}{6400}$
KCN 64.7		$\frac{n}{50}$	$> \frac{n}{400}$	$\frac{n}{100}$	$\frac{n}{100}$
HCl 36.19..........		$> \frac{n}{50}$	$> \frac{n}{100}$	$> \frac{n}{50}$	$\frac{n}{50}$
H_2SO_4 97.34.......		$> \frac{n}{50}$	$> \frac{n}{100}$	$> \frac{n}{50}$	$\frac{n}{100}$
C_2H_6O 45.7........	$> n$	$> 5n$		n	$> 5n$
$CuSO_4+5H_2O$ 247.54	$\frac{n}{3200}$	$\frac{n}{6400}$		$\frac{n}{200}$	$\frac{n}{3200}$
$Cu(NO_3)_2+3H_2O$ 239.6	$\frac{n}{3200}$	$> \frac{n}{3200}$		$\frac{n}{200}$	$\frac{n}{3200}$
$Cu(C_2H_3O_2)_2$ 179.96	$\frac{n}{3200}$	$\frac{n}{3200}$		$\frac{n}{800}$	$\frac{n}{800}$
$CuCl_2+2H_2O$ 166.96		$\frac{n}{3200 \text{ or less}}$	$\frac{n}{6400}$	$\frac{n}{200}$	$\frac{n}{3200}$
K_2CrO_4 192.92.....	$< \frac{n}{640}$	$\frac{n}{40}$		$< \frac{n}{640}$	$\frac{n}{40}$
$K_2Cr_2O_7$ 292.2	$< \frac{n}{1280}$	$\frac{n}{1280}$		$< \frac{n}{1600}$	$\frac{n}{640}$
NaCl 58.18.........	$> \frac{n}{2}$	$> n$		$> 2n$	$\frac{n}{2}$
KOH 54.74		$> \frac{n}{100}$		$\frac{n}{40}$	$> \frac{n}{100}$
NaOH 38.76		$> \frac{n}{100}$		$\frac{n}{40}$	$> \frac{n}{100}$
NH_4NO_3 79.52.....	$\frac{n}{2}$			$\frac{n}{2}$	$\frac{n}{2}$
KI 164.76..........	$> \frac{n}{20}$	$> \frac{n}{20}$		$> \frac{n}{10}$	$> \frac{n}{20}$
KBr 118.21	$> \frac{n}{20}$	$> \frac{n}{20}$		$> \frac{n}{10}$	$\frac{n}{20}$
$Na(C_2H_3O_2)+3H_2O$ 134.71	$\frac{n}{2}$	$> \frac{n}{4}$		$> n$	$\frac{n}{12}$
$MgSO_4+7H_2O$ 245 7				$> \frac{n}{10}$	
$BaCl_2+2H_2O$ 242.13				$> \frac{n}{10}$	
NH_4Cl 53.13.......				$> \frac{n}{10}$	
$MgCl_2+6H_2O$ 201.88				$> \frac{n}{10}$	
$K_2Mn_2O_8$ 313.94 ...				$> \frac{n}{10}$	$\frac{n}{200}$
NH_4OH 34.82				$> \frac{n}{25}$	

case of Penicillium, which uniformly grew in $\frac{n}{200}$. So the fact must be accepted that KCN has a low toxic power for these fungi.

TABLE XVIII

STRENGTH REQUIRED TO PREVENT GERMINATION

[Expressed as parts per million]

Substance	Botrytis	Macrosporium	Glœosporium	Penicillium	Uromyces
$HgCl_2$ 239.2	4.6	2.3		74	37
KCN 64.7		1294	> 162	647	647
HCl 36.19		> 724	> 362	> 724	724
H_2SO_4 97.34		> 1947	> 973	> 1947	973
C_2H_6O 45.7	> 45700	> 228500		45700	> 228500
$CuSO_4+5H_2O$ 247.54	49—77	25—38		791—1237	49—77
$Cu(NO_3)_2+3H_2O$ 239.6	58	> 58		930	58
$Cu(C_2H_3O_2)_2$ 179.96	56	56		225	225
$CuCl_2+2H_2O$ 166.96		20 or less	20	656	41
K_2CrO_4 192.92	< 301	4823		< 301	4823
$K_2Cr_2O_7$ 292.2	< 228	228		< 183	456
NaCl 58.18	> 29090	> 59190		< 119380	29090
KOH 54.74		> 547		1368	> 547
NaOH 38.76		> 388		1938	> 388
NH_4NO_3 79.52	39760			39760	39760
KI 164.76	> 8238	> 8238		> 16476	> 8238
KBr 118.21	> 5910	> 5910		> 11820	> 5910
$Na(C_2H_3O_2)+3H_2O$ 134.71	45500	> 20250		> 81000	40500
$MgSO_4+7H_2O$ 245.7				> 12554	
$BaCl_2+2H_2O$ 242.13				> 20637	
NH_4Cl 53.13				> 5313	
$MgCl_2+6H_2O$ 201.88				> 9460	
$K_2Mn_2O_8$ 313.94	392			> 31394	1570
NH_4OH 34.82					

H_2SO_4 and HCl agree closely in toxic effect upon these fungi and are of also about the same toxic action as KCN. The fatal strength for H_2SO_4 is nearly a one per cent. solution.

All of the copper salts agree closely in toxic action.

Between potassium chromate and bichromate there is a remarkable variance; the bichromate has twice the effect upon Botrytis, thirty-two times the effect upon Macrosporium and sixteen times upon Uromyces that the chromate does.

In all the cases considered so far, it will be noticed that with the exception of Penicillium, Uromyces will withstand as great or greater strength than any of the other fungi tried. With NaCl we have a case, however, in which the Macrosporium survives even a greater strength than the Uromyces. The same anomaly is observed with HCl and H_2SO_4 upon these fungi. So it seems that although a fungus may, generally speaking, be more resistant to the action of salts or acids than other fungi are, there may be some particular substances which will affect this fungus at less strength than is required for the other and usually weaker fungus. This fact is especially important in the application of fungicides, in that a fungicide which is most effective for one fungus is not necessarily so for all fungi. It may also be noticed that although Uromyces is generally more resistant than Botrytis and Macrosporium, Uromyces is the most susceptible to the action of NaCl.

The hydroxids KOH, NaOH, and NH_4OH gave quite uniform results, and show a low toxic power. In the case of the hanging drop this might partially be explained by the neutralization by CO_2; but, substantiated as it is by parallel experiments in gross culture with a Penicillium, the fact must be accepted that the hydroxids are of low toxic action on these fungi.

Potassium permanganate is of very low toxic power, but is of peculiar interest in that it has the power of coloring the uredospores a dense black, while the teleutospores were but slightly if at all darkened. The other records made in table XVII show that the solution is practically non-toxic.

An inspection of this table will show that, of the five fungi tried, Penicillium is usually more resistant than any of the others. This is rather to be explained by the means of culture than by any structural or selective difference in the fungi themselves.

Single spores might easily have been protected from the action of the fungicide by the nutrient medium. This idea is further supported by the fact, frequently noted in drop cultures of Uromyces, that often a spore in the midst of a close bunch would grow when others near it and unprotected would fail. This was of such frequent occurrence as practically to prove that

TABLE XIX.

SHOWING LIMIT PREVENTING SPORADIC GERMINATION.

Substance	Botrytis	Glœosporium	Macrosporium	Penicillium	Uromyces
$HgCl_2$	$\frac{n}{25600}$		$\frac{n}{51200}$	$> \frac{n}{3200}$	$\frac{n}{6400}$
KCN		$> \frac{n}{400}$	$> \frac{n}{50}$	$\frac{n}{100}$	$> \frac{n}{100}$
HCl		$> \frac{n}{100}$	$> \frac{n}{50}$	$> \frac{n}{50}$	$> \frac{n}{50}$
H_2SO_4		$> \frac{n}{100}$	$> \frac{n}{50}$	$> \frac{n}{50}$	$> \frac{n}{100}$
C_2H_6O	$> n$		$> 5n$	$\frac{n}{2}$	$> \frac{n}{5}$
$CuSO_4$	$\frac{n}{3200}$		$\frac{n}{3200}$	$\frac{n}{200}$	$> \frac{n}{100}$
$Cu(NO_3)_2$	$\frac{n}{3200}$			$\frac{n}{200}$	$\frac{n}{3200}$
$Cu(C_2H_3O_2)_2$	$\frac{n}{3200}$		$\frac{n}{1600}$	$\frac{n}{800}$	$\frac{n}{200}$
$CuCl_2$		$\frac{n}{6400}$	$\frac{n}{6400}$	$\frac{n}{200}$	$> \frac{n}{1600}$
$K_2Mn_2O_8$		$\frac{n}{800}$		$\frac{n}{400}$	$> \frac{n}{100}$
K_2CrO_4	$< \frac{n}{640}$		$\frac{n}{40}$	$< \frac{n}{640}$	$\frac{n}{10}$
$K_2Cr_2O_7$	$< \frac{n}{1280}$		$\frac{n}{1280}$	$< \frac{n}{1600}$	$\frac{n}{320}$
NaCl	$> \frac{n}{2}$		$> n$	$> \frac{2n}{1}$	n
KOH			$> \frac{n}{100}$	$> \frac{n}{20}$	$> \frac{n}{100}$
NaOH			$> \frac{n}{100}$	$\frac{n}{20}$	$> \frac{n}{100}$
NH_4OH				$> \frac{n}{28}$	

close contact of the spores could prevent the toxic effect of the chemical.

Generally speaking, Botrytis required a stronger solution to kill than did the Macrosporium, while Uromyces required much greater strength than either of them. This might have been expected from the relative thickness of their walls, and is further illustrated by table XIX, which gives the strength of solution required to prevent completely the growth of spores. Exceptions to this generalization occur, however, as has already been pointed out, which indicate a selective difference. Some fungi on experimentation gave with some chemicals a sharp and definite killing point. Others were gradually weakened or the number of germinating spores decreased as the strength of the solution increased. This second phase is particularly well illustrated in the cultures of Uromyces. With each chemical a strength could be found which just perceptibly injured the fungus, and another which prevented most spores from germinating. This is what has previously been given as the killing strength. At this strength one of two things occurred: either about the usual number grew, but grew only slightly and in stunted or often distorted manner; or, in each culture, nearly all the spores failed utterly to grow, while one or a half dozen in the hundreds of a culture would grow and grow usually vigorously and apparently uninjured. In order to kill these few persistent spores much greater strength was required. Thus, in potassium chromate, for Uromyces, $\frac{n}{40}$ killed or prevented most growth. But some spores grew even in $\frac{n}{20}$, and $\frac{n}{10}$ was necessary to inhibit growth completely. On the other hand $\frac{n}{80}$ did weaken growth somewhat. So there is established a wide range between the weakest solution injuring the fungus and the weakest solution surely preventing growth.

Table XX shows the variation in range of susceptibility. In this table two concentrations are named for each fungus. At the weaker normal growth took place, while the stronger completely inhibited growth.

It is here to be noticed that Uromyces gives a remarkable

TABLE XX.

SHOWING RANGE OF SUSCEPTIBILITY.

Substance	Botrytis	Glœosporium	Macrosporium	Penicillium	Uromyces
$HgCl_2$	$\frac{n}{102400}$ $\frac{n}{25600}$		$\frac{n}{819200}$ $\frac{n}{51200}$		$\frac{n}{25600}$ $\frac{n}{6400}$
KCN			$\frac{n}{100}$ $> \frac{n}{50}$	$\frac{n}{200}$ $\frac{n}{100}$	$< \frac{n}{200}$ $> \frac{n}{100}$
HCl			$\frac{n}{100}$ $> \frac{n}{50}$		$\frac{n}{800}$ $> \frac{n}{50}$
H_2SO_4		$\frac{n}{200}$ $> \frac{n}{100}$			
C_2H_6O				$\frac{n}{1}$ $\frac{n}{2}$	
$CuSO_4$	$\frac{n}{12800}$ $\frac{n}{3200}$		$\frac{n}{12800}$ $\frac{n}{3200}$	$\frac{n}{400}$ $\frac{n}{200}$	$\frac{n}{12800}$ $> \frac{n}{100}$
$Cu(NO_3)_2$	$\frac{n}{6400}$ $\frac{n}{3200}$			$\frac{n}{400}$ $\frac{n}{200}$	$\frac{n}{6400}$ $\frac{n}{3200}$
$Cu(C_2H_3O_2)_2$	$\frac{n}{3200}$ $\frac{n}{6400}$		$\frac{n}{6400}$ $\frac{n}{1600}$	$\frac{n}{1600}$ $\frac{n}{800}$	$\frac{n}{6400}$ $\frac{n}{200}$
$CuCl_2$		$\frac{n}{12800}$ $\frac{n}{6400}$		$\frac{n}{400}$ $\frac{n}{200}$	$\frac{n}{6400}$ $> \frac{n}{1600}$
$K_2Mn_2O_8$		$\frac{n}{1600}$ $\frac{n}{800}$		$\frac{n}{400}$	$\frac{n}{400}$ $> \frac{n}{100}$
K_2CrO_4					$\frac{n}{160}$ $\frac{n}{10}$
K_2CrO_7			$< \frac{n}{3200}$ $\frac{n}{1280}$		$< \frac{n}{3200}$ $\frac{n}{320}$
KOH				$\frac{n}{50}$ $> \frac{n}{20}$	
NaOH				$\frac{n}{50}$ $\frac{n}{20}$	

range, particularly with copper sulfate, in which most spores were killed at $\frac{n}{3200}$. Some injury was done by $\frac{n}{12800}$, but some spores grew in even so strong a solution as $\frac{n}{100}$.

A general survey of the tables will show that the following list of chemicals may be selected as having practically no toxic action unless in great strength, as they were tried at $\frac{n}{10}$ with no toxic action, and this was in every case greater than a ½ per cent. solution: $K_2Mn_2O_8$, $MgCl_2$, NH_4Cl, $BaCl_2$, $MgSO_4$, $Na(C_2H_3O_2)$, KBr, KI, NH_4NO_3, NaCl, C_2H_6O.

HYDROLYTIC DISSOCIATION.

Salts in aqueous solution present certain deviations regarding the changes of freezing and boiling point (and also other optical physical, and chemical deviations) which are not in accord with the general laws for solutions containing the number of molecules theoretically supposed to be present. "Thus a solution of KCl + 100 H_2O, instead of showing a lowering of vapor pressure of .01 as required by the law, shows a lowering of about double this. Solutions in alcohol behave like other substances and give normal diminution of vapor pressure."[4] In general the behavior of such aqueous solutions of salts, bases, or acids is such as might be expected if they contained more molecules than their formula indicates.

These phenomena led Arrhenius[5] to the conclusion that each molecule or some of the molecules are separated into part molecules or ions, a term long used by the physicist.

According to this theory of hydrolytic dissociation a solution of mercuric chlorid does not consist of water and molecules of mercuric chlorid, but does consist of water containing ions of mercury and ions of chlorin, designated as Hg^+ and Cl^-, according as the element is electro-positive or electro-negative in electrolytic dissociation.

Careful distinction should be drawn between an element in the condition of dissociation and in a molecular condition. Thus

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[4] OSTWALD: Solutions, trans. by Muir, p. 187.

[5] Zeits. f. phys. Chem. 1:631. 1887.

ions of sodium are very different in their chemical, physical, and physiological properties from molecules of sodium.

Arrhenius, as quoted by Ostwald (*l. c.*), was thus led to the conclusion that "the properties of salt solutions must be capable of representation as the binary sums of the properties of the ions." This generalization has later been made more particular and has been qualified slightly by Kahlenberg and True (*l. c.*), who extend their reasoning to the domain of physiological effects. They say: "Now, if, in the case of the solutions in question, all the chemical and physical properties are due to the properties of the ions plus those of the undissociated molecules it contains, it seems very probable that the physiological effects produced by such solutions are due to these."

The above proposition is then amply substantiated by these authors and by F. D. Heald (*l. c.*) in a series of experiments upon seedlings of flowering plants.

TABLE XXI.

Non-poisonous			Poisonous		
Substance	Cathion	Anion	Substance	Cathion	Anion
$MgSO^4$	Mg +	SO_4 —	$HgCl_2$	Hg +	
$BaCl_2$	Ba +	Cl —	HCl	H +	
NaCl	Na +	Cl —	H_2SO_4	H +	
MgCl	Mg +	Cl —	KCN		CN —
$NaC_2H_3O_2$	Na +	$C_2H_3O_2$ —	$CuSO_4$	Cu +	
KBr	K +	Br —	$Cu(NO_3)_2$	Cu +	
KI	K +	I —	$Cu(C_2H_3O_2)_2$	Cu +	
$K_2Mn_2O_8$	K +	MnO_4	$CuCl_2$	Cu +	
NH_4NO_3			K_2CrO_4		CrO_4 —
NH_4Cl			$K_2Cr_2O_7$		Cr_2O_7 —
C_2H_6O			KOH		OH —
			NaOH		OH —
			NH_4OH		OH —

In the first column of table XXI is given a list of salts which have been proven non-poisonous. The strengths were such that there were in the solution many undissociated molecules; many also of the molecules were dissociated; hence, as these solutions proved non-toxic at the strength used, it may be concluded that both the molecules and the ions, both negative and positive, are devoid of toxic action.

The two next columns of this table show the ions into which the salts are separated. Here then is proof that to the fungi under investigation the cathions Mg, Ba, Na, and K are non-toxic. The anions SO_4, Cl, Br, I, MnO_4, and $C_2H_3O_2$ are non-toxic at the strength used. The second half of table XXI shows those salts which were found to have toxic action.

As Cl^- ions have previously been proven non-toxic the effect must rest with the molecule of $HgCl_2$ or with the ion of Hg^+. The salt at the strength used was almost completely dissociated, hence the effect is due to the Hg^+ ion, which was the most powerful one experimented with.

With the two acids, HCl and H_2SO_4, the anions had proven non-toxic; so, by similar reasoning, the poisonous property rests with the H^+ ion. As H_2SO_4 contains twice as much H^+ as does HCl it should have twice its toxic power in equi-molecular solutions. This statement has met no adverse results in experiment, but there has been slight, though by no means positive evidence, to sustain it.

With KCN the cathion is non-toxic. The CN^- then must be poisonous, and it has about the same toxic action as does H^+.

With all the copper salts the anions are non-toxic, hence the poison is in the molecule or in the copper, and in the more dilute solutions it undeniably rests with the copper. As each copper compound has as many atoms of copper per molecule as the others it would be equally toxic. This expectation is almost fully met, with the exception of copper acetate for Penicillium and Uromyces, and of copper sulfate for Macrosporium. These three slight deviations from the theory stand against thirteen observations with the copper salts tending to support it.

In the potassium chromate and bichromate solutions the poisonous action rests evidently with the anions. The bichromate is in every case more poisonous and in most cases far more poisonous than the chromate, as may be seen by tables XII and XIII.

With the hydroxids the toxic effect rests with the anion, and as far as positive results were secured, they agree precisely. It may be noted, in passing, that the Bordeaux mixture, 22-gallon formula, estimated on basis of copper content, would be of about $\frac{n}{7}$ strength, whereas these experiments show $\frac{n}{200}$ for copper is sufficient to prevent growth, except in extremely rare cases, while $\frac{n}{3200}$ is usually fatal to the spores with which it comes in contact. It is possible, however, that in Bordeaux mixture the copper may enter into the formation of a complex molecule, producing in dissociation a complex ion containing copper which is inferior to the copper ion itself in toxic action. This subject, however, is now under investigation and will be treated of in a separate paper.

TABLE XXII.

	Pisum	Zea	Lupinus	Penicillium	Uromyces
HCl	$\frac{n}{12800}$	$\frac{n}{3200}$	$\frac{n}{6400}$	$>\frac{n}{50}$	$\frac{n}{50}$
H_2SO_4	$\frac{n}{12800}$	$\frac{n}{3200}$	$\frac{n}{6400}$	$>\frac{n}{50}$	$\frac{n}{100}$
$CuCl_2$	$\frac{n}{51200}$	$\frac{n}{102400}$	$\frac{n}{25600}$	$\frac{n}{100}$	$\frac{n}{3200}$
$CuSO_4$	$\frac{n}{51200}$	$\frac{n}{102400}$	$\frac{n}{25600}$	$\frac{n}{200}$	$\frac{n}{3200}$
$Cu(C_2H_3O_2)_2$	$\frac{n}{51200}$	$\frac{n}{102400}$	$\frac{n}{25600}$	$\frac{n}{800}$	$\frac{n}{800}$
$HgCl_2$	$\frac{n}{204800}$	$\frac{n}{51200}$	$\frac{n}{12800}$	$>\frac{n}{3200}$	$\frac{n}{6400}$
KCN	$\frac{n}{12800}$	$\frac{n}{6400}$	$\frac{n}{6400}$	$\frac{n}{100}$	$\frac{n}{100}$

It may be of interest to compare the results of this work on fungi with that of Kahlenberg and True on phanerogams. Table XXII brings together the results upon such substances as we have used in common, and also renders it possible to see at a glance the relative susceptibility of the fungi and phanerogams.

The first two columns are the result of work by Heald, the third that of Kahlenberg and True, and the last two are recorded for the first time in this paper. An apparent but not real discrepancy arises from the fact that, in considering the two acids, the other authors have estimated the normal solution upon the basis of hydrogen present, whereas in mine, it is on the basis of the whole molecule. In view of this it will be seen that our results agree in making H ions as toxic in one acid as in the other and that about equal to the action of CN ions. It should be also noticed that their results represent strengths in which the plants would just grow, and mine a strength in which they would just not grow.

In general the fungi are far more resistant to action of these salts than are the higher plants. The authors quoted find copper approximately thirty-two times as toxic as hydrogen. My results show it sixty-four times as toxic for the fungi. The results with Pisum show Hg to be four times as toxic as copper ions, while with Zea and Lupinus the copper is twice as toxic as the Hg ion. The fungi show Hg twice as toxic as Cu. They show Cu to be about four times as toxic on Lupinus and Zea as are H or Cu ions. It would be interesting to know whether the HCN dissociated would be one half as strong as Cu, as would seem probable from theory.

TABLE XXIII.

SHOWING RATIO OF TOXIC ACTION.

	Pisum	Zea	Lupinus	Uromyces
H:CN	1:1	1:2	1 : 1	1 : 2
H:Cu	1:4	1:32	1 : 4	1 : 64
H:Hg	1:16	1:16	1 : 2	1 : 128

These results, and others along this line, are collated in table XXIII, in which hydrogen, both on account of its low atomic weight and its low toxic effect, is taken as a standard and the toxic action of other ions with various plants are represented as ratios.

It has been suggested that the toxic action may be some function of the atomic weight of the element. To say the least, such a supposition is not strongly supported by this table.

It may be well to add that where the words killed, dead, fatal, etc., have been used it is not intended to imply that life was really extinct, but merely that it was not evident. Experiments are now under way to determine, if possible, whether spores which have been prevented from growth by a toxic solution can grow on being placed in one not toxic.

SUMMARY.

1. Mercuric chlorid is the strongest chemical used in its toxic effect upon the fungi.

2. Potassium cyanid is remarkably weak considering its great toxic action on animals.

3. Various fungi offer different resistance to poisons.

4. The limits of resistance vary in the same species.

5. Alcohol and sodium chloride have a stimulating effect.

6. In general the results are in accord with the theory of hydrolytic dissociation.

7. A chemical may be twice as powerful as another against one fungus, but acting upon another fungus an entirely different ratio may be sustained.

8. The spores of fungi are less susceptible than the roots of seedlings.

9. The Bordeaux mixture holds far more copper than would be needed if it dissociated into simple copper ions.

10. The cathions Hg, H, and Cu are poisonous.

11. The anions CN, CrO_4, Cr_2O_7 and OH are poisonous.

12. The halogen anions are not poisonous.

13. Uromyces offers the greatest range in its susceptibility to poisons.

14. The secondary spores of anthracnoses increase in abundance under the adverse conditions of a toxic solution.

15. Spores protected by actual contact with others may germinate and the tube may grow through a solution which in itself

would have prevented the germination of the spore had it been in contact with it.

16. Peculiar knotted or twisted hyphæ frequently result from the attempt to grow in a poisonous solution.

17. A spore may be able to germinate and grow slightly in a solution but still be unable to attain full development.

18. Potassium permanganate at certain strengths acts as a selective stain, differentiating uredo- from teleutospores of *Uromyces caryophyllinus*.

19. Bread may be moistened with a solution which prevents germination of spores. This solution may evaporate and the spores can then grow.

20. An occasional spore may germinate and grow *perfectly normally* in a solution which prevents hundreds of normal spores around it from germinating.

21. Penicillium in a nutrient medium offers greater resistance to poisons than do any of the other fungi worked upon.

22. Uromyces does not diminish in vigor of growth with the increased strength of the poison, but it does diminish in the percentage of spores which germinate.

In conclusion I offer my most grateful thanks to Dr. B. D. Halsted for much kind assistance and advice as well as for preliminary training in former years; to Dr. W. A. Kellerman for his courtesy in extending to me the privileges of his physiological laboratory and also for material and advice; to Mr. E. M. Wilcox for many courtesies in the laboratory.

THE UNIVERSITY OF CHICAGO.

THE PHYSIOLOGICAL ACTION OF CERTAIN PLASMOLYZING AGENTS.

RODNEY H. TRUE.

INTRODUCTORY.

IN the course of an investigation in which the writer was concerned regarding the physiological action of certain sodium salts, various degrees of destructiveness were observed. In some of the weakest salts, it seemed possible that the osmotic action as well as the chemically harmful properties of the substances might play a rôle, so concentrated were the solutions in which the test plants first survived. It seemed to be very desirable to analyze, if possible, the injurious physiological action of some of the commoner and less harmful salts into its osmotic (physical) and toxic (chemical) components, should it appear that both contribute to the results seen.

The desirability of some clearer understanding of the action of these substances seemed the greater by reason of the frequent use as plasmolyzing agents to which certain of them have long been put by plant physiologists. Sodium chlorid and potassium nitrate, especially, have been much employed in this way. In thus using them, botanists have followed the lead of De Vries, (1) who first applied these substances in this way, and have assumed them to be essentially harmless, as asserted by De Vries (p. 12). He says, "Es ist eine sehr verbreitete irrthümliche Ansicht, dass concentrirte Salzlösungen (z. B., eine Kochsalzlösung von 10–20 %) für des Leben der Pflanzenzelle gefährlich seien." Davenport (2) more recently says, "It is not easy to find a reagent of which we may be certain that it acts only osmotically. NaCl is probably more generally useful in this way than any other substance."

As far as the writer knows, no attempt has been made hitherto to analyze thus the action of a substance, beyond the single one made by Plateau (3), who used as test objects animals, mainly invertebrates. His experiments turned out unfortunately on account of the fundamental error made in using as comparative solutions percentage concentrations. Recently, Davenport (2) has outlined a method of analysis, in itself correct, but likely to lead to error in many cases through the choice of sodium chlorid as a standard substance assumed to exert a purely osmotic effect.

METHOD.

In attempting to analyze the injurious action of a compound into its osmotic and its toxic constituents, a standard solution which has a known osmotic action, and is not open to the suspicion of being in any degree toxic, may be selected for purposes of comparison.

As such a standard substance, I have selected cane sugar. It occurs normally in plant cells, often in high concentration, twenty per cent. having been observed in the sugar beet (4). As has been often proved, it is a most excellent plant food when supplied in cultures. In searching through the results of investigators who have made use of this substance in cultures, I have failed to find in any case toxic action attributed to cane sugar. In higher concentrations it proves harmful on exposure of plants to its action for long periods of time, an effect that seems to be amply accounted for by the osmotic properties of such solutions. Moreover, it diffuses rather slowly, and is less liable to injure the organism by the sudden withdrawal of water than is the case with substances of more rapid osmotic action. A limited opportunity for the cell to accommodate itself to the changing concentration is gained in the more slowly diffusing substances.

Having chosen cane sugar as a standard of pure osmotic effect, solutions were made up on the basis of a molecular weight of substance in the requisite numbers of liters required to give the concentrations desired. Tufts of Spirogyra filaments, first rinsed thoroughly in duplicate solutions to prevent dilution of those used in the experiments, were placed in the desired concentrations and left for twenty-four hours. At the end of this time, the condition of the algæ was examined into with greatest care, and the strongest concentration in which they survived was noted. This limit I have termed the boundary concentration, and regard it as a measure of the purely osmotic action capable of being sustained by Spirogyra. Having determined this point, I calculated, by the use of methods in no way involving the living cell, the concentrations of the solutions of other substances to be studied, which have an osmotic value equal to that of the experimental boundary concentration of cane sugar. The next step was to determine experimentally as just described, the boundary concentration of each substance under study.

If the algæ survived in a concentration greater than that calculated from the value of cane sugar, the conclusion would necessarily follow that the substance in question was less harmful to the plants than sugar. This condition of things was in no case realized. If the algæ first survived in the calculated concentration, the action of the substance would be purely osmotic and equal to that of cane sugar. If the algæ should first survive in a concentration more dilute than the calculated boundary concentration, the substance in question would be more harmful than sugar.

In the realization of the third case, injury by one or both of two possible methods might be wrought; first, by a very rapid extraction of water from the cell, violence might be done to the protoplast through the lack of opportunity for the organism to accommodate itself to the change; second, toxic action due to the chemical interference of the substance in solution with the molecules of living substance might also take place. In each special case, it would be necessary to ascertain the kind of injury operating. In doing this certain plain considerations should be borne in mind. Should Spirogyra be found to survive at a concentration greater than that causing plasmolysis and less than the calculated boundary, the deleterious action would in great probability be due to the osmotic properties of the solution, a point again to be touched on in this paper. If, however, the algæ should die in a concentration less in osmotic value than the cell sap, *i. e.*, at a concentration weaker than the plasmolyzing strength, death could hardly be attributed to the water-extracting properties of the molecules or ions.

EXPERIMENTAL RESULTS.

I have studied, according to the method just described, those substances which have been most used by biologists as plasmolyzing agents, cane sugar, glycerin, sodium chlorid, and potassium nitrate.

The numerical data obtained are brought together for more ready reference in the following table. Three important points determined for each substance are presented: (1) the concentration of the solution in which plasmolysis begins in the Spirogyra studied stated in gram-molecules of the substance per liter of water; (2) the calculated boundary concentration, assuming a purely osmotic action of a type not more injurious than that seen in cane sugar; (3) the boundary concentration found by experiment.

The temperature varied between 22° and 30° C. as limits. Although the significance of relationships is lost when the concentrations are so stated, I have added percentage values to facilitate comparison with results obtained by other investigators. As an "antidote" for the percentage values, the molecular weights of the substances under study are also added.

Substance	Mol. wt.	Plasmolyzing concentration		Calculated boundary concentration		Experimental boundary concentration	
		gm. mol. per l.	Per cent.	gm. mol. per l.	Per cent.	gm. mol. per l.	Per cent.
Cane sugar.....	342.0	0.33 (⅓)	11.4			0.75 (¾)	25.7
Glycerin	92.0	0.33 (⅓)	3.1	0.75 (¾)	6.9	0.50 (½)	4.60
Sodium chlorid..	58.5	0.25 (¼)	1.5	0.46	2.7	0.10 (1/10)	0.58
Potassium nitrate	101.0	0.25 (¼)	2.5	0.47	4.5	0.06 (1/18)	0.63

As appears in this table, Spirogyra just begins to plasmolyze in a cane sugar solution having a concentration of ⅓ gm. mol per liter, and the most concentrated solution in which it can survive is ¾ gm. mol. Since cane sugar is assumed to have a purely osmotic action, we have in ¾ gm. mol. of cane sugar per liter of water an osmotic quantity just small enough to permit life, and any other substance acting likewise in a purely osmotic manner will have as its boundary concentration, that concentration which is equal in its osmotic action to a solution of cane sugar containing ¾ gm. mol. per liter.

We are able, assuming purely osmotic action, to calculate the concentration in which the algæ will just survive. The boundary concentration of cane sugar, the osmotic value of cane sugar and that of the substance in question, being given, the boundary concentration would be found to be related to that for cane sugar inversely as the known osmotic values, according to the proportion

$$S : x :: ox : oS$$

in which S is the boundary solution of cane sugar; x the boundary solution of the substance; ox the osmotic value of the substance; and oS the osmotic value of cane sugar.

Osmotic pressure is known to depend directly on the number of molecules or part molecules, ions, in the solution, and whatever be the size of the molecules, an equal number will produce an equal osmotic pressure. Since the glycerin molecule undergoes no splitting into ions, like fractions of a gram molecule of cane sugar and of glycerin per liter of water should have the same osmotic value. Hence, assuming physiological properties like those of cane sugar the theoretical boundary concentrations should be the same, ¾ gm. mol. per liter. It is seen, however, that Spirogyra is not able to survive under the conditions of the experiment, until a solution containing but one-half gm. mol. per liter is reached. It should be noted, however, that this concentration is stronger than that first causing plasmolysis.

Why is glycerin more harmful than cane sugar? In spite of repeated experiments, no change of position could be determined for the boundary concentration. Since the Spirogyra still survives in a concentration stronger osmotically than the cell sap, a toxic action seems hardly probable. It has been long known to physiologists that glycerin (5) penetrates the cell wall and the protoplast very quickly (6) and can be demonstrated in the cell sap. Thus plasmolysis is rapidly diminished. This speaks for the rapid penetration of the cell by glycerin and the question suggests itself whether the consequent loss of time to accommodate itself to the decided osmotic changes brought about by the solution may not account in some measure for the greater harmfulness seen in glycerin. This question, however, will receive further attention.

In the case of sodium chlorid, one finds a different condition of things. As appears in the table of results, common salt, NaCl, plasmolyzes Spirogyra cells first at a concentration of $\frac{1}{4}$ gm. mol., and first can be survived when containing $\frac{1}{10}$ gm. mol. only. If we assume for sodium chlorid a purely osmotic action, we are able, by making use of the action of cane sugar as a standard of osmotic effect, to calculate the corresponding concentration of sodium chlorid that should just permit the survival of the alga.

Since the molecules split up in large proportion into ions, each of which exerts an osmotic effect equal to that of a molecule not so split, it is necessary to have recourse to the experimental results of physical chemistry. On the basis of the molecular conductivity of salt solutions, it is possible to calculate the percentage of salt molecules dissociated in a solution of a given strength. The electrical conductivity at the given volume (μ_v) divided by the electrical conductivity at an infinite dilution (μ_∞) gives the degree of dissociation. Since the electrical conductivities are not worked out for all boundary concentrations reached in this study, it has been found necessary to use the closest possible approximation. The error thus occasioned, however, is believed to be not sufficiently large to detract materially from the usefulness of the results, since it is impossible to eliminate many minor inaccuracies when working on a question of this nature.

By using tables of molecular conductivities of NaCl, brought together perhaps in the most complete and convenient form in the work of Landolt and Börnstein (7), one can readily estimate the number of undissociated molecules and of ions in the solution. This number will express the osmotic value of salt when that of cane sugar is taken as one. Knowing, therefore, the boundary concentration of sugar and the osmotic value of NaCl at the different degrees of dilution, we are able to find a theoretical boundary concentration for NaCl, assuming for it a purely osmotic action.

As appears in the table, Spirogyra first survives in NaCl at a concentration of 0.1 gm. mol. per liter instead of 0.46 gm. mol., the approximate boundary required by purely osmotic action. Since the plants succumb in a solution of NaCl hardly one-fourth as concentrated as would be required by pure osmotic action, as seen in sugar, either the method of exerting this osmotic effect is much more disastrous than is seen in the case of sugar, or some form of toxic activity is here exerted by the NaCl. Since the boundary concentration is so dilute (0.1 gm. mol. per l.), it seems extremely improbable that the mere withdrawal of water from the cell sap by the salt solution could exert a harmful effect commensurate with the numerical disparity here observed.

In the case of potassium nitrate (KNO_3), a result very similar to that seen in the case of NaCl was obtained. The salts dissociate in about the same degree under like conditions. A concentration of KNO_3 equal osmotically to the boundary concentration of sugar would be about 0.47 gm. mol. per liter. If the physiological action of KNO_3 were totally osmotic the Spirogyra should first survive in about this concentration. The boundary concentration of KNO_3 determined experimentally was found to be $\frac{1}{16}$ gm. mol. per liter. With an osmotic activity very nearly identical with NaCl, a boundary is found at a greater dilution, indicating a degree of toxic activity somewhat greater than that of NaCl.

In the course of a study by Dr. Kahlenberg and myself of the sodium salts of a number of acids, mainly organic, the boundary concentrations for Spirogyra were obtained. A wide range of variation was found. In but one instance did a salt give a boundary concentration greater than 0.04 gm. mol. per liter (sodium hippurate, 0.08 gm. mol. per. liter), and in a number of cases the algæ did not survive until a solution containing but 1 gm. mol. in 200 liters was reached, viz., sodium cinnamate and sodium protocatechuate. In no case does it appear probable that osmotic action plays any noticeable rôle in bringing about the death of the plants; in all cases, therefore, practically toxic action only can be invoked as the cause of death. Assuming roughly dissociation in both of these salts to be approximately 15 per cent., the osmotic value of these compounds would be 1.15, that of cane sugar taken as unity. On the assumption of purely osmotic action, the theoretical boundary concentration would lie for each of these salts at about 0.65 gm. mol. per liter. Against these roughly calculated values may be contrasted the experimental boundary concentration, 0.005 gm. mol. per liter. The sodium compound most easily tolerated, sodium hippurate, is seen to act chiefly through its toxic properties, the cinnamate and protocatechuate practically entirely so.

It is interesting in this connection to note that boric acid, the much used antiseptic, shows for Spirogyra less toxicity than any of the above mentioned sodium salts.

Substances	Concentrations in fractions of a gram-molecule per liter.									
	∞ dil.	.06	0.1	0.17	0.25	0.33	0.46	0.50	0.67	0.75
Cane sugar						*p*				*e*
Glycerine						*p*		*e*		*t*
NaCl			*e*		*p*		*t*			
KNO_3		*e*			*p*		*t*			
Sodium hippurate			*e*						*t*	
Sodium cinnamate	*e*								*t*	

In closing this review of the experimental details, a diagram is given which presents in a somewhat more graphic form the cardinal numerical relations which have served as a basis for the discussion. In this diagram, *p* stands beneath the concentration just beginning to call forth plasmolysis; *t* beneath the concentration representing the theoretical boundary concentration; *e* beneath the concentration experimentally determined to be the boundary concentration.

In view of the results above presented, it appears that plants may be fatally affected both by solutions acting osmotically and by solutions acting through their chemical properties.

In the case of solutions acting osmotically and by this method causing death, it should be pointed out that while osmosis furnishes the means, the operation of which leads to a fatal outcome, chemical processes may very well be here involved. One may imagine that the attraction of the sugar molecules for water results in the removal of water more or less rapidly from the organism enclosed within the cell wall. At first, as the cell sap is relatively dilute, it parts with its water to the larger mass of plasmolytic solution without at a relatively rapid rate. The substances dissolved in the cell sap not being yielded up, the cell sap concentration rises. If this process does not continue beyond a certain point, the organism is able, when osmotic equilibrium is reached, to retain enough water to preserve its organization and to sustain for weeks, or even months, a quiescent existence. If, however, an equilibrium between the cell sap and the surrounding medium is not reached until the water necessary to the maintenance of the integrity of the substance and of the processes of life is encroached upon, death must result and probably in the last analysis through chemical changes. Hence, one may imagine that cane sugar in a solution of too great concentration in time will kill the cell through its interference with the chemical integrity of the substance or processes of the cell exerted along the lines of osmotic activity.

In the case of the other compounds working through their toxic properties, the penetration of the substance into the cell is probably followed more or less promptly by chemical changes due to interference with the compounds essential to life, and death results without any marked withdrawal of water from the cell substance.

In conclusion, it may now be safely asserted that, whereas there exist very many plants which suffer when removed suddenly from salt water to fresh, and appear to be dependent for life itself on the presence of this substance in the substratum, it seems certain that for Spirogyra, sodium chlorid and potassium nitrate act as poisons. It is my opinion, based on a considerable number of experiments not detailed here, that all sodium and potassium salts injure Spirogyra through their chemical properties chiefly, and exert but a minimal harmful influence through their osmotic properties.

In this discussion, I have assumed the accuracy of the classic conclusion that the plasmolytic method as used by De Vries, Pfeffer, and others gives an essentially correct measure of the concentration of the cell sap.

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THE EARLY BOTANICAL VIEWS OF PRUNUS DOMESTICA LINN.

F. A. WAUGH.

THE European plums have been in cultivation so long that we have lost sight of their wild progenitors. This of itself is likely to introduce confusion into botanical notions of their specific relationships. But this long period of cultivation presents a more prolific source of misunderstanding in the wide diversity of cultural and climatic forms which have naturally arisen. These forms were numerous and diverse when the binomial nomenclature and the *Species Plantarum* began to crystallize our notions of species and botanical varieties. Gerarde says in *The Herball* in 1597 that he had in his garden "more than three score sorts, all fine and rare." In America, especially, we have fallen into a very convenient way of lumping off all the cultivated European plums into *Prunus domestica*, with some slight reservation for *Prunus cerasifera* Ehrh.; but if we go back to the beginning we find that the matter was not always so simple.

Linnæus thought it proper, when he described *Prunus domestica*,[1] to divide it into fourteen botanical varieties. It is altogether probable that differences have increased rather than diminished since then; but, in this country at least, we recognize no botanical varieties at all for this species. What has become of them? It would be interesting to know.

In 1789 Ehrhart[2] separated a single one of these varieties to make his species *Prunus cerasifera*,[3] a species which is generally understood and accepted in this country. Seringe in presenting this group in the second volume of the *Prodromus* (1825) did not accept Ehrhart's species, but retained the varietal

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[1] Sp. Pl. 475. 1753. [1st ed.]

[2] Beiträge zur Naturkunde 4:17. 1689.

[3] *Prunus cerasifera* Ehrh. = *P. Myrobalana* (Linn.) Lois.

name of Linnæus. At the same time he reduced the fourteen varieties given by Linnæus to eight of his own. So the consolidation has gone on, till now we have nothing left either in our botany or in our horticulture, except the names *Prunus domestica* and *P. cerasifera*, to preserve to us the early view of one of our most important fruits.

It has seemed to me that so important a change is worthy of examination. And besides it will be of some present horticultural interest to know how many distinct types we have included in *Prunus domestica*, and to understand the vicissitudes of their several phylogenies. Just at present the work of hybridizing plums is assuming considerable proportions. Sundry varieties of *Prunus domestica* are being brought into these combinations, and the existence of old and more or less distinct types within the species comes to have a new significance.

As soon, however, as we endeavor to acquaint ourselves with the Linnæan view of these cultivated plums, we meet with serious difficulties. Linnæus had no types at all, in the technical sense. That is, he made his descriptions from literature and not from specimens. He did not even write fresh descriptions from his own garden. Instead of this he took the descriptions bodily from Bauhin's *Pinax*, adding nothing but his own varietal names. The same descriptions, with slight modifications, had meanwhile been used also in Tournefort's *Institutiones*.

The *Prodromus* leaves us in a somewhat better position. For though Seringe took no pains to make clear the connection between his varieties and those of Linnæus, he did, however, refer to certain definite types. The principal ones of these are the figures and descriptions in the two editions of Duhamel's *Traité des Arbres Fruitiers*. These figures and descriptions are fairly accurate and full, and, moreover, the varieties there recorded are nearly all described and figured in many other places, particularly in Poiteau's *Pomologie Française*, and many of them are retained with us to the present day with no more variation than such fruits are subject to under the ordinary methods of bud propagation. With the help of Duhamel we are thus able

GENERAL EXHIBIT OF THE PRE-DE CANDOLLEAN SYNONYMY OF THE VARIETIES OF PRUNUS DOMESTICA LINN.

Bauhin	Tournefort	Linnæus	Seringe
P. rotunda, flava dulcia, Mali amplitudine. P. amygdalina.	P. fructu maximo, rotundo, flavo & dulci. P. fructu Amygdalino.	var. maliformis var. amygdalina ?	var. Armenioides.
P. parva ex viridi flavescentia.	P. fructu parvo, ex viridi flavescente.	var. cereola.	var. Claudiana.
P. fructu rotundo, nigropurpureo, dulci. P. magna rubra rotunda.	P. fructu rotundo, nigropurpureo, majori dulci. P. fructu majori, rotundo rubro.	var. myrobalan. var. acinaria.	var. Myrobalana.
P. magna dulcia atrocaerulea. P. parva, dulcia atrocaerulea.	P. fructu magno, dulci, atrocaeruleo. P. fructu parvo, dulci, atrocaeruleo.	var. Damascena.	var. Damascena.
P. magna crassida subacida.	P. fructu magno, crasso, subacido.	var. hungarica.	
P. Augusto maturescentia minora et austeriora. P. parva præcocia.	P. fructu minori, austero. P. fructu parvo, præcoci.	var. augustana ? var. praecox ?	
P. nigra carne dura.	P. fructu nigro, carne dura.	var. pernicona. (var. pertigona.)	var. Turonensis.
P. oblonga caerulea.	P. fructu oblongo caeruleo.	var. juliana.	var. Juliana.
P. coloris cerae ex candido in luteum pallescente. P. ex flavo rufescentia mixti saporis gratissima.	P. fructu cerei coloris. P. Brignoniensis, fructu suavissimo.	var. cerea. var. Brignola ?	var. Catherinea.
			var. Aubertiana.
Pruneoli albi oblongiusculi acidi.	P. fructu albo, oblongiusculo, acido.	var. galatensis ?	var. Pruneauliana.

to read backward through Seringe, Linnæus, Tournefort and Bauhin, and to see more clearly what those early botanists were describing. Of course such a method is always open to mistakes, and it will not do to be too sure that we have Bauhin's exact view of the various groups. The following table will show, as accurately as I am at present able to trace, the relation of the varieties of Bauhin, Tournefort, Linnæus, and Seringe to one another.

It is seen at once that Seringe had very little regard for Linnæus' names in preparing the monograph for the *Prodromus*. Only three of the Linnean variety names are retained. The other groups given in *Species Plantarum* are totally disregarded. This is very unfortunate; for in coming to any understanding of the early botanical types of *Prunus domestica*, Seringe's classification offers much the best basis for study. I have thought it best to accept tentatively the eight varieties as given by Seringe, since they doubtless represent the most distinct, as well as the only well-recorded types, and to study these groups separately. A due respect to the rules of botanical nomenclature, however, makes it necessary to revise some of Seringe's names. It will therefore be better if we give here with this revision a more complete record of the pre-DeCandollean synonymy.

PRE-DECANDOLLEAN SYNONYMY OF THE VARIETIES OF PRUNUS DOMESTICA LINN.

1. Var. MALIFORMIS Linn. (var. *Armenioides* Ser.)
    - P. fructu maximo, rotundo, flavo & dulci Tourn.
    - P. rotunda flava dulcia Mali amplitudina Bauh.
    - P. à Malis cognominata Caes.
  - Var. amygdalina Linn ?
    - P. fructu Amygdalino Tourn.
    - P. amygdalina Bauh.
    - P. amygdalina Pliny.

2. Var. CEREOLA Linn. (var. *Claudiana* Ser.)
    - P. fructu parvo, ex viridi flavescente Tourn.
    - P. parva ex viridi flavescentia Bauh.
    - P. parva serotina, cereola Gesn.
    - P. viridacia Gesn.
    - P. verdacea Cam.

3. Var. MYROBALAN Linn. (var. *Myrobalana* Ser.)
    - P. fructu rotundo, nigro-purpureo, majori dulci Tourn.
    - P. fructu rotundo nigro-purpureo dulci Bauh.
    - P. cognominata Myrobalanus Clus. (?) Cam. Tab. Ger.
    - P. myrobalanus rotundus Eyst.
  - Var. acinaria Linn.
    - P. fructu majori rotundo, rubro Tourn.
    - P. magna robra rotunda Bauh.
    - P. asinina Trag. Dod. Lugd. Caes.
4. Var. DAMASCENA Linn. (var. *Damascena* Ser.)
    - P. fructu magno, dulci, atro-caeruleo Tourn.
    - P. magna dulcia atro-caerulea Bauh.
    - P. Damascena Trag. Matth. Dod. et al.
    - P. Brunensia Clus.
    - P. Ungarica duplicia etc. Matth. Gesn. Lugd.
    - P. fructu parvo, dulci, atro-caeruleo Tourn.
    - P. parva dulcia atro-caerulea Bauh.
  - Var. hungarica Linn.
    - P. fructu magno, crasso, subacido Tourn.
    - P. magna crassida subacida Bauh.
    - P. Ungarica praestantissima Gesn.
  - Var. augustana Linn.? (var. angustana Linn. Sp. Pl. 2d. ed.)
    - P. fructu minori, austero Tourn.
    - P. Augusto maturescentia minora & austeora Bauh.
    - P. Augustana & Albanula Caes.
  - Var. praecox Linn.?
    - P. fructu parvo, praecoci Tourn.
    - P. parva praecocia Bauh.
    - P. praecociora, a tempore avenacea dicta Gesn.
    - P. averaria Taber.
5. Var. PERNICONA Linn. (var. *Turonensis* Ser.)
  (Var. pertigona Linn. Sp. Pl. 2d ed.)
    - P. fructu nigro, carne dura Tourn.
    - P. nigra carne dura Bauh.
    - P. Iberica & Pertigona vocata Trag.
    - P. Hispanica Dod.
    - P. Perdigona Ludg.
    - P. pernicona vulgo Caes.
6. Var. JULIANA Linn. (var. *Juliana* DC.)
    - P. fructu oblongo, caeruleo Tourn.
    - P. oblonga caerulea Bauh.
    - P. dactyla purpurea & ovata Ludg. "qui Noberdiana et Juliana addit."

7. Var. CEREA Linn. (var. *Catherinea* Ser.)
        P. fructu cerei coloris Tourn.
        P. coloris cerae ex candido in luteum palliscente Bauh.
        P. cerea & Ceriola Trag. Dod. Lugd. Taber.
        P. cerea Cord. Gesn.
        P. amygdalina Ger.
    Var. Brignola Linn. ?
        P. Brignoniensis, fructu suavissimo Tourn.
        P. ex flavo rufescentia mixti saporis gratissima Bauh.
8. Var. AUBERTIANA, DC.
9. Var. GALATENSIS Linn ? (var. *Pruneauliana* Ser.)
        P. fructu albo, oblongiusculo, acido Tourn.
        Pruneoli albi oblongiusculi acidi Bauh.
        P. Galatensia, sive Perani pruneoli Clus.

As has been already said, one of the chief means of tracing these groups is through the cultivated varieties. Perhaps also the greatest good to be gained from an understanding of the botanical types is in the light it throws on the history and relationships of the horticultural forms. Let us examine them in order.

PRUNUS DOMESTICA MALIFORMIS.—For his types of this group (var. *Armenioides* Ser.), Seringe referred to the cultivated varieties Abricotée, Mirabelle, Drap d'Or, and Abricotée-hative of Duhamel.[4] The citation of the first, Abricotée, is evidently an oversight, and incorrect, the same variety being given under the next head. Of these the Mirabelle seems to stand most clearly for the group in hand. This Mirabelle is not the Myrobalan known in this country and referred here to var. *Myrobalana*. Just what it is does not seem to be perfectly clear, though Koch[5] has discussed the distinction at length and Downing[6] describes and illustrates the variety separately. Nearly all the leading works on pomology give the Mirabelle similar treatment; and though I am at present unacquainted with any such variety,

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[4] Direct references are given to Traité des Arbres Fruitiers **2**: 93, 95 and 96 and to op. idem, ed. nov. **5**: 195. Figures are cited carefully. This is true for all varieties.

[5] Deutsche Obstgehölze 151.

[6] Fruits and Fruit Trees of America, 282. 1847. [7th ed.]

it is not too much to expect that we may understand the characters of the group and presently find a modern representative of it. Seringe's characterization of the group was as follows: "Fructibus rotundatis flavis vel viridi-flavescentibus, nucleo obtusiusculo."

The figures usually represent a small plum, somewhat ellipsoid, and with an evident suture.

PRUNUS DOMESTICA CEREOLA.—The Reine Claudes, or Green Gages. This is one of the most distinct and important of all the groups mentioned, and one of the oldest. It seems to have been clearly understood as a separate group by all the early botanists, and is specially recognized in many of the herbals. It is particularly mentioned by almost every writer in Europe and America from the time of Bauhin to the present. A great deal of speculation has been spent on the problem of its geographic and genetic origin, but no finally defensible conclusion has been reached. Its birthplace may have been southern Europe or eastern Asia. Koch[7], who is one of our best authorities on these questions, advances the rather unlikely hypothesis that it originated from a crossing of the Zwetsche and the Damson, *i. e.*, *Prunus domestica galatensis* × *P. domestica damascena.* Our first definite knowledge of the variety, however, comes from Italy, where it was cultivated under the name of Verdochia. It was brought to France about 1500, the story being that it was introduced by Queen Claudia, wife of Francis I. Thus it took the name of Reine Claude. It came early to England, both from Italy and from France. The plums from Italy were grown in England under the name of Verdoch, and under that name are mentioned by Parkinson in 1629.[8] It was probably later than this that they were brought from France, at which time the labels were lost, and the variety was renamed Green Gage, a name which has followed it to America, and which is now the one best known both here and in Britain. American nurserymen have

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[7] Deutsche Obstgeholze 150. 1876.

[8] This and divers other points in the history of the Reine Claude group are taken from Hogg, Fruit Manual 552. London. 1875. [4th ed.]

also imported several horticultural varieties of this group from France under the names Reine Claude, Reine Claude de Bavay, etc., so that we have both names still in common use. Poiteau, a most excellent student of pomology, remarks[9] that the Reine Claude is reproduced more or less true from seed, and the same statement is made elsewhere. The fact is still evident in the large number of seedling varieties in this country closely resembling the Reine Claude. All this justifies very well the work of Linnæus and Seringe, while holding to their notions of species and varieties, in making a separate variety of this group. We have dozens of modern representatives of this type. One catalogue which I consulted gave approximately 50 separate varieties, and 149 synonyms.

PRUNUS DOMESTICA MYROBALANA.—This is identical with Ehrhart's *Prunus cerasifera*, which is given as a distinct species in the revised *Field, Forest and Garden Botany*, and which will probably be generally accepted in this country. Linnæus' var. *acinaria* seems to belong here also, but this point cannot be determined with certainty.

PRUNUS DOMESTICA DAMASCENA.—The Damsons. This group is so distinct that it has often been given specific rank. If there were anything to be gained by it there is no reason why it should not be revived as a separate botanical variety at the present time. The Damsons as a class, come fairly true to seed, preserving their group characters quite well enough for ordinary purposes of classification. Var. *hungarica* of Linnæus is doubtless to be included in Seringe's var. *Damascena*. Var. *augustana* Linn., ought perhaps to fall into the same group, though it is very difficult to see just what Bauhin had in view in *Prunus Augusto maturescentia minora et austeora*. The name in the second edition of *Species Plantarum* was changed to *angustana*, but the derivation from Bauhin makes it clear that the earlier spelling is the one to be retained. Linnæus' variety *praecox* has been referred to this group still more doubtfully. It falls here by exclusion from the other groups, rather than by any positive characters of

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[9] Pomologie Française (no page). 1846.

identity. The group of Damsons is numerously represented in American orchards of the present day.

PRUNUS DOMESTICA PERNICONA.—These plums have long been known in cultivation under the name of Perdrigons. Two hundred years ago they seem to have been as distinct and important as the Reine Claudes. The first edition of *Species Plantarum* gave this name *pernicona*. In the second edition it was changed to *pertigona*. As both names appear in the pre-Linnean synonymy of the group it is apparent that this change was entirely arbitrary. The earliest spelling is therefore to be retained.

None of the Perdrigons specifically so-called are in general cultivation in this country now, though Downing[10] describes White Perdrigon, Blue Perdrigon, Red Perdrigon, and some other varieties properly referred to the same group. It is possible that further study of existing horticultural varieties will point out some good types of this group; but for the most part the Perdrigons, as a definite type, seem to be lost from American gardens, though several of the old time varieties are still cultivated in Europe. Even those varieties like Goliath, Diamond, etc., which may perhaps belong here, are not favorites in this country. They appear to be generally large, round, coarse-fleshed fruits of poor quality.

PRUNUS DOMESTICA JULIANA.—The St. Julian plums, at the time when the *Prodromus* was written, were plainly understood to belong to a separate type. They seem largely to have disappeared, however, from modern horticulture. Downing does not give the name, even as a synonym. Neither does Thomas. Hogg[11] describes one St. Julian, and says that "it is scarcely ever cultivated for the fruit," but makes a good stock. The St. Julian is still used as a stock in some parts of Europe. It has been employed to some extent in this country, but proved insufficiently thrifty to suit American commercial nursery methods. Professor Bailey tells me that the St. Julian, as he has seen it recently in European nurseries, is to be referred evidently to *Prunus*

[10] Fr. & Fr. Trees Am. 287, 290, 312. 1847. [7th ed.]

[11] Fruit Manual 570. 1875. [4th ed., London.]

cerasifera; and the fact that it grows from cuttings and its use as a stock may be held to strengthen this view. However, it is perfectly plain that in the view of early botanists the St. Julians were more closely allied to the Damsons, from which they were distinguished by their more ellipsoid fruit.

PRUNUS DOMESTICA CEREA.— The St. Catherine plums form a considerable pomological group, and are fairly well represented at the present day. St. Catherine, still cultivated in some parts of America, is probably the same variety figured and described by Duhamel in 1768, and taken by Seringe as the type of his botanical variety *Catherinea.* Linnæus' var. *Brignola* perhaps also belongs in this group.

PRUNUS DOMESTICA AUBERTIANA.—It seems impossible to refer any one of Linnæus' varieties to this group of Seringe. Nor do any of the descriptions of Tournefort, Bauhin, or other early writers seem to suit. This is so very odd as to raise a fair doubt of our understanding, at this point, of the Linnæan classification. The plum, Dame Aubert, figured and described by Duhamel and (doubtfully) taken by Seringe for his type, was certainly old enough to have been known by Linnæus, and was altogether too conspicuous a thing to have been overlooked. The type is preserved to us in Magnum Bonum.

PRUNUS DOMESTICA GALATENSIS.—This group was evidently intended to include the prunes, a class of plums which has often been felt, especially in Europe, to stand by itself. The fruits are usually pyriform, with free stones, and are suitable for drying. Considerable confusion exists as regards the reference of many cultivated varieties to this group, but the type is fairly clear, permanent, and well understood. The common prunes of the Pacific states and the ordinary Italian Prune of eastern orchards may be taken as the modern representatives of the group.

I ought now to hasten to say that, in recalling the early views of these varietal types, I do not wish for a moment to recommend that they be revived for future use. Perhaps it would be worth while to resurrect the variety *Damascena,* but certainly botany has no use for the other variety names now, and horticulture is, I think, able to make a better classification out of fresh whole cloth. I have no doubt that a re-study and re-classification of the horticultural varieties of *Prunus domestica* would be a very proper and profitable thing at this time. If any one is inclined to attempt that work, this review of the early history of varietal types ought to be of some use.

In conclusion I wish to acknowledge my indebtedness to Professors W. W. Rowlee and L. H. Bailey for help in looking up these questions. The library of Cornell University has been of especial service.

UNIVERSITY OF VERMONT.

BRIEFER ARTICLES.

RECENT WORK UPON THE DEVELOPMENT OF THE ARCHEGONIUM.[1]

In a recent paper already reviewed in the Gazette,[2] M. L. A. Gayet has presented the results of an extended series of observations upon the development of the archegonium in the Muscineæ. These studies were pursued in part under the direction of Professors Van Tieghem and Flahault, and include the principal groups of Hepaticæ and Musci.

Having covered much the same ground in a work published nearly three years ago,[3] I have followed with much interest the results of M. Gayet's investigations. Inasmuch as these differ a good deal from my own observations in certain details] of the development of the archegonium in both liverworts and mosses, I have examined again a considerable number of my preparations to see how far these would confirm the results obtained by Gayet.

Of the genera studied by Gayet, my own work included Riccia, Sphærocarpus, Targionia, Madotheca, and Anthoceros, all of which were examined in detail. On the other genera, Pellia, Marchantia, Preissia and Lophocolea, my own observations were either very incomplete or entirely lacking, but a number of other genera were included.

It has been generally supposed that the Hepaticæ differ radically from the Musci in the fact that the growth of the archegonium in the latter is mainly apical, while in the liverworts the growth in length is for the most part intercalary, the "cover-cells" of the archegonium being very early divided by intersecting quadrant walls. Gayet claims, in the first place, that he has demonstrated that this division does not take place until a late period, and that repeated segments are cut off from the cover-cell which add to the length of the neck; that is, in the

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[1] Gayet, L. A.: Recherches sur le développement de l'archegone chez les Muscinées. Annales des Science Naturelles Bot. VIII. 3: 161–258. 1897.

[2] January 1898.

[3] Structure and development of the mosses and ferns: Macmillan, London. 1895.

Hepaticæ, as in the true mosses, the growth in length of the archegonium neck is in part apical. On the other hand, he maintains that, contrary to the generally accepted view, the moss archegonium does not have the canal cells of the neck cut off from the base of the apical cell, but they are the result of the division of a primary neck-canal cell as in the Hepaticæ. In short, he recognizes no essential difference in the type of archegonium in the two classes of bryophytes.

The first genus treated by Gayet is Riccia, of which he studied several species, including *R. glauca*. He does not, however, make it clear in his figures from which species the drawings were made. I have drawn from one of my slides of *R. glauca* a longitudinal section of the young archegonium which is shown in the accompanying *fig. 1*. It is perfectly evident that here the cover-cell has already undergone the quadrant divisions and no longer can function as an apical cell. The archegonium here figured is about the same age as the one figured by Gayet in *fig. 7* of his first plate. The occurrence of two resting nuclei in the terminal cell, without any trace of a division wall, shown by him in *fig. 5* of the same plate, is, to say the least, remarkable. It is extremely likely, however, that proper staining would have shown a vertical wall between them.

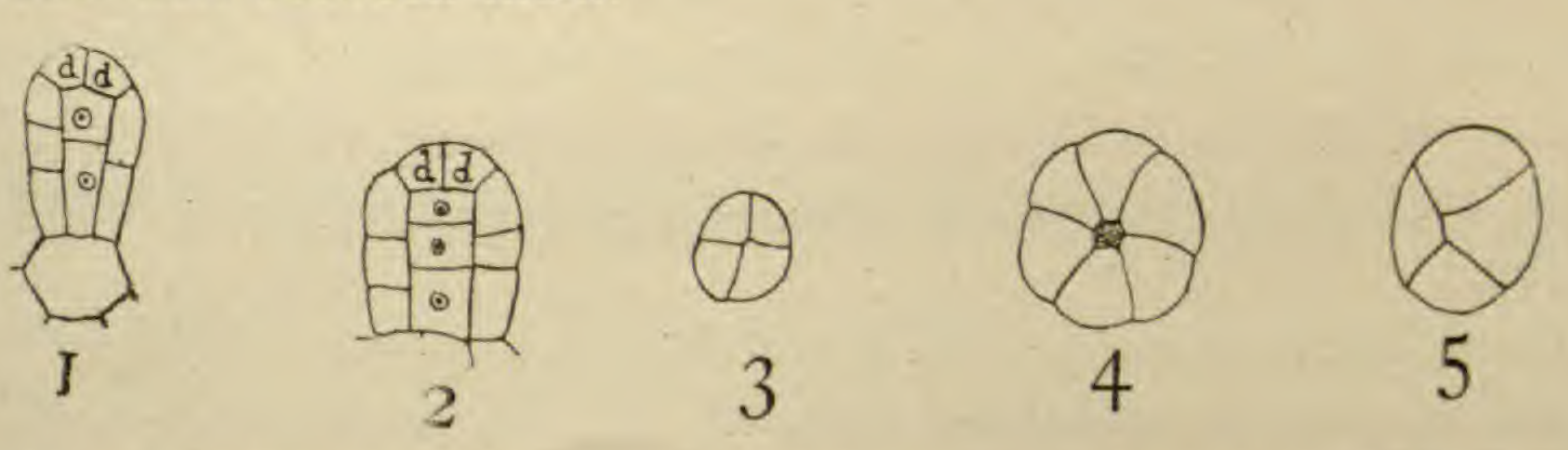

Fig. 1. Median longitudial section of the young archegonium of *Riccia glauca; d, d,* the cover-cells.— Fig. 2. A similar section of the archegonium of *Targionia hypophylla.*—Fig. 3. Transverse section of the four cover-cells of the young archegonium of Targonia.— Fig. 4. Cross-section of the neck of the archegonium of *Sphærocarpus terrestris*, var. *Californicus,* showing the six peripheral cells.— Fig. 5. The four cover-cells from a young archegonium of *Porella* (*Madotheca*) *Bolanderi.*—All the figures drawn with the camera from microtome sections.

The accompanying figures of the young archegonium of Targionia, *2, 3*, show that here too, the quadrant divisions of the terminal cell occur very early, and that any appreciable growth in length of the neck due to the activity of an apical cell is out of the question.

Of all the forms examined by me, the one which approached nearest the condition described by Gayet was *Porella* (*Madotheca*) *Bolanderi.*

While in this species there is an early quadrant division of the cover-cell (see *fig. 5*), the four resulting cover-cells are larger than is usually the case, and there may apparently be a limited number of the outer neck-cells which are cut off from these cells. Such a case is shown in *fig. 46, E*, of my *Mosses and Ferns*. That the cover-cells of the liverwort archegonium may undergo one or two divisions subsequent to the original quadrant-divisions, has been long known, but I have been unable to convince myself that any apical growth, in the sense in which it is understood among the true mosses, can be demonstrated in any of the liverworts examined by me.

Six rows of peripheral neck-cells are regularly found in the archegonium of the Marchantiaceæ while the normal number is five in the Jungermanniaceæ. I have found that in *Sphaerocarpus terrestris* var. *Californicus* and the allied Geothallus, there are six rows of peripheral neck-cells, in which respect, as well as others they are intermediate between the Ricciaceæ and thallose Jungermanniaceæ. Gayet disputes the accuracy of my statement in regard to Sphærocarpus, and it is possible that the European form of the species may show but five rows of cells. Neither of the two figures of Sphærocarpus shown by Gayet is a cross-section, nor does he say whether he actually examined such sections. In the few cross-sections of the archegonium neck which I have made, the number of cells was six (see *fig. 4*), although it is possible that this number may not always be constant.

It is to be regretted that M. Gayet has not given a more detailed account, as well as additional figures, of the archegonium of the thallose Jungermanniaceæ. He finds that in Pellia, as well as other Anacrogynæ, there may be six rows of peripheral cells, instead of the usual five rows hitherto supposed to be constant in this group, aside from Sphærocarpus and Geothallus. It is not strange that these primitive forms should show this approach in their structure to the Ricciaceæ with which they are closely connected by Sphærocarpus. It is to be hoped that we may soon have further information on this interesting point.

In regard to the statement that in the Musci the neck canal-cells are not cut off from the base of the terminal cell, as has been hitherto supposed, it cannot be said that Gayet's figures are very convincing. This very difficult point can only be settled by means of very thin axial sections of young archegonia. Here, too, a proper staining of of the division walls, such as M. Gayet seems to have considered superfluous, is very essential.

In studying M. Gayet's technique it is evident that he has depended too much upon rather primitive methods. While he has had recourse to various fixing and staining agents, he admits that so far as possible he has depended upon free-hand sections or "dissociation," *i. e.*, the dissection with needles of material treated with a strong macerating fluid. Where objects were too small to be thus handled they were imbedded in celloidin, which was then included in a coating of glycerine-soap. He does not appear to have employed paraffin for imbedding, nor to have employed any but nuclear stains, and it is very evident from some of his figures, *e. g.*, *5*, *83*, that cell-walls were in some instances entirely overlooked. In my own studies of the archegonium I have found such thin serial sections as can most readily be made by the paraffin method indispensable, and some good stain for the cell-walls, like Bismarck-brown, is necessary in order to differentiate the young cell-walls. The doubtfulness of conclusions drawn from a study of optical sections alone, from material rendered transparent by potash or other clearing agents, need not be insisted on here.

In short, until some of the statements made by M. Gayet can be confirmed by a thorough study of properly stained serial microtome sections, his conclusions can hardly be accepted without a certain amount of reservation.— DOUGLAS HOUGHTON CAMPBELL, *Leland Stanford Junior University.*

THE HOMOLOGY OF THE BLEPHAROPLAST.

THE recent investigations upon plant spermatozoids have not only added immensely to our knowledge of the structure and development of these organisms, but have brought out interesting suggestions as to the homologies of certain structures.

Previous to 1894, writers were concerned largely in discussing whether the body of the spermatozoid consisted of nucleus alone, or of both nucleus and cytoplasm. All agreed that the cilia are developed from the plasma. Later contributors, Belajeff, Hirasé, Ikeno, Webber, Shaw and Fujii, have shown conclusively that the body of the mature spermatozoid consists of both nucleus and cytoplasm; and, further, all connect the formation of cilia with definite organs which are variously designated Höcker, Körnchen, Körperchen, Nebenkern, attraction sphere, directive sphere, centrosome, centrosome-like body, and blepharoplast. It may safely be assumed that the various writers would now agree that the body described under so many names is the same morphological structure in all the forms studied. In this sketch Webber's peculiarly appropriate term blepharoplast will be used, disregarding the terms used by the various writers.

In *Equisetum arvense*, according to Belajeff, there appears in the mother cell of the spermatozoid not only the cytoplasm and nucleus, but also a deeply staining body resembling a centrosome. This body stretches into a thread lying along the nucleus. The thread becomes differentiated into a row of granules (Höcker), each of which gives rise to a single cilium. In the fern, *Gymnogramme sulphurea*, in the cell which is to give rise to two spermatozoid mother cells, Belajeff figures two blepharoplasts at opposite poles of the nucleus, giving a very centrosome-like aspect, but the blepharoplasts do not divide like Guignard's centrosomes, and each spermatozoid mother cell receives but a single blepharoplast. The further history of the blepharoplast is essentially the same as in Equisetum. It is suggestive to note that in Chara there are two *Höcker*, each of which gives rise to a single cilium.

Shaw's figures of *Marsilea vestita* might lead one to infer that the blepharoplasts have some relation to nuclear division, their position at the poles giving them a very centrosome-like appearance; but we are assured that there is no ground for the assertion that blepharoplasts are homologous or analogous with the centrosomes of those plants which have centrosomes, and that whether they have any relation to the centrosomes of lower plants must be settled by an investigation of the spermatogenesis and zoospore formation of these plants. Shaw did not succeed in determining the origin of the cilia, but believed it to be as described by Belajeff for Equisetum.

The blepharoplasts of Gingko, Cycas, and Zamia are of gigantic size in comparison with those already mentioned. In these three forms, as in the cryptogams mentioned above, the blepharoplast stretches out into a band which gives rise to the cilia. Hirasé's figures and descriptions of Gingko show that the blepharoplast is surrounded by kinoplasmic radiations in nearly all stages of its history. Two blepharoplasts first appear at opposite poles of the nucleus of the body cell and during mitosis maintain a position at opposite poles of the spindle, although at some distance from the spindle and from the daughter nuclei after division has taken place. Judging from the figures, one might conclude that, while the blepharoplasts do not appear to be concerned in the formation of the spindle, they may perhaps determine its orientation. As a matter of fact, the wall between the daughter nuclei is at right angles to a line connecting the two blepharoplasts. Belajeff's figures of Gymnogramme and Shaw's of Marsilea show the same orientation. Hirasé believes that the blepharoplast is a centrosome.

Ikeno's description of blepharoplasts in *Cycas revoluta* agrees in general with Hirasé's account of Gingko. After reviewing Hermann's work on the spermatogenesis of the salamander and the mouse, Ikeno comes to the conclusion that the blepharoplasts of the Characeæ, Filicineæ and Equisetaceæ, and also those of Gingko, Cycas and Zamia, not only bear a superficial resemblance to centrosomes but are genuine centrosomes which become enormously elongated and furnish a place of attachment for the cilia. Belajeff had previously reached a somewhat similar conclusion, although it was left for Ikeno to formulate it. Belajeff homologizes the blepharoplast of Characeæ, Filicineæ and Equisetaceæ with the deeply staining body of the spermatid of the salamander and the mouse, while the middle piece of the animal spermatozoon corresponds to the elongated cilia-bearing band of the plant spermatozoid. The thread-like tail of the spermatozoon of the salamander and mouse corresponds to a single one of the cilia of the plant spermatozoid.

The blepharoplasts of *Zamia integrifolia* described by Webber are the largest yet discovered. Webber does not believe that they are centrosomes. It may be true that they take no part in the formation of the spindle, but an examination of the figures forcibly suggests that they either orient the spindle or are oriented by it.

The centrosome of the alga Dictyota, recently described by Mottier, becomes elongated into a band which gives rise to cilia-like radiations. Mottier, as will be remembered, declares that in the higher plants there are neither centrosomes nor centrospheres in vegetative or reproductive cells, whether in the resting condition or during division, and he further asserts that there are no bodies which have any resemblance whatever to these structures or which stand in any relation whatever to karyokinesis. In the paper on Dictyota, Mottier, referring to the blepharoplasts of higher plants, states that they have nothing to do with spindle formation, a more conservative statement which, though probable, still remains to be proved, and even if proved determines no homologies.

It is readily admitted that the presence of centrosomes is not established in any of these plants which have such conspicuous blepharoplasts, and that the blepharoplasts are reported only in the last two generations of cells concerned in the formation of the spermatozoid; but it must also be admitted that the usually spherical centrosome may in certain cases assume other shapes, and that an increasing number of competent observers do not regard the centrosome as a permanent organ of the cell. Furthermore, the absence of the centrosomes from the higher cryptogams and the flowering plants is far from being established, and a most convincing demonstration is necessary before the testimony of Guignard, Rosen, Campbell, Schaffner and others can be disregarded.

If our conception of the centrosome is formed exclusively from the familiar figures of karyokinesis and the function of the centrosome in this process, we shall doubtless look for a new name whenever we find a centrosome-like body performing any other function than that of the typical centrosome; but it seems probable that a thorough investigation of karyokinesis and the formation of cilia in the lower plants may support the theory that the blepharoplast is a centrosome. —CHAS. J. CHAMBERLAIN, *The University of Chicago.*

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OPEN LETTERS.

ANOTHER QUESTION OF NOMENCLATURE.

THE receipt of Mr. G. B. Sudworth's *Check-List of the Forest Trees of the United States* (U. S. Dept. Agriculture), stirs me up to make a protest against a nomenclatural heresy which seems to find favor in certain quarters. It is this: *that a varietal name must be changed if it occurs elsewhere in the genus, even as the name of another species, or of a variety of another species.* This doctrine does not seem to me to be justified by the codes, nor is it conducive to the stability of varietal names. I have for many years had a good deal to do with the varietal nomenclature of animals, particularly mollusca, and have always considered it commendable to give the same name (*e. g.*, *minor*, *alba*, *elongata*, *hirsuta*, etc.) to similar variations of different species. This plan is widely accepted among zoologists, and is found advantageous in every way. The first time I noticed any general application of the contrary plan was when I received Bull. 9 of the *Minnesota Botanical Studies*. In this work (1894) Mr. E. P. Sheldon proposes ten varietal names in Astragalus, all of which I consider quite needless. Mr. Sudworth, in his *Nomenclature of the Arborescent Flora of the United States* (1897), and again in the above-mentioned *Check-List*, has followed the same doctrine, and has made sixty-six substitutions of new names for old, which I think should not be accepted. He has also made a number of other substitutions which rest on other grounds, and are apparently valid.

It is particularly important to decide at this time what we are going to do about the doctrine here discussed, because Mr. Sudworth has very excellently prepared a revised nomenclature of the cultivated varieties of our native trees, and unless some protest is made, it will doubtless become current as it stands. The desirability of a correct nomenclature for cultivated plants need not be urged, nor need it be pointed out that it must be for botanists to decide, eventually, what system shall be adopted. The system introduced by Mr. Sudworth, if supported, will logically compel us to make a revision of varietal nomenclature in many other groups, productive of much inconvenience, and, as I believe, of no good.

I append herewith a list of the Sheldonian names in the work cited, which I would reject, giving the corrected nomenclature in the second column. I have also prepared a list of the Sudworthian names, but it is too long to print here.

Other similar instances may be found in the *List of Pteridophyta ana Spermatophyta in Northeastern North America* (1894), particularly under *Carex.*

A reasonable rule, which would avoid these changes, would be: *Only identical combinations shall be considered homonyms.*

NAME PROPOSED BY SHELDON.	CORRECT NAME ACCORDING TO PRESENT WRITER.
Astragalus viridis impensus.	*A. v. elatus* (Wats.).
A. speirocarpus curvicarpus.	*A. s. falciformis* A. Gray.
A. preussii laxispicatus.	*A. p. laxiflorus* A. Gray.
A. p. arctus.	*A. p. latus* Jones.
A. leucopsis curtus.	*A. l. brachypus* Greene.
A. franciscanus longulus.	*A. f. virgatus* (A. Gray).
A. megacarpus prodigus.	*A. m. parryi* A. Gray.
A. sparsiflorus majusculus.	*A. s. major* A. Gray.
A. glabriusculus spatiosus.	*A. g. major* A. Gray.
A. atratus arctus.	*A. a. stenophyllus* Jones.

It will be noted that Mr. Sheldon himself gives the same varietal name to two species. This may be an oversight, or it may be that he considers a varietal name invalid only when used (if not under the same species) in a specific sense elsewhere in the genus. At the same time, he changes a varietal name when the alleged homonym is a pure synonym, so long as it is a binomial.

A curious case is that of *A. crotalariæ* var. *virgatus* Gray. It seems that both names are preoccupied in a specific sense, so Sheldon calls the species *A. franciscanus.* According to my views, Gray's varietal term *virgatus* may be retained *as varietal,* though it cannot be applied to the species, because of the earlier *A. virgatus* Pall. Thus we get *A. franciscanus* var. *virgatus,* an instance of a varietal name older than that of the species.—T. D. A. COCKERELL, *Mesilla Park, N. M.*

CURRENT LITERATURE.

BOOK REVIEWS.

The organography of plants.

A FEW months ago we had the pleasure of receiving the first part of Goebel's *Organographie der Pflanzen*. The hope that was then expressed[1] is now in a measure realized by the publication of the first section of the second part.[2] This section is devoted to the bryophytes. In the general part the author sought to picture the fundamental principles of organ formation, illustrated by a few examples. In the special part he seeks to carry out the plan in greater detail, so far as concerns the archegoniates and seed plants.

At the outset he meets the question, "in what relation organ formation stands to adaptation, or, in other words, whether the specific characters which separate the individual species, genera, etc., in any order, are of an adaptive nature only, as the extreme believers in the importance (*Bedeutung*) of natural selection think, or whether specific and adaptive characters are to be distinguished." Goebel expresses the positive conviction that the latter is the case, holding that, although "organization must, of course, always meet the life demands, the characteristic impress which it bears in every group, in spite of all the variety in the special adaptive external conformation, shows that the 'inner constitution'—if we may use this expression to hide our ignorance—plays the most important rôle, even were the polymorphism of organ formation not comprehensible." When, however, an adaptive character appears in all, or almost all, the members of the group, *e.g.*, the thallus structure in Marchantiaceæ, there arises a difficulty which the author dismisses with these words: "this is to be considered more than an accidental coincidence with the specific characters; an agreement, indeed, which one can make thoroughly intelligible only when one supposes the adaptation to be ancient, having taken place before there occurred a separation of the group in question into forms developing in different directions." This, of course, one of those "extreme believers in the importance of natural selection" (from whose ranks Goebel excludes himself), would call a begging of

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[1] See review in this journal, **25** : 290. 1898.

[2] GOEBEL, K.—Organographie der Pflanzen, insbesondere der Archegoniaten und Samenpflanzen. Zweiter Teil: Specielle Organographie. 1 Heft: Bryophyten. 8vo. pp. 283–385. *figs. 131–359.* Jena: Gustav Fischer. 1898. *M* 3.80.

the question! Is it conceivable that the "inner constitution" is anything more than the aggregate result of ancient adaptations?

Here is another sentence which seems to strike a false note in its implications. "All speculations, proceeding from the highly developed archegoniates, as to the connection of liverworts and mosses, bryophytes and pteridophytes, etc., are, therefore, only products of the poetic imagination, arising from our mental necessity of assuming connections even where they cannot be directly observed, but having no adequate support in the facts of experience. Their sole value consists in that they incite to the raising of new questions." What higher value, we may ask, has any hypothesis?

We shall have concluded all adverse criticism when we further point out that in this section, much more than in the general part, the author yields to the seductive temptation to assign definite purposes to certain organs, and to say: this is an adaptation for thus and so, with the same airy grace to which we have become accustomed in Haberlandt's *Physiologisches Pflanzenanatomie*. One can hardly help thinking, like Cato, "It must be so: Plato, thou reasonest well; else, whence this. . . . ." Yet, all the while, there is a subconscious certainty that the solution is too easy, and that, in some measure at least, we are listening to fairy tales — "lediglich Produkte dichterischer Phantasie," to use the phrase Goebel has given us. We are unpleasantly reminded of the outgrown teleology by this new attempt to explain

> The reasons of things —
> Why Injuns wore rings,
> In their red aboriginal noses.

We cite only one example (p. 242): "I entertain no doubt that the mucilage filling the neck-canal [of the archegonium] protects the egg chiefly against contact with water." Can one avoid asking evidence that there is need for protection of the egg against contact with water, and, if that is furnished, demanding proof that water movement is restricted by this mucilage when it is not by other kinds?

But it is in the clear stream that one discerns the snags along its bed, while turbid waters hide their dangers. On the whole, this section of the work is, like its predecessor, most interesting, suggestive, and valuable. The new point of view for the discussion of the bryophytes is the striking feature. We have grown used to the purely formal standpoint — even to the *Standpunkt der Mikrotomtechnik* — which, the author well declares, "is greatly inferior to the apprehension of nature by the great bryologist of the preceding century, Hedwig, whose view was not yet narrowed by the verbal blinders, morphology and physiology." And so the facts which the author sets before us are presented in a new light. Seen in this way they are certain to suggest new investigations. No higher result can be sought or obtained from such a book, and none so sure to redound to the permanent fame of the author.

Moreover, the book is far from a review of already published facts. It sets before the reader a great number of new investigations of much interest, illustrated by many new figures, whose freshness is as invigorating as a sea breeze. To one who restates in better form our old knowledge, and adds so much that is new, it is easy to forgive the possible slight distortion of perspective which we shall easily escape when at a greater distance from the facts. It is only bare justice to recognize in this work a master hand, and to hail it as one of the books predestined to become a classic. — C. R. B.

A new school botany.

IT is a good sign when university professors interest themselves in secondary education. Too often text-books for high schools have been prepared by those who do not know the subject; and it may be further stated that occasionally text-books have been prepared by college men who do not know the schools. That happy combination of experience which brings together the two kinds of knowledge is demanded for the preparation of such books.

Almost every university will be represented presently by a botanical textbook for the secondary schools. In the opinion of the reviewer, the chief criticism to offer in reference to most of these books is that they attempt to present too great an abundance of material, and also material that is too difficult. It is hard for the average college man to appreciate how unfamiliar the material of modern botany is to the young student of the secondary school. A rapid succession of facts, all of which are new to his experience, is too apt to result in bewilderment rather than knowledge.

The last candidate in this field is from the pen of Professor Atkinson,[3] of Cornell University, who shows an appreciation of the situation, and who has certainly had a large and successful experience with elementary classes. The book is a hard one to criticise, as it is a combination of commendable and careless features. Some of the features that should receive warm commendation are wealth of illustration, short paragraphs with distinct headings, originality of presentation, and especially the ecological chapters upon soil formation, zonal distribution, and occupation of land. Certainly so many commendable features more than justify the publication of the book.

On the other hand, carelessness of statement and want of logical organization are apparent. This carelessness amounts frequently to error. The lack of organization is indicated on the surface by such facts as that the division of the book devoted to physiology has received no title and part number, such as have been given to Morphology and Ecology; and that the matter included

[3] ATKINSON, GEORGE FRANCIS. — Elementary Botany. Small 8 vo. pp. xxiii + 444. *figs. 509.* New York: Henry Holt & Co. $1.25.

under the various headings is frequently not what the heading indicates, as, for example, Chapter XII. This fault culminates in the division of the book given to ecology, which is in a remarkably indefinite condition.

It may be that an occasional lapse into poetical style has its place in stimulating interest in the secondary schools, but the reviewer questions whether a sentimental interest should have any connection with scientific training.

The introduction of photographs of typical plant associations is very commendable, but something must be done to make such photographs significant. This criticism has reference not only to the book in hand, but to the general use of such pictures. If ecology is to take the prominent place in elementary botanical education that it deserves, we must have publishers get beyond the dim and hazy landscapes which may be capable of interpretation by the trained ecologist, but which mean little or nothing to the elementary student.

Professor Atkinson's book is one of great interest, and will be a stimulus to proper botanical study in secondary schools. The weak points are such as often appear in the work of a very busy man, who may not lay special stress upon logical presentation and exact statement.—J. M. C.

Bokorny's text-book.[4]

THIS is the latest contribution to the long list of German text-books. It is intended for use in the technical schools and gymnasia, and seeks to present the subject without requiring of the student too great "expenditure of time or effort of memory." To this end a novel approach to the subject is introduced. Thirty-five pages are devoted to the illustrated descriptions of some of the commonest seed plants, the violet, mustard, pear, etc. These descriptions are in the simplest language, and are evidently intended to be taken in connection with laboratory study of the types selected. However remote such an approach may be from a logical presentation of the subject, there is some reason in the plea that the student may be thus gently induced to careful observations, and well oriented in the new field by learning first the technical interpretation of the plants he has always known. The rest of the text suggests an effort to give good place to each of the schools with too great emphasis upon none. It is an exemplification of the extremely various ideas which prevail as to which interpretation of the plant world may best be presented first to the beginner. The author, save for the departure in the first chapters, does not commit himself. The organs of the plant body are taken up in logical sequence in the second part. This would serve equally

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[4] BOKORNY, TH.—Lehrbuch der Botanik. 8vo. pp. vi + 226. *figs. 170.* Leipzig: Wilhelm Engelmann. 1898. *M.* 2.40.

well morphology, taxonomy, ecology, physiology, what not. Then a few pages are devoted to minute structure, and a review of forms follows with the highest spermatophytes leading the procession, and in the usual modern proportion of about four pages of spermatophytes to one of the "sporophytes" (the author's word).

The physiology is divided into the chemical and physical processes within, and the "biology," *i. e.*, relations to environment; a separation not without difficulty. Three pages are devoted to "something about plant geography," and a key for identifications completes the work. The text is exceptionally clear, simple, and free from technical phraseology. Most of the illustrations are borrowed from the *Natürlichen Pflanzenfamilien*, which is sufficient commendation.—JOHN G. COULTER.

MINOR NOTICES.

THE WRITINGS of Professor Dr. P. Magnus, of Berlin, include much matter that is of moment to American botanists. Dr. Magnus is a student of fungi, but writes to some extent upon other subjects. His interests are catholic, and he has often contributed to the solution of problems arising in distant quarters of the globe. A number of separates (which he generously sends to all whom he knows to be interested in such subjects) have recently come to hand, and the opportunity is taken to give a brief account of their contents.

In a communication to the *Botanisches Centralblatt*[5] some criticisms are offered upon the treatment given the Hemibasidii and Uredinales by Dr. Dietel in Engler and Prantl's *Natürliche Pflanzenfamilien*. It is pointed out that the sorus of Doassansia is never imbedded in the parenchyma of the host, as stated by Dietel (*l. c.*, p. 21), but always lies immediately beneath and in contact with the epidermis. He reviews the genera Doassansia and Burrillia and their subgenera as characterized by Setchell, and holds them to be more logical and natural than the arrangement proposed by Dietel. Turning to the Uredineæ he states that *Puccinia Schweinfurthii* Magn. forms witches' brooms, and should not be confounded with *P. Mesneriana* Thüm. or *P. digitata* Ell. & Hark., which never do so, although otherwise much alike. Exception is taken to the establishment of the genus Phragmopyxis with a layer around the spores that swells in water, while ignoring Schröter's genus Uropyxis with just the same claim to recognition. It is pointed out that aside from this equivocal character, Uropyxis possesses good generic characters in the number and position of the teleutosporic pores. The suppression of the genera Xenodochus and Chaconia, and the grouping of some of the genera are not approved.

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[5] Einige Bemerkungen zu P. Dietel's Bearbeitung der Hemibasidii und Uredinales in Engler-Prantl Natürliche Pflanzenfamilien Bd. I.—Bot. Centr. **74**: 165–170. 1898.

An extended account of the structure and occurrence of some new species: *Phleospora Jaapiana*, from Germany,[6] *Aecidium Opuntiæ* from Bolivia,[7] and *Aecidium Jacobsthalii-Henrici* from the Straits of Magellan,[8] with fine detailed illustrations in each case, gives much information beside the usual diagnoses.

In 1897 Dr. Magnus traveled in the United States, and he took the opportunity to make observations upon the lilac mildew[9] so familiar to everyone in this country, and especially to all pupils in college classes in botany. In Europe the lilac is free from mildew, only one collection being recorded, and that proved to be *Microsphæra Ehrenbergii* Lev., a common species on *Lonicera tartarica*. The American form was for a time referred by American botanists to *M. Friesii* Lev., but since the study of it by Burrill in the preparation of his article on the Parasitic Fungi of Illinois, it has been called *M. Alni* (DC.) Wint. Dr. Magnus shows that although it is very closely related to *M. Alni* of Europe, yet there are some morphological differences which indicate that it is geographically modified, and entitled to a separate name. Priority requires that it be called *M. Syringæ* (Schw.) Magn., which he considers unfortunate in view of the fact that the American forms upon Betula, Corylus, Castanea and Ilex must also be placed under it, all being native plants while Syringa is introduced, and is therefore a comparatively recent host for it. Attention is called to the fact that so far no cultural studies have been made among the Erysipheæ to determine relationship.

While in this country Dr. Magnus read a paper at Toronto before the British Association for the Advancement of Science upon the mycelium of witches' brooms of the barberry[10] in Europe. It had been asserted by Eriksson that the mycelium of this Aecidium penetrates the cells of the host, and develops colored granules within, both being exceptional for members of the Uredineæ, but both claims are shown to be errors. This is the Aecidium of *Puccinia Arrhenatheri* (Kleb.) Eriks.

In a short communication to *Hedwigia* on *Puccinia Lycii* Kalchbr.,[11] some errors in the original description are noted, and also an increase in the number of pores of the uredospores corresponding to an increase in size.

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[6] Eine neue Phleospora. Hedwigia **37**: 172–174. 1898.

[7] Eine neues Aecidium auf Opuntia sp. aus Bolivia. Ber. d. deutsch. Bot. Ges. **16**: 151–154. 1898.

[8] Ein auf Berberis auftretendes Aecidium von der Magellanstrasse. Ber. d. deutsch. Bot. Ges. **15**: 270–276. 1897.

[9] Der Mehlthau auf *Syringa vulgaris* in Nordamerika. Ber. d. deutsch. Bot. Ges. **16**: 63–70. 1898.

[10] On *Aecidium graveolens* (Shuttlew.). Ann. Bot. **12**: 155–163. 1898.

[11] Ein kleiner Beitrag zur Kenntniss der *Puccinia Lycii* Kalchbr. Hedw. **37**: Beiblatt 91–93. 1898.

The teleutospores are also exceptional in having the pore of the lower cell at the bottom rather than in the upper part.

Two articles before us are of local interest,[12] but another, the last to be mentioned, brings out the interesting fact that the production of lateral flowering stems from the base of the common century plant, *Agave Americana*,[13] when the central shaft has been injured, was recorded as early as 1705 —J. C. A.

THE ADVISABILITY of using pure cultures of yeasts in the process of fermentation in breweries has been clearly demonstrated by a number of writers. It has been suggested frequently that the same purity of yeasts is no less desirable in the manufacture of bread, and in order to determine whether this is true, Miss Katherine E. Golden has made a study of several commercial yeasts and their effects.[14] It was found that almost all market yeast packages contain corn or potato starch ; and that they are adulterated with alum which is added as an antiseptic against bacteria and molds. The bacteria were constantly present, however, and the molds in many of the packages. These greatly change the fermentative effect of the yeasts, and produce unpleasant odors which are indications of the less nutritious condition thus induced in the bread.

Experiments were made to test the efficiency of various commercial yeasts, and of pure cultures made from the same. It was found that young cultures of pure yeast would bring a much greater fermentation in bread sponge in less than half the time required by ordinary market yeast. With such pure cultures the desired fermentation within the sponge is secured before there has been sufficient time for undesirable organisms to develop. This is not true with the yeasts usually employed, since by waiting for the necessary fermentation there occurs frequently a large and injurious growth of bacteria and molds which begin to induce putrefaction in the sponge. When pure and vigorous yeasts were used the bread was always sweet, and remained good much longer than when made with the adulterated cake. The flavors of good bread may be varied by the use of various kinds of yeasts. If the same care is used in this manufacture as is used in the

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[12] Zweiter Beitrag zur Pilz-Flora von Franken. Abh. d. Nat. Ges. Nürnberg 11 : 23–57. *pl. 1.* 1898.

Ein weiterer Beitrag zur Kenntniss der Verbreitung der *Thorea ramosissima* Bory im mittleren Deutschland. Deutsch. Bot. Monatssch. **1898** : 17–18.

[13] Blühen der Agaven an Seitentrieben, von Dr. Otto Kuntze. Mit Bemerkungen zu den vorhergehenden Mittheilungen, von P. Magnus. Gartenflora **1898** : 215–216.

[14] GOLDEN, KATHERINE E.—(1) Yeasts and their properties. 8°. pp. 28. (2) On bread and bread-making. 8°. pp. 22. Purdue University Monographs ; Series relating to food, nos. 5 and 6. 1898. (3) Pure yeast in bread. Proceedings of Indiana Academy of Science **1897** : 62–64. 1898. (Reprint repaged !)

selection of yeasts for the manufacture of beer and other liquors, a very much finer quality of bread may be secured, and many deleterious effects may be avoided.

Further work was done to determine whether the yeast cells live in bread after baking, and the conclusion was reached that yeasts are always killed by the heat necessary to bake the bread. If living yeast cells were taken into the alimentary canal, however, they would probably produce no bad results as experiments made seem clearly to demonstrate.

The papers contain most careful and interesting descriptions of the many kinds of bread and the best processes of making them.—OTIS W. CALDWELL.

THE FLORA of Costa Rica has been receiving its share of attention, the results appearing in parts under the title *Primitiæ Floræ Costaricensis.* Parts I–III were published at Brussels in 1891, 1893, and 1896, respectively, under the joint direction of Th. Durand and H. Pittier. These three parts completed the first volume, and at its close M. Durand was compelled to withdraw from the undertaking. The first part of the second volume has now appeared,[15] published at St. José de Costa Rica, under the auspices of the National Geographical Institute, and with M. Pittier as sole editor. Mr. J. Donnell Smith has contributed the part by preparing a list of the known Polypetalæ, including descriptions of new or recently described species, and omitting those families which have been presented in previous parts. It is a great gratification to those interested in the American tropics that this important publication is to be continued.—J. M. C.

PROTOPLASMIC streaming in Characeæ has been again investigated and is discussed from a strictly physiological point of view by Dr. Georg Hörmann in an extended paper, independently published.[16] He seeks a theoretical explanation of the movement of streaming and the conduction of impulses. An explanation of the direction and plane of streaming, both in cells of the axes and rhizoids, Hörmann finds in the advantage of securing the shortest route from the places of absorption or manufacture to the places of utilization of the materials, which thus, in their transfer, are subject to a minimal loss. The larger part of the paper is devoted to a discussion of experiments to ascertain the causes and nature of the movement, and the conduction of stimulation impulses. In his experimental work the application and ingenious adaptation of the modern methods of animal physiology yield new and valuable suggestions as to the theory of movement.

[15] PITTIER, H.—Primitiæ Floræ Costaricensis. Vol. II, pp. 1–126. Polypetalae. by John Donnell Smith. San José de Costa Rica. 1898. $1.00.

[16] HÖRMANN, GEORG.—Studien über den Protoplasmaströmung bei den Characeen 8°. pp. iv + 79. *figs. 12.* Jena: Gustav Fischer. 1898. *M* 2.

Finding that, just as in muscle and nerve, the nitella cell may be stimulated by the production of katelectrotonus and the disappearance of anelectrotonus and that the stimulation wave is accompanied by the so-called "negative" wave, he concludes that muscle, nerve, and nitella cell must have some fundamental structural element in common. As the nerve has only conductivity he concludes that conductivity and contractility are properties of different substance. The conductive plasma, existing alone in the nerve, is accompanied in muscle and nitella cell by another substance, which conditions the phenomena of contraction and streaming. Nor has he overlooked the difference between muscle and nitella, in that a stimulus in the one case causes a resting organ to work, while in the other it brings a working organ to rest.

The explanation of this is to be found only in a fundamental difference in the structure of the mechanism of movement. The details of the discussion must be sought in the work itself.—C. R. B.

DR. P. SYDOW has brought together much useful information in a botanical calendar.[17] Besides the astronomical calendar, there is a calendar for notes and memoranda for each day, with the birth and death days of many distinguished botanists; tables of equivalents in money, weights, and measures; post and telegraph rates; the Berlin rules for nomenclature; a list of the cryptogamic exsiccatæ which have been issued; a list of the botanic gardens and museums; and finally a list of the botanical collections to be found in the larger museums and herbaria. The difficulty of securing accuracy and completeness in the last three lists is very great. The author realizes that it has not been attained and appeals for assistance by corrections.—C. R. B.

A VERY USEFUL ACCOUNT of the economic grasses, by F. Lamson-Scribner, has been published as Bulletin 14 of the grass and forage investigations of the Division of Agrostology, Department of Agriculture. Brief descriptions and illustrations are given of the more important economic grasses of this country, or those which have been introduced because possessing some merit. Bulletin 15 of the same division is a report upon the forage plants and forage resources of the Gulf states, by S. M. Tracy, containing descriptions, comments, and illustrations, in addition to the general discussion of the forage problems of the south.—J. M. C.

F. H. KNOWLTON has done botanists great service in the preparation of his *Catalogue of the Cretaceous and Tertiary plants of North America.*[18] The

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[17] SYDOW. P.—Deutscher Botaniker-Kalender für 1899. 16mo. pp. 198. Berlin: Gebrüder Borntraeger. 1898. *M* 3.

[18] KNOWLTON, F. H.—Bulletin of the U. S. Geological Survey no. 152. pp. 1–247. Washington, 1898. 20 cents.

first catalogue of the kind was that of Lesquereux, published more than twenty years ago, and containing 706 species. The present catalogue testifies to the fact that since that time species have been described with great industry. Although no statement is given as to the number of species, it is remarked that the Potomac flora alone now numbers more than the total Cretaceous and Tertiary floras known to Lesquereux. The catalogue is a real bibliography and must prove of great service.—J. M. C.

NOTES FOR STUDENTS.

H. H. DIXON has turned his attention to transpiration, and in Proc. Roy. Irish Soc. III. **4**:618–635. 1898 discusses the effects of stimulative and anæsthetic gases on transpiration, and transpiration into a saturated atmosphere. —C. R. B.

CZAPEK points out[19] an interesting case of adaptation in leaves of *Cirsium eriophorum*. Plants growing in very sunny situations on the southerly mountain slopes in central Bohemia had the segments of their pinnatifid leaves erected into two comb-like rows, while in shady places these are transverse. The erect segments of the sun-beaten leaves were inrolled at the edges and were different in structure from the shade leaves, having palisade cells 25 per cent. longer, and richer in chlorophyll. The same difference was remarked between the erect segments and transverse portions of the same leaf.—C. R. B.

THE CYTOLOGY of the yeast cell has been a difficult matter to investigate, but important results have been obtained by Janssens and Leblanc.[20] They used malachite green, dahlia, gentian violet, Delafield's hæmatoxylin, and "black hæmatoxylin" (black hæmatoxylin differs from Delafield's in that the ammonia alum of the latter is replaced by iron alum). These stains show that every yeast cell contains a nucleus and a nucleolus. During budding there is indirect division of the nucleus in some species, while in the common *Saccharomyces cerevisiæ* and some others the division is direct. Cells about to produce spores contain two nuclei which fuse. The resulting spore on germination shows a much modified form of division. The paper is illustrated by excellent plates.—CHAS. J. CHAMBERLAIN.

UNDER THE TITLE *Analecta bryographica Antillarum* Dr. Karl Müller-Halle has published[21] a long list of mosses from the Greater and Lesser

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[19] Œsterr. bot. Zeit. **48**:369–371. 1898.

[20] JANSSENS, FR. A. and LEBLANC, A.—Recherches cytologiques sur la cellule de levure. La Cellule **14**: 203–343. 1898.

[21] Hedwigia **37**:(2–?) 266. 1898.

Antilles, a publication which has special interest in view of the botanical collections now being made in Cuba and Porto Rico. These "crumbs" Müller has swept up from various collections, some as old as Charles Wright's (1856). He enumerates 175 species, of which almost 100 are marked *n. sp.* Of these, however, nearly one-fourth have been previously otherwise determined by such bryologists as Sullivant, Mitten, and Bescherelle. In view of these ratios we are inclined to think the finding of so many "crumbs" is due rather to the fineness of the crumb brush than to the carelessness of other sweepers.—C. R. B.

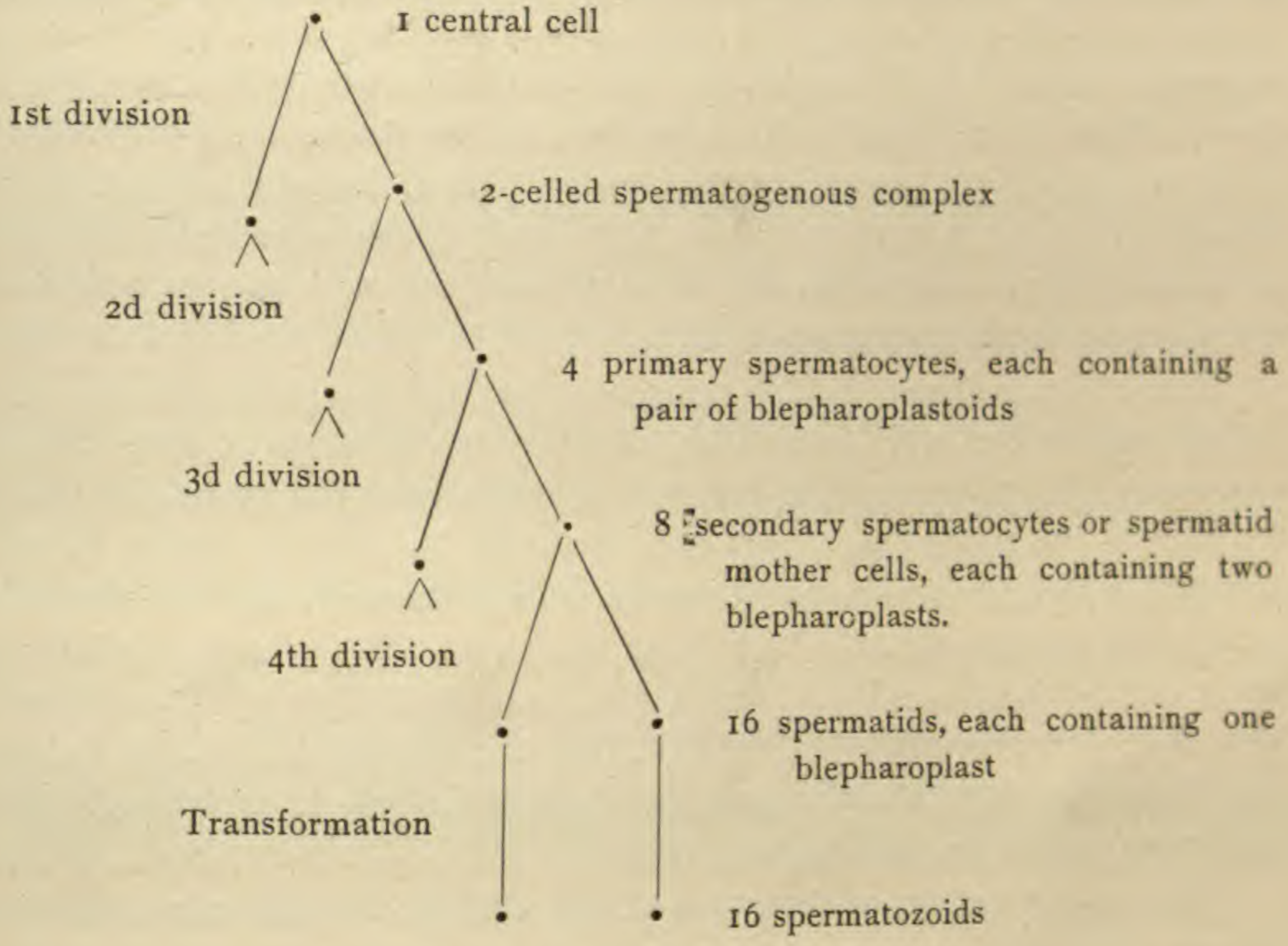
BELAJEFF'S account[22] of the origin of the cilia of spermatozoids has been confirmed and supplemented by Dr. W. R. Shaw,[23] who has taken Onoclea and Marsilea as his types. In these plants, as in Equisetum and Gymnogramme, the cilia arise from a small cytoplasmic body lying in the mother cell of the spermatozoid. For this cytoplasmic body, which was designated "Nebenkern" by Belajeff, Dr. Shaw proposes to adopt the more expressive name "blepharoplast," a name first employed by Webber to denote a similar structure in Zamia. Dr. Shaw has sought to discover the origin of the blepharoplasts and their behavior in karyokinesis. In the antheridia of Marsilea true blepharoplasts are found only in the last two cell generations. In the early stages nothing like a blepharoplast is present, but in the karyokinesis intervening between the two- and four-celled stage a small body appears at each pole of the two spindles; subsequently each of them divides into two. Since these bodies disappear into the cytoplasm and do not give rise directly to the true blepharoplasts, the author calls them "blepharoplastoids." About the time when the blepharoplastoids are lost sight of, the blepharoplasts make their first appearance as small granules situated in the spindle-poles of the nuclear figures which precede the eight-celled stage of the antheridium. Each of them divides into two. During the following resting condition of the nucleus these two halves gradually separate, at the same time increasing in size, and move round to the positions to be taken by the poles of the next following spindles. During the ensuing karyokinesis they remain practically unchanged. In the mother cell of the spermatozoid the blepharoplasts become granular, elongate, and probably undergo the same transformations which Belajeff has described in detail.

The accompanying diagram, copied from Dr. Shaw's paper, will help to make clear the relations of the blepharoplast as, well as to explain his substitution of the zoological terms "spermatocyte" and "spermatid" for the exceedingly cumbrous phraseology in use among botanists. While changes in terminology are difficult to secure, the advantages of the suggested modifications are obvious. Indeed it would be almost ludicrous to speak of "great-

[22] Berichte der deutschen bot. Gesell. **15**: 337–345. 1897, and **16**: 140–143. 1898.

[23] Berichte der deutschen bot. Gesell. **16**: 177–184. 1898.

grandmother cells," as would be necessary in describing the primary spermatocytes.



Naturally the question arises: Is there any relationship between blepharoplasts and centrosomes? The identity of the two structures was conjectured by Belajeff and is accepted by Ikeno; and certainly when one considers their similarity in staining reaction, position, size, and divisions, together with the analogies which animal spermatogenesis affords, it seems a not unreasonable conjecture to suppose the blepharoplast to be a centrosome modified for the performance of a new function. Such a view will probably be taken by those who share the opinions of Guignard and Schaffner, and by most animal cytologists. But those who hold with Strasburger and his assistants that there are no centrosomes among cormophytes will of course reject it. Neither Belajeff nor Shaw is prepared at present to maintain the homology of centrosome and blepharoplast. Dr. Shaw says: "At present we can only express the view that the blepharoplast is a kinoplasmic body set apart for the purpose of forming cilia."—WILSON R. SMITH.

SINCE THE ANNOUNCEMENT by Treub in 1891 of chalazogamy in Casuarina there has been on the part of morphologists a persistent interest in knowing just how far this process extends in fact and in meaning. It was for a time supposed that the phenomenon is shown by Casuarina only, and this was used as the basis of a new classification—the chalazogams represented by Casuarina, and the porogams represented by all other angiosperms. But such ideas had to be abandoned when Miss Margaret Benson reported chalazogamy in Alnus, Corylus, Betula, and Carpinus. Later, Nawaschin announced that in *Juglans regia* the pollen tube takes an intercellular course within the ovule and agrees in a general way with the first reports of chalazogamy. Since Miss Benson's publication it was supposed that this peculiar condition was confined to the Casuarinaceæ, Betulaceæ, and Juglandaceæ, until, in Nawaschin's laboratory, the genera Urtica, Cannabis, Humulus, and Morus were found to have the pollen tube evading the micropyle and taking an intercellular course within the ovule, though not agreeing in details with the previous accounts of chalazogamy.

New evidence is now furnished by Nawaschin,[24] the plants studied being *Ulmus pedunculata* and *U. montana*. The writer indulges in a discussion of the nature and location of the influence which directs the growth of the pollen tube of the porogams. This influence may be entirely within the tube; or within a secretion produced by certain cells of the style and nucellus which attract and nourish the tube; or these cells of the style and nucellus may serve only as mechanical guides, while the real impulse to growth rests within the tube. It is now probable, however, that a combination of all these factors constitutes the directing influence. Such might furnish an explanation for the porogams but not for the chalazogams.

The behavior of the pollen tube of the elms is divided into three categories. The first is given as the normal behavior, in which the pollen tube passes down the funiculus of the anatropous ovule, which is suspended from the top of the carpel cavity. From the funiculus the tube passes across above the short outer integument and through the inner one, reaching the top of the nucellus, after which the regular behavior is observed. In the second category the tube may branch profusely and with no definiteness within the funiculus and the integument. This branching may occur out of the tissues after the pollen tube has reached the tip of the nucellus. In such cases the male cells within the tube always follow the newest branch. In the third category the tube grows down the funiculus near to the bases of the integuments, then grows up through the inner integument to a region on a level with the nucellus tip, when it turns across to the bottom of the micropyle as before. Or, instead of passing up between the cells of the inner integument, it may pass through the chalaza into the embryo sac as the tube of a true chalazogam.

In no case was any tissue found which could be considered especially conductive or nutritive tissue. Nawaschin thinks these two species represent a region in which these tissues are not yet definitely differentiated, but that the chalazogamic habit is being dropped as is evidenced by the varied attempts of the pollen tube to reach the tip of the nucellus, and by occasional reversion

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[24] NAWASCHIN, SERGIUS: Ueber das Verhalten des Pollenschlauches bei der Ulme. Bull. d. l'Acad. Imper. d. Sci. d. St. Petersbourg **8**: 345. 1898.

to passage through the chalaza. He would look upon the elms as one of the transition types from the chalazogams to the porogams.

Supplementing this work of Nawaschin, N. Zinger has found[25] that in the ovules of Cannabineæ the inner integument, which is elsewhere very delicate, over the apex of the nucellus becomes massive and is completely coalescent with the thick outer integument. The micropylar canal before fertilization is entirely closed by papillary outgrowths from the surface and marginal cells of the integuments. These outgrowths form a densely interwoven firm tissue above the apex of the nucellus, passing into the tissue of the ovary wall above. The pollen tube follows the central cells of the styles (conducting tissue ?) downwards, passes along the upper wall of the ovary, penetrates the outer and inner integuments or bores through the tissue filling the micropyle, and reaches finally the nucellus. Here it produces numerous sac-like tumid branches about the apex, until one very delicate tube penetrates to the embryo-sac.— OTIS W. CALDWELL.

A RECENT MONOGRAPHIC work by Adamovic on the vegetation formations of eastern Servia adds greatly to our knowledge of the flora of that country.[26] Botanical research in Servia is a matter of the last two decades, because of the blighting rule of the Turkish government. The names of Pancic and Petrovic are about the only ones that need to be recollected, with the exception of that of the author of the monograph under review.

Servia is a mountainous country in the truest sense, even the river valleys being some hundreds of meters above sea level. The mountains belong to the Balkan and Rhodope systems and are of various geological ages from Precambrian to Recent. The country is drained by the Morava and Timok rivers, tributaries of the Danube. The climate is intermediate between that of continental Europe and the Mediterranean climate to the south.

The author first discusses the formations of the plains and lower hills. There are extensive rocky pastures, mostly along the slopes of hills; the floral covering is sparse and the plants are decidedly xerophilous in structure and periodic in their life functions. These rocky pastures grade into hilly steppes, where the soil is more gravelly or sandy than rocky. In both of these formations euphorbias are characteristic. The meadows are divided into valley or true meadows and swampy meadows, the latter grading into swamps. Rock formations are quite abundant and closely related to rocky pastures, though the rocks are larger and the vegetation more open. The northern slopes have a richer flora because of greater moisture. The swamp and water formations do not form a very large part of the flora of the country. Among the shrub and tree formations there are extensive areas of brushwood;

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[25] Flora **85** : 189–253. 1898.

[26] ADAMOVIC, LUJO.— Die Vegetationsformationen Ostserbiens. Engler's Bot. Jahrb. **26** : 124–218. 1898.

along streams are thickets with a dominance of willows; the only formations with tall trees are the poplar forests. The influence of man on the flora of the plains and hills has been very great, especially in the destruction of forests.

On the mountains below the timber line mountain meadows are found quite commonly. In the calcareous regions there are peculiar funnel-shaped depressions formed by the erosion of the limestone. These depressions are called *Dolinen*, and their flora is more or less xerophytic. The rock formations of course are well developed, and the author divides them into calcareous and eugeogenous, the latter with a much richer plant covering. (The term eugeogenous was introduced years ago by Thurmann; it means easily decomposed into good soil.) There are low forest thickets (*Buschwald*) in very many places, representing a second growth. There are two true forest types, the oak forests and the subalpine forests with a dominance of beeches.

Above the timber line there are subalpine meadows, heaths and thickets. Higher up are alpine mats and extensive lithophytic formations. The influence of man becomes less and less evident as the altitude increases. The last chapter gives a short summary of the most important results. Adamovic subdivides eastern Servia into four altitudinous regions based on barometric measurements. (1) The regions of plains and hills reaches up to 600^m, and is characterized by the almost entire absence of forests, a condition wholly due to the influence of man. The areas once wooded are occupied by culture plants, mainly cereals, hemp, tobacco, and melons. The hillsides are covered by vineyards and fruit trees. The vegetation belongs to Drude's Pontic type, mixed with some Mediterranean elements. The average annual temperature is 11.5°C., and the vegetation period is ten months. (2) The mountain region extends from 600^m up to 1100^m. Culture formations are much less abundant, the Mediterranean floral elements have disappeared, the Pontic elements are less abundant, and the characteristic vegetation of central Europe is preeminent. The low second growth timber is the most common formation. The mean temperature is 9.5°C. and the vegetation period nine months. (3) The subalpine region extends between 1100^m and 1660^m. The beech forests have replaced the oak and the second growth. The heaths and subalpine meadows are also prominent. The floral elements coincide mainly with the mountain zone of central Europe. The average temperature is from 7° to 8°C. and the growing period less than eight months. (4) The alpine region has no culture formations and the dominant landscape features are given by rocks and the variegated alpine mats. The floral elements are a mixture of the alpine types of central Europe and endemic types. The mean temperature is about 6°C. and the vegetation period scarcely six months.— HENRY C. COWLES.

M. CH. DASSONVILLE has made an elaborate study of the effect of mineral salts upon plant structure.[27] A great number of experiments were made, in which direct control was had by germinating in solutions, while supplementary evidence was gained by germination in soil to which either solutions of a single salt of graded strengths were presented, or complex solutions accompanied by check experiments in which the salt under study was omitted from the complex solution presented. Check experiments in distilled water accompanied those in which germination was effected in a liquid solution. Certain mineral solutions induced more vigorous growth of both vegetative and floral parts, but a period of life no longer than in aqua pura. M. Dassonville presents also the surprising results that cutinization, sclerification, and lignification are much more accentuated in young plants in distilled water than those of the same age in mineral solutions. The observations are not directed so much to general effects as to the most intimate histological alterations. One comprehends that the work must be most extensive to present reliable results.

The effect of particular salts may be summarized as follows: magnesium sulfate retards normal development only at first, later becoming indispensable for it. In the castor-oil plant the retarding effect is chiefly upon the terminal root, which is atrophied. Later adventitious roots develop, the more the stronger the solution. In hemp there is no adventitious development, but the secondary wood is stimulated and the primary vessels retarded.

Potassium phosphate is necessary at all stages. Its absence insured a characteristic abnormal development of the roots. Its presence stimulates the sclerification of the pericycle.

Potassium silicate deepens the green of the leaves and affects their structure and lignifies the peripheral cells of the root tip.

The effect of nitrates varies in different plants, and with the strength of the solution and the stage of development. No attempt was made to formulate a general law from the confusing results of the seven types studied. However, the acetates of ammonia and potassium seem best for hemp and buckwheat, while sodium acetate is deleterious. No matter what the base, the acetates call forth a special tint in the leaves, which the author attributes especially to acetic acid.

Potassium stimulates growth, but retards the differentiation of sclerenchyma, and may thus increase the liability of "lodging" in the Gramineæ. Sodium is less favorable to growth, but hastens lignification of the stem-base, preventing "lodging."

Calcium chloride and magnesium seem equally beneficent to hemp and buckwheat, and the decreasing order of utility of acids for these types is acetic, phosphoric, hydrochloric.

[27] Influence des sels minéraux sur la forme et la structure des végétaux. Revue générale de Botanique 10:15 sqq. 1898.

The author argues that the absence of high nutrition, *i. e.*, germination in distilled water, induces the seedling to direct its energy chiefly to cell differentiation. And, vice versa, it is to be expected, and his results demonstrate, that a seedling grown in a rich nutrient medium, such as Knop's solution, will multiply cells rapidly without differentiation. In other words, sterile soil predicates precocious sclerification ; rich soil a later appearance of the ultimate structure, but a more rapid division of cells without differentiation. Apparent counter evidence is offered by the effect of single salts, which stimulate the differentiation of particular regions, as the effect of potassium phosphate on the pericycle or of magnesium sulfate on the vessels of the root. M. Dassonville evades a contradiction of results, asserting the latter to be a differentiation of a particular region called upon to play a definite rôle by the abundance of particular substance, and holding that, for the rest, the meristem reserves as long as possible the expenditure of energy in the way of differentiation. The author seriously questions the taxonomic value of anatomical characters, a challenge which, with the trend wholly in the direction of phylogenetic characters as the ultimate basis of classification, will find few takers. Such specific distinctions are altogether too cumbrous for taxonomic purposes.

The value of these results is apparent and we recognize the great difficulties surmounted in their attainment. The deductions, however, are by no means final, because there is too little accord among even the few types studied. Results obtained from the investigation of lupine, wheat, oats, morning glory, egg plant, tomato, and pine, do not permit the induction of general laws. Though the methods show the work to have been stupendous, we are impressed with the impossibility of eliminating disturbing factors aside from the one under consideration. For example, the author concludes that the optimum of potassium phosphate "augments only the quantity of water in the plant," a result obtained from buckwheat. But, he adds, "sometimes the amount of dry matter is increased. It is so in hemp."—JOHN GAYLORD COULTER.

NEWS.

M. CAMILLE SAUVAGEAU has been appointed professor of botany in the University of Dijon.

WE NOTE the recent death of Professor Joseph Gibelli, professor of botany at the University of Turin.

DR. DOMENICO SACCARDO has been called to Bologna as the assistant of Professor Fausto Morini in the botanical garden of the university.

THE distinguished phycologist, J. B. Edouard Bornet, of Paris, celebrated his seventieth birthday on the second of September last.

THE SECOND annual meeting of the Society for Plant Morphology and Physiology will be held at Columbia University, Wednesday to Friday, December 28 to 30.

PROFESSOR DR. C. SCHRÖTER, of Zürich, began about the last of August a tour of the world, intending to visit North America, Japan, China, Java, Sumatra, India, and Egypt.

ACCORDING to the newspapers Professor Dr. Oscar Brefeld of Münster has accepted the call to the University of Breslau as successor to the late Dr. Ferdinand Cohn.—*Bot. Zeit.*

DR. G. VENTURI, the well-known Austrian bryologist, died on the fifth of June. His moss herbarium, containing about 4000 species, and his library were bequeathed to the city of Trent.

DR. ERNST BAUER (Smichow bei Prag, N. C. 961) has begun the issue of a set of exsiccati, entitled *Bryotheca Bohemica*. In the issue of Century I Dr. V. Schiffner and other less known bryologists have cooperated with Dr. Bauer. The price per century is *M* 14.

FROM the *Forester* we learn that the New York College of Forestry has about thirty-five students taking advantage of its courses. Only two are regularly matriculated in the college, the rest being students of engineering who registered in College of Agriculture to escape fees, intending to change over to the College of Forestry later.

DR. CARL FREIHERR VON TUBEUF, private docent in the university and the technological school of Munich and director of the Bavarian station for plant protection and plant diseases, has been given permission by the government to take a staff position in the biological experiment station for agriculture and forestry connected with the imperial bureau of hygiene at Berlin. He will direct the botanical laboratory.

PROFESSOR DR. G. LEIMBACH, the editor of the *Deutsche botanische Monatsschrift*, announces that, at the end of the year, the journal again comes into his possession as publisher. It will be published as heretofore at *M* 6 per year. The office of publication is at Arnstadt, Thüringia.

THE *Deutsche botanische Monatsschrift* announces in its October number (received late in November) that a most annoying delay has occurred in the issue of the Ascherson-Gräbner *Synopsis* of the flora of central Europe. No explanation is given, but the *Monatsschrift* is authorized to say that, at all events, no additional part is to be issued this year.

MR. W. T. SWINGLE has been commissioned by the United States Department of Agriculture to investigate the agriculture of the countries in Europe, Asia, and Africa which border on the Mediterranean. He is to study the plants cultivated and the methods of culture, in the hope of discovering plants which may be introduced to advantage into America. The work is to be done under Mr. Fairchild's section of seed and plant introduction, and will occupy about six months, after which Mr. Swingle will return to America. During his absence letters may be addressed in care of Thomas Cook & Son, Ludgate Circus, London, E. C.

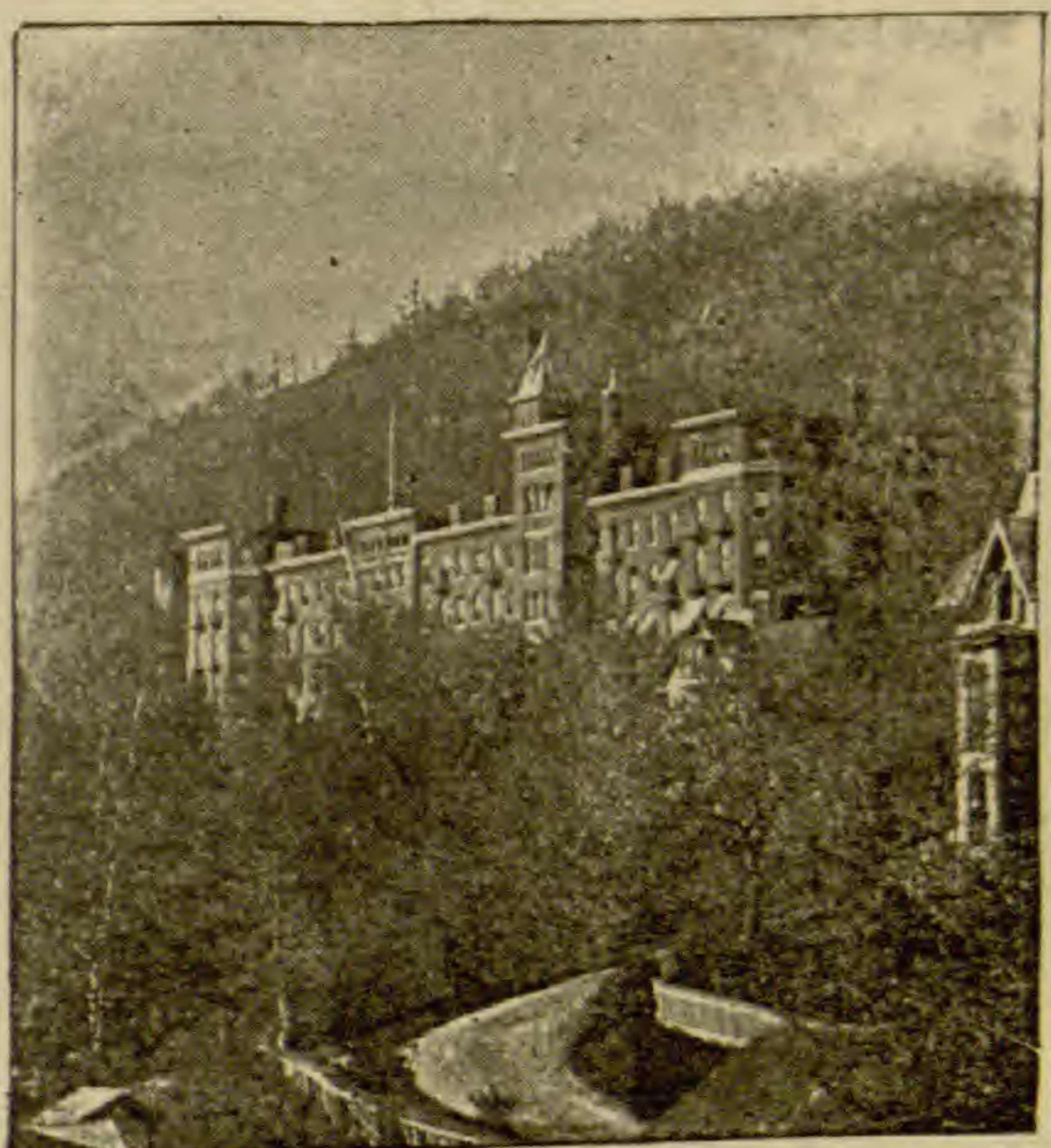
MR. D. G. FAIRCHILD, formerly special agent in charge of the section of seed and plant introduction, U. S. Department of Agriculture, has been assigned, at his own request, to duty as an agricultural explorer. He will visit both coasts of South America, in company with Mr. Barbour Lathrop, of Chicago, to investigate the economic plants of those regions and import stock of the more promising sorts into the United States. Mr. O. F. Cook, formerly Liberian agent of the New York Colonization Society and director of the college and the coffee experiment farm near Monrovia, has been appointed to take charge of the seed and plant introduction work, under the direction of the botanist of the department.

DR. C. F. MILLSPAUGH, of the Field Columbian Museum, is to leave New York about December 20 for the West Indies, where he will spend the winter months in botanical exploration. He is a guest upon the private yacht of Mr. Allison Armour, which will be largely under his direction as to the ports visited. Ample arrangements have been made for rapid and complete collecting, the purpose being not to obtain duplicates, but to secure as complete a representation of the flora as possible. Mr. E. P. Allen, the photographer of the museum, will also accompany the expedition, and will pay special attention to the general ecological features.

The places to be visited are as follows: San Juan de Puerto Rico; San Domingo; Santiago de Cuba; islands of Grand Cayman, Little Cayman, and Cayman Brac; Isle of Pines; Cape Corientes; islands of Cozumel, Mugeres and Holbox; interior of Yucatan as far as Buena Vista Xbac and Chichea Itza; the Alacran Shoals; and Havana.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Diseases, Necrology, 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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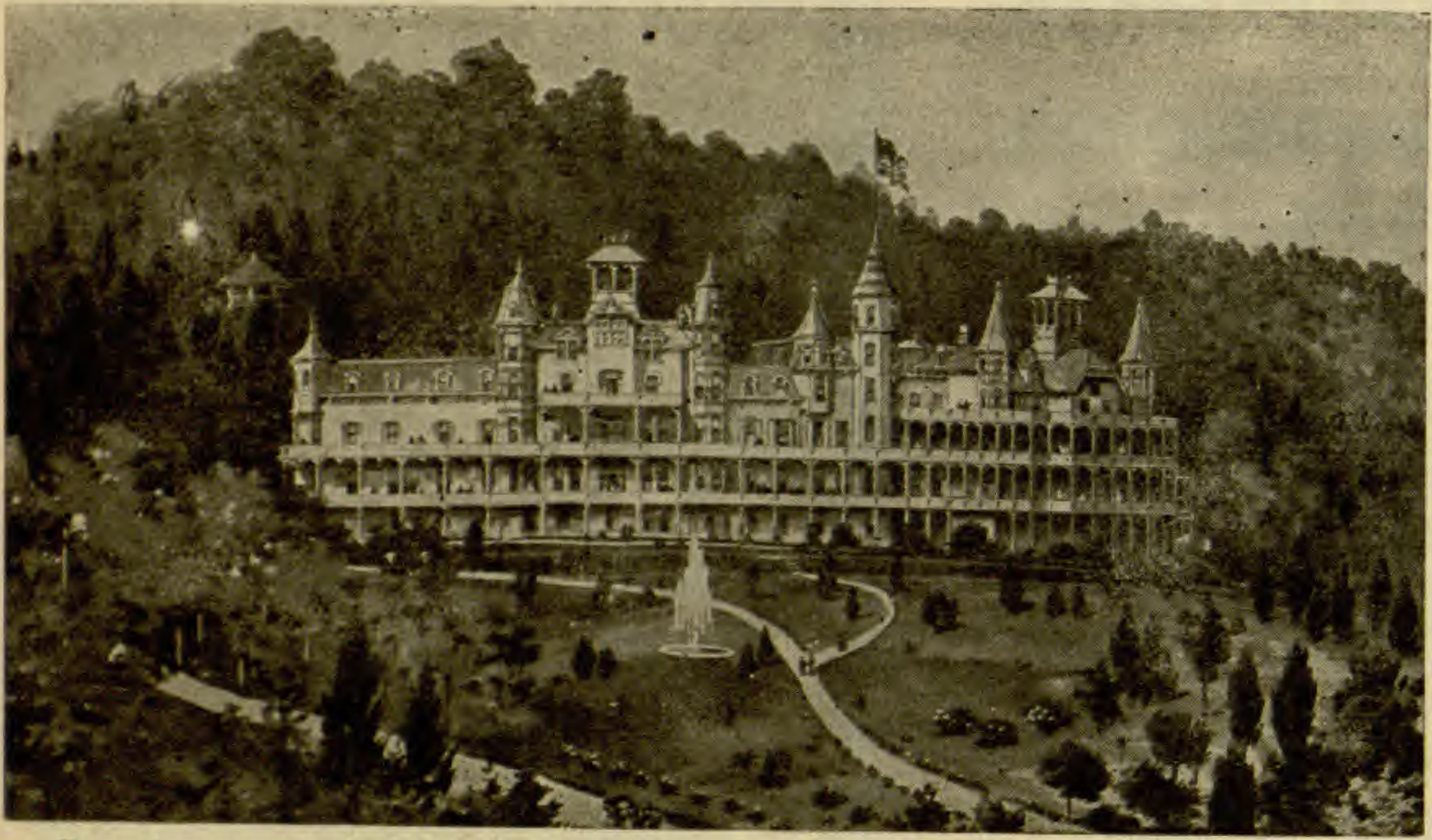

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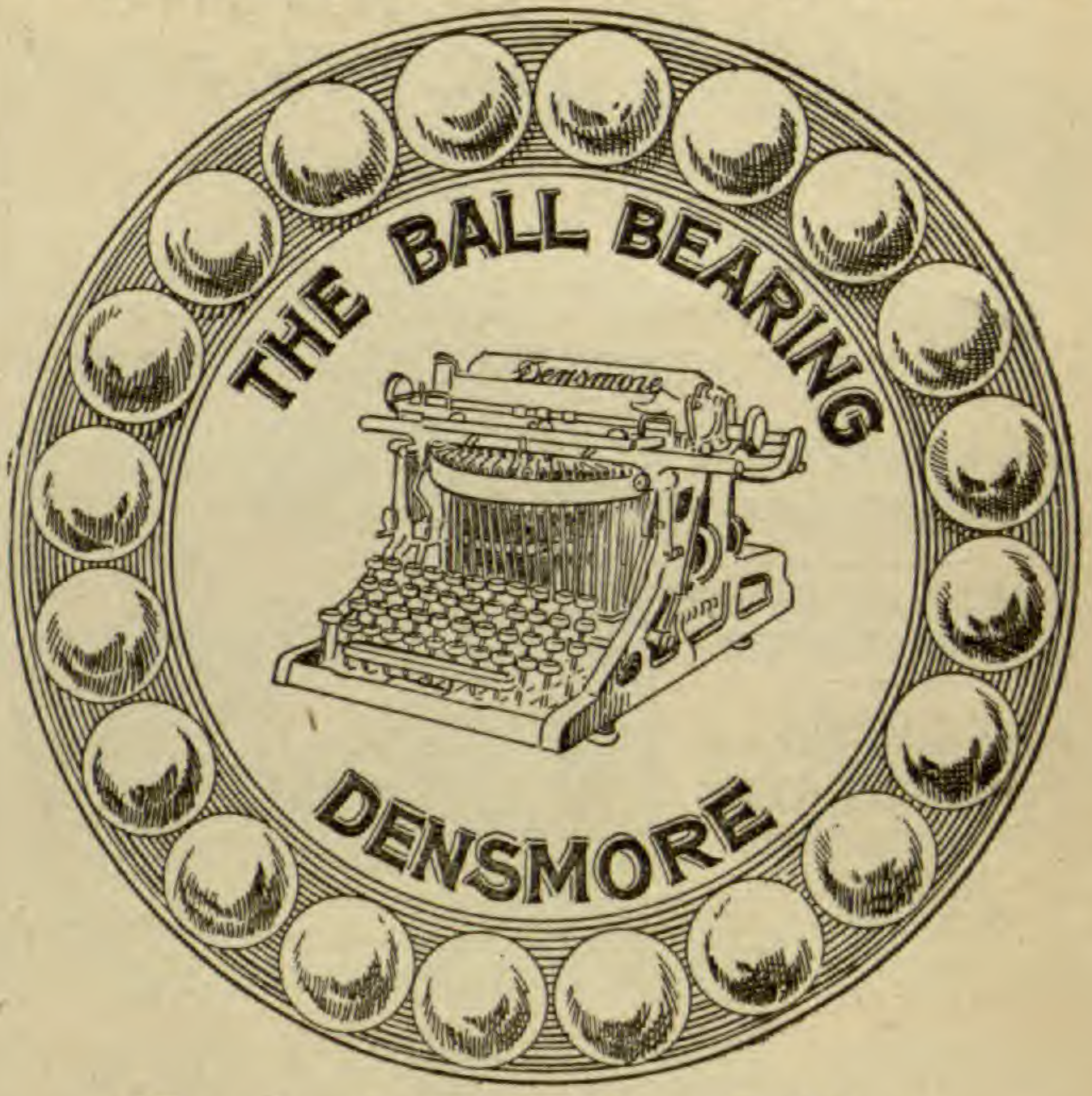
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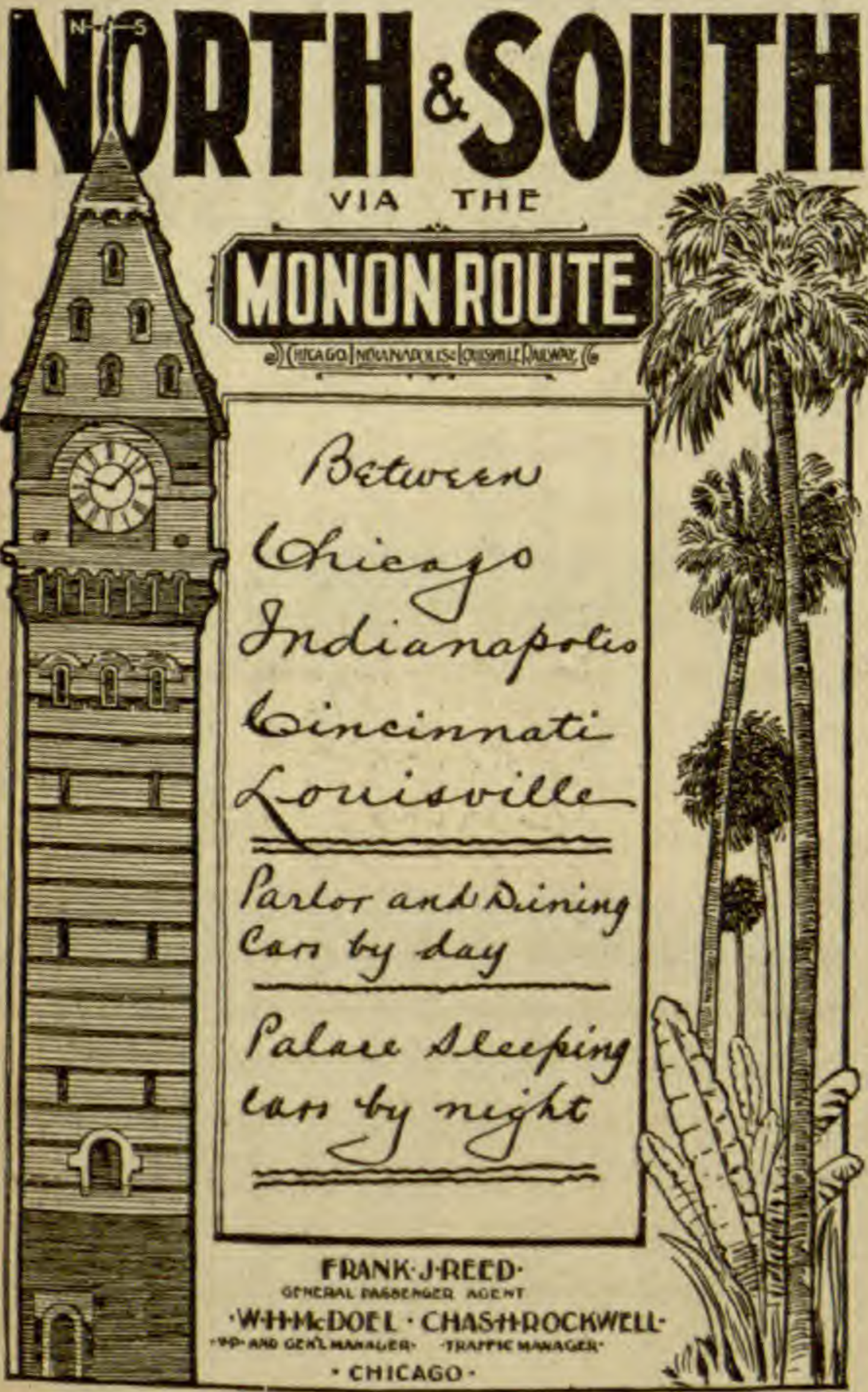
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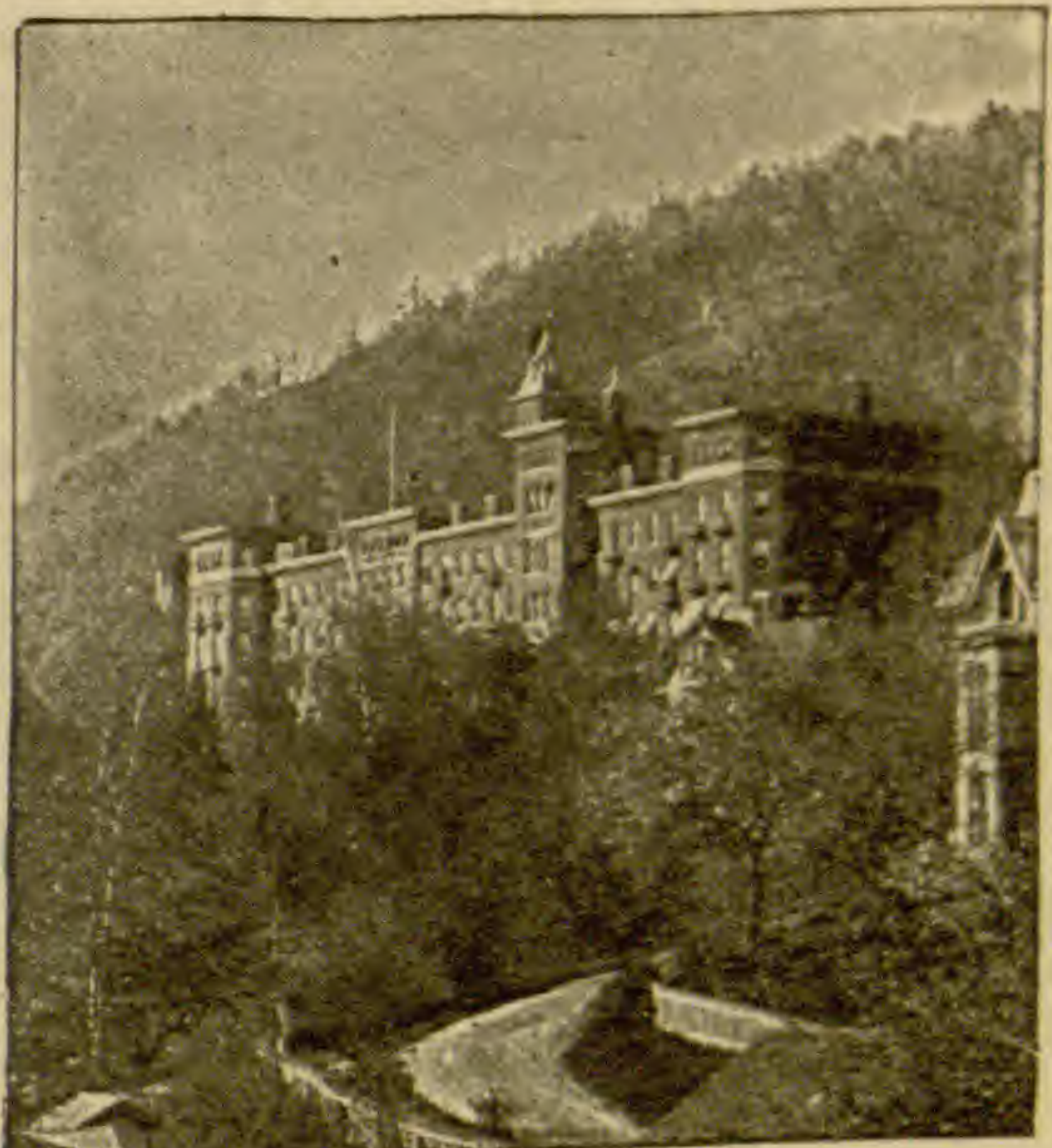

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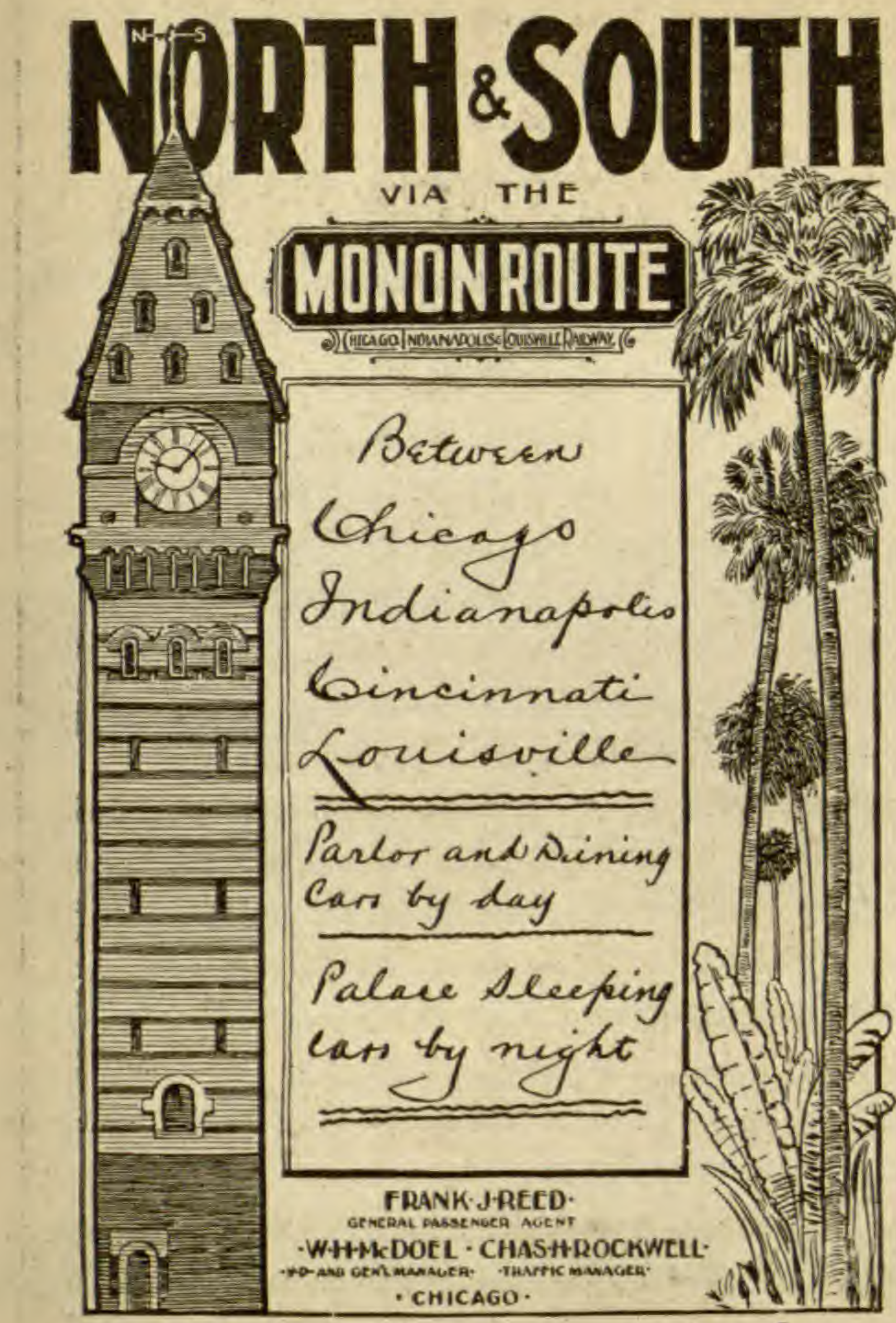
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