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THE
BOTANICAL GAZETTE

EDITORS

JOHN M. COULTER AND CHARLES R. BARNES,

WITH OTHER MEMBERS OF THE BOTANICAL STAFF
OF THE UNIVERSITY OF CHICAGO

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BOTANICAL GAZETTE

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ASSOCIATE EDITORS:

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TABLE OF CONTENTS.

BRIEFER ARTICLES—

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No. 1, January 20; No. 2, February 18; No. 3, March 18; No. 4, April 16; No. 5, May 17; No. 6, June 20.

ERRATA.

P. 2, line 26, Horn (3) should read Horn (11).

P. 53, line 4 from below, for CENTROSTEGIA CRYPTANTHA read CENTROSTEGIA **cryptantha.**

P. 58, line 5 from below, for *Langloisia setossissima* read *Langloisia setosissima.*

P. 152, line 1, add *d*, at end of line.

P. 213, line 5 from below, for **Zebrina pendula** read ZEBRINA PENDULA.

P. 221, line 19, omit dash at end of line.

P. 221, line 21, indent United States.

P. 239, line 5, for Arnold read Arnoldi.

P. 319, line 18 from below, for Carboniferousage read Carboniferous age.

P. 394, line 7 from below, for phto- read photo-.

P. 399, line 12 from below, for building read budding.

P. 399, line 17 from below, for *U. exalata* read *U. exoleta.*

P. 403, line 16, for Dematicae read Dematieae.

The following errata are in W. F. Ganong's paper in **36**: 161–186, 280–302, 349–367, 429–455. 1903.

P. 354, line 3, for are read is.

P. 431, line 28, for importaace read importance.

P. 434, line 21, for 291 read 292.

P. 438, line 34, add the before Staticetum.

Throughout the paper change Phleumetum to Phletum.

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CONTENTS

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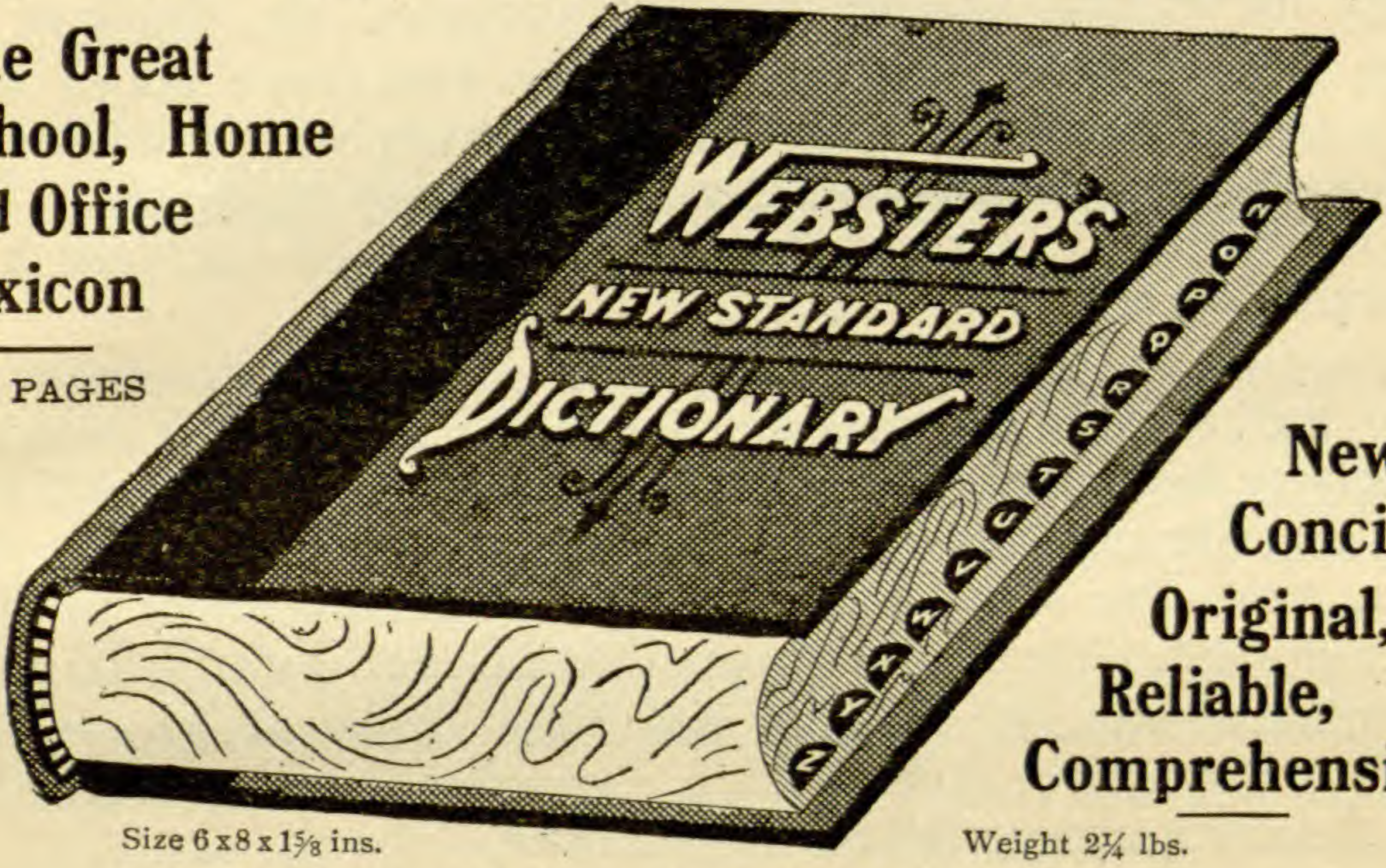

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VOLUME XXXVII NUMBER 1

BOTANICAL GAZETTE

JANUARY, 1904

THE MORPHOLOGY OF ELODEA CANADENSIS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LII.

ROBERT B. WYLIE.

(WITH PLATES I–IV)

THE Helobiales occupy a place of special interest among monocotyledons. Beginning with members having the simplest flowers, the group includes an ascending series of forms and finds its climax in the Hydrocharitaceae which display considerable floral complexity. This series has attracted much attention from plant morphologists and early investigation naturally centered among the simpler members. It was with the hope of adding something to the data concerning one of the higher forms that this study was undertaken Elodea further invites attention on account of its being one of the most specialized of submersed aquatics.

My thanks are due Professor John M. Coulter and Dr. Charles J. Chamberlain for kindly suggestions and valued assistance.

FLORAL DEVELOPMENT.

The flowers of *Elodea canadensis* are usually borne singly in the axils of leaves, and are scattered along the stem in a loose indeterminate inflorescence. They are so far apart, however, being separated by fifteen to twenty internodes, that one flower is well developed before the primordia of the next younger one are established.

The flowers are functionally monosporangiate, though rudiments of the suppressed parts are often present. Three sterile stamens are commonly found in the pistillate flower, and six have been reported to occur in rarer instances. These staminodia are composed of uniform parenchyma and show no evidence of the suppressed sporangia. Much more unusual is the development of stigmas upon the staminate flower. Eichler (5) refers to these as being possibly rudimentary stamens; the writer, however, has found well-developed stigmas above the nine stamens usually borne by the staminate flower. In one instance the stigma was clothed with papillae and covered with pollen grains which had sent their tubes into its tissue. In such a case it would appear that the usual stigmatic secretions are present and that it differs in no essential respect from a normal stigma. Such conditions recall Chamberlain's (2) discussion of the teratology of Salix, in which monosporangiate, dioecious genus he reports almost all possible combinations in the production of the sporangia.

The occurrence of these rudiments in Elodea must point back to an ancestry with perfect flowers, and their specialization has no doubt been correlated with the changed conditions of the submersed habitat. The flowers are now dioecious and are peculiarly adapted to the combined influences of wind and water for pollination. The pistillate flower is quite complex and presents one of the most striking cases of epigyny known; the staminate flower is simpler and has acquired the habit of breaking loose from the stem at maturity.

The development of the pistillate flower was studied by Horn (3), who also investigated the vegetative plant body; but since his work was based on the external aspects or rough sections only, the account, while accurate in a very general way, lacks most of the details secured through modern methods. The pistillate flower begins as a protuberance from the side of the stem near the growing point (*fig. 1*). This swelling pushes out rapidly, soon equaling the stem tip in length and giving it the appearance of having bifurcated (*fig. 2*), but the main axis soon reasserts its dominance, leaving the flower as a distinctly lateral member (*fig. 3*). At this time ridges near the base of the flower mark the origin of the spathe (*fig. 2*), which pushes out rapidly and for a long time envelops the developing flower (*figs. 2–12*).

The apex of the receptacle now flattens and broadens slightly, and, with the earliest indication of the floral parts, a cylindrical mass of tissue grows up (*figs. 5–10*), leaving a triradiate slit down its center, the walls being closely pressed together. The various parts of the flower continue meanwhile to develop at the outer end of this rapidly elongating growth. The calyx pushes out first (*fig. 5*), the sepals soon curving over the growing parts within; next comes the whorl of three sterile stamens (*figs. 8–9*), followed by the three stigmas (*figs. 10–12*); last of all appears the corolla (*figs. 11–12*).

Simultaneous with the development of the stigmas at the outer end of this floral tube is the growth of the ovules within its base. These push out from the surfaces of the central opening (*fig. 10*), but it is only as they develop that traces of the ovarian cavity appear (*fig. 11*). The walls which have previously remained in contact are now pushed apart, forming the rounded triangular ovary (*fig. 12*). The parts above ultimately coalesce, roofing over the cavity.

The various parts of the flower having been established, the floral tube, that region of fused parts between ovary and sepals, enters upon a period of more rapid elongation. The direction of growth is at first a negative geotropic response, and the young flowers stand up quite stiffly, but during later development proper orientation is probably due entirely to the buoyancy of the enclosed gases. Very early in the history of the flower the beginnings of three rows of air spaces can be seen, extending through its whole length (*fig. 11*). These start as rifts between cells and increase in size with the growth of the flower (*fig. 12*), until at maturity they constitute a large part of its volume. It is the low specific gravity of the floral tube that insures its direction toward the surface of the water, as these parts are very weak and cannot support themselves. A cross-section of the floral tube shows an outer ring, composed of two layers of cells, and a central conducting strand joined to the outer part by three bridges of tissue, leaving the three rows of air spaces between. The outer wall has no stored food, but all other cells are richly provided with starch.

The adult pistillate flower presents unusual proportions; the diameter of the floral tube is about 0.3^{mm}, while its length in extreme cases may be over 30^{cm}, in such an instance the flower being one thousand times longer than wide. The lower part is invested by the spathe, which is 2 to 3^{cm} long. The sessile ovary at the time of pollination is about 4^{mm} long and less than 1^{mm} in diameter.

The staminate flower originates in the same general manner as the pistillate, and in early stages they might easily be confused. The later development of the pollen-bearing flower differs markedly, as it shows none of the complexities described above. The receptacle, instead of pushing up into a floral tube, becomes merely conical, and gives rise in turn to sepals, outer stamens, inner stamens, and very much later the corolla, which is not prominent and may be quite rudimentary (*figs. 13–22*). A conical protuberance is often seen in the center of the flower to which the inner stamens may be adnate for a part of their length (*fig. 22*). That part of the pedicel between the insertions of spathe and sepals elongates slightly and develops large air chambers (*fig. 22*). It is at the upper end of this region that the break occurs which sets free the flower at maturity. The exact mode of detachment was not determined.

THE FEMALE GAMETOPHYTE.

The female gametophyte is developed while the floral tube is elongating toward the surface of the water. The tube had a length of about 4^{mm} when the primary sporogenous cell was established; was twice that long when the ovule contained a 2-celled embryo sac; and had attained a length of 15^{mm} at the 8-celled stage.

The single archesporial cell (*fig. 23*) cuts off a primary parietal cell which ordinarily divides first by an anticlinal wall (*fig. 24*). The details of development of the parietal tissue were not studied, but it seems to be very limited in amount and probably does not persist long.

The primary sporogenous cell enlarges greatly, and in its division the spindle lies wholly in the outer half of the cell (*fig. 25*). The resultant cells differ greatly in size, the deeper one being six or eight times larger than the micropylar one. In the division of these daughter-cells the spindles show a corresponding difference in size and vary in direction, especially in the outer cell, in which it may lie at right angles to the longer axis of the ovule (*figs. 26, 27*). Four megaspores are usually formed, which are separated by walls. In one instance it was observed that the two central cells of the row of four had each divided again, resulting in six megaspores (*fig. 28*). This case was made very clear as the megaspore at either end of the row had enlarged, thus lessening the possibility of confusing sterile cells with megaspores. This particular row is of interest also in showing a struggle for dominance between the innermost and outermost cells. In all other cases noted there were but four megaspores, and the innermost one seems regularly to be the successful one (*fig. 29*).

With the division of the megaspore there is introduced a change in the form of the embryo sac, which, though often seen in later development, is seldom introduced at so early a stage. The upper one-third of the embryo sac begins to enlarge, and by the time this first division is completed has a diameter nearly twice that of the cylindrical part beneath (*fig. 30*). As development proceeds this differentiation becomes more marked. The outer part, in which all the growth takes place, continues to enlarge, being at first spherical, then oblong, and finally assuming the usual embryo sac form. The inner part persists with dimensions unchanged or somewhat diminished by encroachments of the main body of the embryo sac (*figs. 31–36*). While such a pouch-like antipodal end is not uncommon, the emphasis laid on its early development in this instance might suggest its being a rudiment of a once prominent nutritive device, but it probably functions now in no important way.

At the two-celled stage one nucleus passes to each end of the sac (*fig. 30*). The divisions giving rise to the antipodal group occur deep within the pouch (*figs. 31, 32*). The spindles seen here are much smaller than those of the micropylar end, and the resultant nuclei of the two groups show a proportional difference in size (*fig. 32*).

The antipodal polar appears regularly to issue from the pouch at an early stage, and as it passes into the body of the embryo sac it increases in size, until at the time it arrives in the vicinity of the other polar no difference in their dimensions is discernible (*figs. 34, 41, 42*). The polars soon approach one another and may remain for a long time in contact. Their actual fusion was not observed and seems not to occur until the time of fertilization. Shibata (14) has shown for Monotropa that pollination hastens the fusion of the polars. In Elodea neither pollination nor the entrance of pollen tubes into the ovary constitutes a sufficient stimulus. In ovules which have failed to receive pollen tubes the polars may still be seen lying side by side, even though surrounded in the same ovarian cavity by other ovules whose eggs have been fertilized, and which contain embryos. The actual presence of the pollen tube in the ovule seems to be necessary to bring about their union. Guignard (9) has shown a similar behavior of polars in Capsella. In this form the polar nuclei are distinct until the male elements penetrate into the embryo sac; their union appears to be accomplished, however, before fertilization takes place.

The antipodals always remain in the pouch in which they were formed, and before the entrance of the pollen tube are inconspicuous and stain feebly. At the time of fertilization, however, and during the early development of the embryo, some activity is manifest in this region. The group then generally shows a fourth nucleus (*figs. 35, 36, 38, 39*), the uppermost of which becomes quite large and may have more than one nucleolus. This enlarged nucleus is often surrounded by a considerable mass of cytoplasm which may be enclosed by a definite membrane, giving it the appearance of an egg (*figs. 38, 40*). In rarer instances two enlarged nuclei are seen, making five in all (*fig. 37*), while not uncommonly the tip displays the usual number, three (*fig. 40*).

The sudden appearance of the extra nucleus in the antipodal group, when one has in mind the behavior of the polars, might suggest that these nuclei do not always fuse, and that one of them passes down to the lower end of the embryo sac and joins those in the antipodal pouch. The general evidence, however, is against this view. The irregular number of nuclei displayed here and the general arrangement of the cytoplasm about them would indicate that any increase in number has come from divisions among the antipodals—an activity in this region that often results from fertilization. In all embryo sacs studied at earlier stages the lower polar had passed out of the tip, and its return to the antipodal group seems here improbable.

THE MICROSPORANGIUM.

The stamens are very short-stalked, the sporangia being practically sessile, and are further characterized by a relatively small amount of sterile tissue. Each stamen develops only two sporangia, there being no suggestion of a greater number at any stage. This condition seems to occur regularly in but a limited number of forms. The presence of only two sporangia to the stamen has long been known for the Asclepiadaceae, and has recently been reported by Shoemaker (15) for Hamamelis. The occurrence of this phenomenon in such widely separated and differently specialized forms offers no clue to its significance.

The developing stamen is at first circular, later becoming oblong in cross-section. From a homogeneous meristematic mass there differentiates at either side of the stamen a hypodermal archesporial column (*fig. 43*). These cylinders of tissue extend the whole length of the stamen and have from five to eight cells each in cross-section. They are separated by a mass of sterile cells which later develops the rudimentary bundle and contributes somewhat to the tapetum of both sporangia. The archesporial cells become quite distinct, differing from these sterile cells in size and staining reactions.

In the establishment of the primary wall layer the divisions of the archesporial cells are not simultaneous, the outer ones tending to divide a little earlier than those nearer the body of the stamen. It follows, from the form of the stamen and the extent and location of the archesporium, that the primary wall layer nearly invests the column of primary sporogenous cells, and this investment is made more nearly complete in places by the introduction of curved walls at the axial corners of the archesporium (*fig. 44*). While in no observed instance was the inclosure quite complete at this time, it was noted that a little later the cells on the axial side may divide (*fig. 45*), thus bridging the gap in the wall layer. Coulter (**3**) has shown that in Ranunculus a part of the tapetum may come from the sporogenous tissue. Rosenberg (**12**) finds in Zostera that the tapetum on both the inner and outer sides can be traced back to the divisions of the greatly elongated sporogenous cells. In Elodea these divisions of sporogenous cells on the axial side seem to be of common occurrence, and there is probably a regular contribution to the tapetum from the sporogenous cells in that region. In addition there may be a contribution to the diffuse tapetum on any side by the sacrificing of potential spore mother-cells to the nutritive function. When the time of spore formation is at hand the functioning mother-cells are fewer than were the primary sporogenous cells, notwithstanding divisions may often take place among these tending to increase their number. The successful spore mother-cells become greatly enlarged before their division (*fig. 47*). A cross-section of the sporangium at this time may show only one of these cells, the others having broken down, though commonly there are three side by side (*fig. 46*), and portions of four are often seen in a given section.

The primary wall cells form a zone several layers of cells in thickness, of which the outer one only, the endothecium, persists until the discharge of the spores.

THE MALE GAMETOPHYTE.

The male gametophyte is considered to have begun with the spore mother-cells. Both the first and second divisions of the mother-cells are characterized by slender curved spindles terminating at either end in the plasmatic membrane (*figs. 48, 49*). Such spindles have been figured by Strasburger (**16**) for Ceratophyllum. Following the first division a delicate wall is formed, dividing the mass into two hemispherical cells. The nuclei of these daughter-cells are greatly elongated. The number of chromosomes was not made out with certainty, but is probably twelve for the gametophyte.

In the second division the spindles commonly lie parallel, in which case the four spores of the tetrad develop in one plane; but the spindles may be rotated so that their planes intersect at right angles, resulting in a correspondingly different grouping of the pollen grains. Following the second division, the four microspores are organized in the usual manner. The young spores lie for a time within the wall of the mother-cell (*fig. 50*), but the small tetrads soon appear naked (*fig. 51*) and enter upon a period of rapid enlargement. The four members of the tetrad do not fall apart, but remain attached and are ultimately shed from the sporangium still firmly joined together. This union is so intimate at maturity that violent shaking in a closed vessel partly filled with water seldom breaks them apart.

Though borne by one of the most specialized of submersed aquatics, a plant entirely devoid of cutinized walls in all its vegetative parts, the microspores of Elodea exhibit a strongly cutinized exine and a well-developed intine. In this connection it is interesting to note that in Naias and Zannichellia, also submersed aquatics, Campbell (1) finds no exine developed. Strasburger (**16**) reports for Ceratophyllum, which has a similar habitat, a pollen grain without intine and with a thin smooth exine which is cutinized, but not nearly so strongly as in air blooming plants. In Elodea the exine closely resembles such coats borne in normal aerial sporangia, and is beset with multitudes of spines, which play an important part in the process of pollination, as we shall see later. These spines (*fig. 67*) are cylindrical, with conical points barbed at the base and each bearing at its tip a tiny disk.

The intine possesses in numerous instances peculiar thickenings reaching into the cavity of the spore. These ingrowths may be merely papillae, though they are often rod-like, or even membranous, forming trabeculae extending well across the pollen grain. These protrusions are integrated with the intine at their junctions, and appear to be perfectly uniform in character and substance with it.

The microspore nucleus divides long before the pollen grain has attained its full size (*fig. 52*), and at a time when the spore wall is not yet differentiated into two layers. This first division appears to be simultaneous in the four spores of a given tetrad (*fig. 53*), though widely varying stages may be found within a single sporangium. The spindle fibers in this division after the cell plate is laid down are much more prominent on the tube nucleus side (*fig. 54*). The generative cell when first cut off along the wall of the spore is crescentic in outline, with a greatly elongated nucleus, but it soon becomes lenticular in form. Later, after its passage into the cytoplasm of the tube cell, it is for a time spherical (*fig. 55*); subsequently it becomes greatly elongated, and just before its division into the male cells is curved and may extend nearly across the spore (*fig. 57*).

The tube nucleus enlarges soon after its formation so as to become very conspicuous. It is at first spherical (*fig. 54*), but a little later becomes amoeboid in shape and assumes the most varied forms, accompanied by a changed reaction to stains (*fig. 56*). Shortly before the division of the generative cell the tube nucleus regains its original form; with the organization of the male cells, however, it may again exhibit irregularities of outline. Schaffner (**13**) in his studies of Erythronium found the generative cell very large and displaying such general activities as are here associated with the tube nucleus.

The formation of the male cells seems to occur regularly long before the pollen grains are shed from the sporangium. The spindle formed within the long crescentic generative cell is itself slightly curved (*fig. 58*), and the daughter nuclei retreat quite far apart before the partition is formed between them (*figs. 61, 62*). The male cells when first organized remain for some time end to end in the relation occupied at the time of their formation, and thus continue the bow-shaped outline which characterized the generative cell. Subsequently, with the symmetrical elongation of both male cells, their adjoined ends become long drawn out, yet still remain attached by their tips. This point of union acts like a hinge, permitting the cells to take the most varied positions with respect to one another, even swinging about so as to lie side by side (*figs. 63–66*). In no observed instance did the male nuclei lie far enough apart to preclude the possibility of their cells being still united by these elongated ends. As will be seen later, there is reason for believing the male cells of Elodea make the greater part of the journey through the pollen tube still hitched together in this tandem fashion.

During their continuance in the pollen grain the male structures clearly reveal their morphology as cells. About the nucleus, which usually shows a nucleolus, there is an extensive mass of cytoplasm differing considerably from the contents of the spore, and all clearly invested by a limiting membrane. It was observed that one or two more deeply staining bodies usually lie outside the nucleus along the median line of the cell (*figs. 64, 65*); if two of these are present, one lies at each side of the nucleus, though at varying distances from it.

PHENOMENA OF POLLINATION.

While the general mode of pollination in Elodea is well known, the details, which seem never to have been published, are of such interest as to merit a brief description.

The staminate flowers are borne entirely beneath the surface of the water, and these, as is well known, break off and rise to the surface, there shedding the pollen. It is probable that with the ripening of the sporangia, in the still submerged flower, gases given off by the plant fill the spaces about the spores as well as any other cavities developed in the flower. At maturity a bubble of oxygen forms at the tip of the flower, and with its enlargement the sepals open slightly. At this time, looking down into the flower one can see that the sporangia have opened, and that many of the spores have been shed into the central space. The oxygen bubble may finally become nearly as large as the flower, and, when conditions are proper, the buoyancy of the enclosed gas, aided by the low specific gravity of the flower itself, overcomes the weakened attachment, and the flower darts to the surface. Upon reaching the surface the bubble disappears, the sepals snap back quickly, and in their recurved position form three boat-like floats which support the sporangia above the water; these catch the breeze and the flower sails away. While such float devices for the staminate flower are thought to be of great importance in the pollination of Vallisneria, it is doubtful if any significance can be attached to them in Elodea. The pollen was nearly all discharged at the moment the flower came to the surface, and any remaining portion would have no better opportunity for reaching the stigma of the pistillate flower. The snow-white tetrads are quite conspicuous floating on the water, or scudding along the surface with the wind.

The floating of the pollen grains is due to the nature of the outer spore coat. In a previous paragraph it was mentioned that the exine was covered with spines, each bearing at its tip a slight enlargement; these spines tend to hold back the surface film from contact with the body of the spore, and thus imprison enough air to keep it afloat. The microspore has a greater specific gravity than water, and will sink at once if wetted. This can be demonstrated easily by placing the spores in dilute alcohol, then transferring quickly to water. A simpler and more striking method is to float a quantity of these spores on the surface of water half filling a stender dish; then cover and shake vigorously for a moment. The violent agitation of the water breaks the surface film, permitting the liquid to come into more intimate contact with the body of the spores, which sink at once to the bottom of the vessel.

While the gas bubbles may not be necessary for pollination, they are certainly very helpful. Their buoyancy aids in detaching the flowers, raises them quickly to the surface, and the sudden recurving of the sepals may be related in some way to the escape of the bubbles on reaching the air. The accumulation of gas about the spores in the submerged flower is also of significance in that it prevents the moistening of the ripe spores while yet submerged; for this, as we have seen, would lead to their sinking upon release. The general relation of these accumulations of oxygen is shown by the fact that in quiet waters of aquaria the rapid appearance of the staminate flowers at the surface of the water is simultaneous with the first marked photosynthesis of the day. During the early part of the forenoon the flowers which have ripened during the hours of darkness are rapidly brought up as the liberation of gas by the plant is increased, and very few appear in afternoon or evening.

The pistillate flower, as has been noted above, reaches the surface of the water by the lengthening of the fused parts above the ovary. Elongation does not cease immediately upon reaching the surface, as there is usually developed some surplus length before the floral parts open. These parts are repellent to water and so resist wetting for many hours. With the opening of the flower the three prominent stigmas quickly recurve, arching well out over the floral envelopes. Lying thus, commonly on its side at first, the weight of the flowers rests chiefly upon the stigmas. Since the stigmas are not readily wetted by water, they form a depression in the surface film. Pollen grains floating near the flower therefore approach and quickly slide down into contact with the stigma. There is thus established about each flower "a circle of influence," which in quiet waters is about 2^{cm} in diameter, and spores floating into this area are immediately brought into contact with the stigma. When numerous, pollen grains may form a layer lining the bottom of the depression. If at such a time the flower is submerged, as may happen from wave action, etc., the surface film binds together floral parts and spores as they pass beneath the water, and invests them with a considerable volume of air. When all again come to the surface the pollen grains may be seen sprinkled over all parts of the flower including the other stigmas. Spores lodged against any part of the flower may in this way be transferred to the stigmas.

It will be seen that the whole process of pollination is dependent in one way or another upon the *surface film* of water: (1) such a film makes possible the accumulation of oxygen bubbles within and above the staminate flowers, with whatever of advantage that may follow; (2) it is directly responsible for the floating of the pollen grains on the surface of the water; (3) the surface film brings the floating pollen grains into contact with the stigmas of the pistillate flower.

THE POLLEN TUBE.

As might be expected, considering the remarkable morphology of the pistillate flower, the study of the pollen tube was not without interest. These growths not only have great length, $5–30^{cm}$, but are quite large and display some unusual activities.

While the formation of the pollen tube was not studied in detail, it seems to take place in the usual way. Microspores germinating on the stigma show the male cells still distinct (*fig. 69*). In no observed instance did all the spores of a group develop tubes; usually only one or two members of the tetrad germinate, the others being held back from the stigmatic secretions. The tubes show very prominently in cross-sections of the flower. They pass down the central conducting strand; occasionally one may be seen in one of the air chambers, but serial sections generally show it to be only a loop put out from the central tissue.

Having reached the upper end of the ovary, the pollen tubes pass with singular directness down through the ovarian cavity to the upturned micropyles of the ovules. One can but remark the efficiency of the chemotropism and the precision with which the tubes pass to the openings in the ovules (*fig. 75*). Few to many curved, tangled, and feebly staining pollen tubes are usually present among the fertilized ovules in the cavity. These seem to have come into the ovary too late; at any rate, the functioning pollen tubes are always much straighter and stain more deeply than the ones which have failed to enter the ovules.

It not infrequently happens that one of these functionless pollen tubes, having failed to enter a micropyle, may swell up at its tip and terminate its development in a cyst-like enlargement (*figs. 70–74*). Scores of these growths were encountered in material of all stages of development after fertilization, collected through two seasons from various stations, and killed in different ways. Their occurrence, therefore, is so uniform as to merit some attention, especially as they do not seem to have been discussed in connection with any other plant. These cystoids may be found lying anywhere in the cavity of the ovary, but seem never to occur in the style nor in any tissue through which the tube passes. They may lie along the walls of the cavity or in contact with the ovules, but usually are free in cavity of the ovary. In form they vary from spherical to oblong; some may be irregular in outline or even lobed, while those in contact with the wall or ovule are often much flattened or elongated (*fig. 74*).

These enlargements vary in size from slight swellings to growths ten or fifteen times the normal diameter of the tube. Their contents were studied with interest, as it seemed they might throw light on the nuclear conditions in the pollen tube. Their staining properties are uniform with those of the ordinary pollen tube, and nuclei are nearly always present, sometimes evidently disorganizing (*fig. 73*), but in other cases presenting a normal appearance. The tube nucleus was often quite conspicuous, but it was of special interest to note that in certain of these cystoids the male cells could be distinctly made out (*figs. 70, 71, 72, 74*). Each presented, under favorable conditions, its characteristic appearance. The ample cytoplasm was bounded by a definite membrane and showed within a distinct nucleus with its nucleolus. It was also noted that these male cells generally lie near one another, as though still joined together, and in certain cases this connection was very evident (*figs. 70, 74*).

The presence of the male structures as distinct cells in these cystoids lying among the ovules affords very definite information as to their condition during the journey through the pollen tube, and it is obvious that they have retained the features that characterized them in the pollen grain. Guignard (6) has contended that the male structures are found as cells in the pollen tubes of Lilium, though this is denied by Koernicke (4). More recently Guignard (9) has reported a similar condition for Lepidium, which unfortunately is accompanied by no satisfactory figure. Since the tubes producing these cystoids in Elodea may be longer than the functioning ones, and apparently differ from them in no essential respect, it is probable that, in this form at least, the male structures regularly maintain their integrity as cells until they come into the vicinity of the micropyle.

The pollen tubes of Elodea, furthermore, are remarkable for their persistence. Long after fertilization the enlarged tip of the pollen tube may be seen clearly outlined by the side of the suspensor cell (*figs. 78–83*), while stretching upward from the micropyle into the cavity of the ovary extends the tube still darkly staining and apparently turgid. These conditions persist until the embryo is well developed. Those portions of the tube in the ovary more removed from the ovules show diminished contents or may be empty, but their course can be readily followed in the floral tube where the protoplasm is massed into the deeply staining "Propfen." The cystoids likewise remain long among the enlarging ovules, but their adjoined tubes, which are never conspicuous, soon collapse. All other functionless tubes seem quickly to perish in the ovary.

The male gametophyte as represented by the pollen tube, therefore, both in size and in length of life becomes a conspicuous generation. It is at first nourished by the stored foods of the spore and conducting tissue. After fertilization, with the growth of the ovary, connection is severed between the part in the floral tube and that near the micropyle, the lower end continuing to live apparently parasitically on the embryo sac for a time.

FERTILIZATION.

The pollen tube is usually much contorted in its passage through the micropyle, and upon reaching the embryo sac it swells out in bulbous fashion, at the same time causing one of the synergids to disappear. The whole region is so disturbed by the vigor of the tube that the fate of this cell could not be certainly determined, but appearances indicate that the pollen tube may have passed into the synergid inflating it (*figs. 76–82*). It often happens that two pollen tubes pass into one ovule; in such cases both synergids disappear, and a favorable view of the embryo sac shows the two swollen, darkly staining tips of the pollen tubes arranged symmetrically side by side (*fig. 75*), as though growth of each had been stopped at a certain point. In one instance where three tubes had passed in through one micropyle the whole upper half of the embryo sac was filled by their contents. Guignard (8) has reported that in *Nicotiana Tabacum* and *Datura laevis* the pollen tube passes into one of the synergids.

The male cells were not seen in the embryo sac before fertilization. Numerous preparations showed one male nucleus in contact with the egg, and the fate of the second male nucleus was determined in a few cases when it was found uniting with the endosperm nucleus (*figs. 35, 36*). In all instances but one the male nuclei seen in the embryo sac were in resting condition.

THE EMBRYO.

The oospore divides by a transverse wall. The upper nucleus retreats toward the micropyle and becomes the center of the vesicular cell, which later becomes enormously enlarged. The endosperm nucleus does not divide until a two-celled embryo is established. In many cases the oospore was found dividing with the endosperm nucleus still in resting condition (*fig. 76*); in other instances the endosperm nucleus was in mitosis, but the egg fully divided (*fig. 77*). Figures were never seen in both at the same time. Such a tardy division of the endosperm nucleus seems very rare. Guignard (**7**) has figured for *Naias major* the primary endosperm nucleus in the spirem stage by the side of a two-celled embryo. Hall (**10**) also finds in *Limnocharis emarginata* two nuclei in the young embryo before "the upper polar, which forms the endosperm, has gone through the first division."

A proembryo of four or five cells is established before the end cell divides by a vertical wall (*fig. 79*). While the development of the embryo was not studied in detail, certain variations were noted in these earlier divisions. The basal cell becomes very prominent. When the parts of the embryo are established, this cell has a volume fully forty times that shown in *fig. 82*, and when the seed is nearly ripe it still shows prominently, though somewhat flattened, at the root end of the embryo (*fig. 83*). The remaining synergid also often enlarges for a time nearly as rapidly as the suspensor cell (*fig. 81*), and seems during the early stages to share with it a common function.

The embryo seems to be of the usual monocotyledonous type. The primary root probably does not function, and secondary roots are seen in the seed pushing out near the base of the stem (*fig. 83*).

SUMMARY.

1. The pistillate flower is strongly epigynous, and develops a long floral tube reaching from the sessile ovary to the surface of the water.

2. Four megaspores are usually formed; six were noted in one instance.

3. The embryo sac early develops a pouch in which the antipodal group of nuclei is formed.

4. The polars approach one another at an early stage and may remain for a long time side by side; their fusion, however, was not noted before fertilization.

5. The stamens regularly produce two sporangia each. The primary wall layer nearly invests the sporogenous tissue, which later may contribute to the tapetum on the axial side.

6. The pollen grains adhere in tetrads and have a greater specific gravity than water. The exine possesses spines which hold back the surface film and imprison sufficient air to keep the spores afloat.

7. The male cells are organized in the pollen grain and are joined together by their elongated ends.

8. Gas bubbles aid in detaching the staminate flowers and in bringing them promptly to the surface of the water.

9. The pistillate flower is impervious to water and so produces a depression in the surface film. Pollen grains floating near are brought into contact with the stigmas by means of gravity operating through the declined surface film.

10. The large pollen tubes, having penetrated the long floral tube, pass directly through the ovarian cavity to the upturned micropyles of the ovules.

11. Pollen tubes which have failed to enter ovules often swell up into cyst-like enlargements in the ovary. In these cystoids the male structures can be seen as distinct cells instead of nuclei only.

12. Fertilization takes place in the usual manner, and the second male cell was found uniting with the endosperm nucleus.

13. The primary endosperm nucleus does not divide until a two-celled embryo is established.

14. The pollen tubes persist until the embryos are well developed.

15. The suspensor cell of the embryo becomes enormously enlarged and the synergid often increases in size. The primary

root probably does not function, and secondary roots are developed in the seed from the lower parts of the stem.

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EXPLANATION OF PLATES I–IV.

All figures were made with Bausch and Lomb camera lucida, and original drawings were reduced one-half in reproduction. Figures with magnification greater than 600 diameters were made with Zeiss apochromatic objective 2^{mm}, 1.30 N. A., and Zeiss compensating oculars 4 and 12. All others with Spencer 5^{mm} and 16^{mm} objectives and oculars 4 and 8. The original magnifications in diameters were approximately as follows: figs. 1–22, 120; 23–42, 850; 43–66, 670; 67, 2300; 68, 69, 670; 70–74, 850; 75, 380; 76, 77, 850; 78–82, 600; 83, 30.

The abbreviations employed in describing figures are as follows: *a*, air cavity; *ar*, archesporium, *at*, antipodals; *e*, egg; *en*, endosperm nucleus; *fl*, flower; *g*, generative cell; *m*, male cell; *o*, ovule; *p*, petal; *po*, polar; *pt*, pollen tube; *s*, sepal; *sg*, synergid; *smc*, spore mother-cells; *sp*, sperm; *spt*, spathe; *st*, stem; *stg*, stigma; *stm*, stamen; *t*, tube nucleus; *v*, vesicular cell; *w*, primary wall cell.

PLATE I.

FIG. 1. Early stage in the development of pistillate flower. Flower seen at side of stem.

FIG. 2. Flower grown out, nearly equaling stem tip in length. Spathe pushing out at base of flower.

FIG. 3. Stem tip resuming original direction. Receptacle flattens.

FIGS. 4–6. Stages immediately preceding development of the floral tube. Calyx showing at margin of receptacle.

FIGS. 7–9. Early development of floral tube. Sterile stamens next to calyx.

FIG. 10. Stigmas and ovules developing simultaneously.

FIG. 11. Later stage showing beginning of corolla.

FIG. 12. Pistillate flower with principal parts all established, and floral tube entering upon period of more rapid elongation.

FIGS. 13–16. Early stages of staminate flower.

FIG. 17. Outer stamens showing next to calyx.

FIGS. 18–20. Development of stamens.

FIG. 21. Corolla growing up between calyx and outer stamens.

FIG. 22. Later stage in development of staminate flower.

PLATE II.

FIG. 23. Early stage in development of ovule, showing archesporial cell.

FIG. 24. Primary sporogenous cell and two parietal cells.

FIG. 25. Division of primary sporogenous cell.

FIGS. 26, 27. Division of daughter cells.

FIG. 28. Ovule with six megaspores. The two central cells of the row of four have each divided, making six in all. The innermost and outermost megaspores developing.

FIG. 29. Row of four megaspores. The deeper-lying one is developing and others are being crowded out.

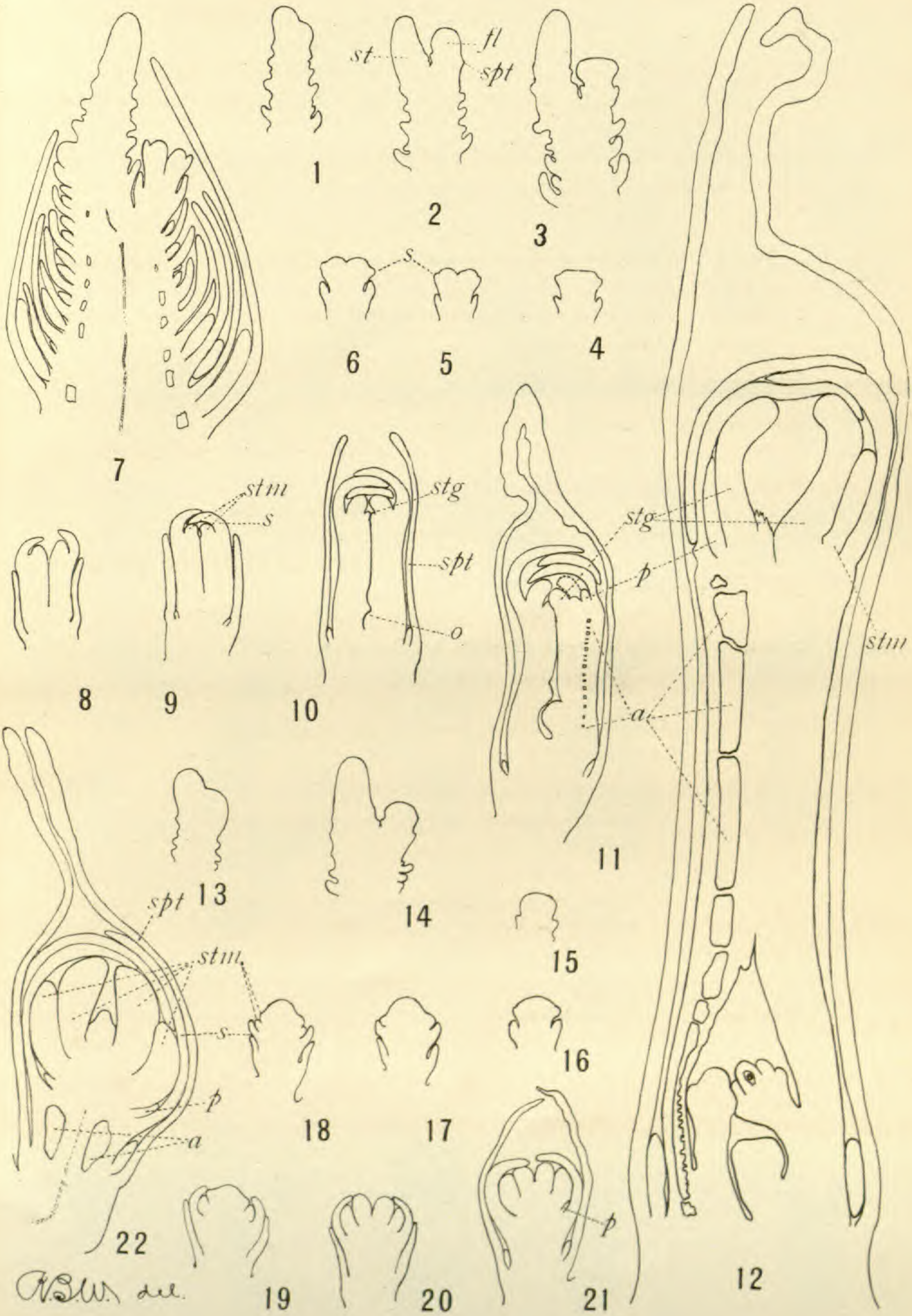
FIG. 30. Two-celled embryo sac, showing early development of antipodal pouch.

FIG. 31. Division of these nuclei.

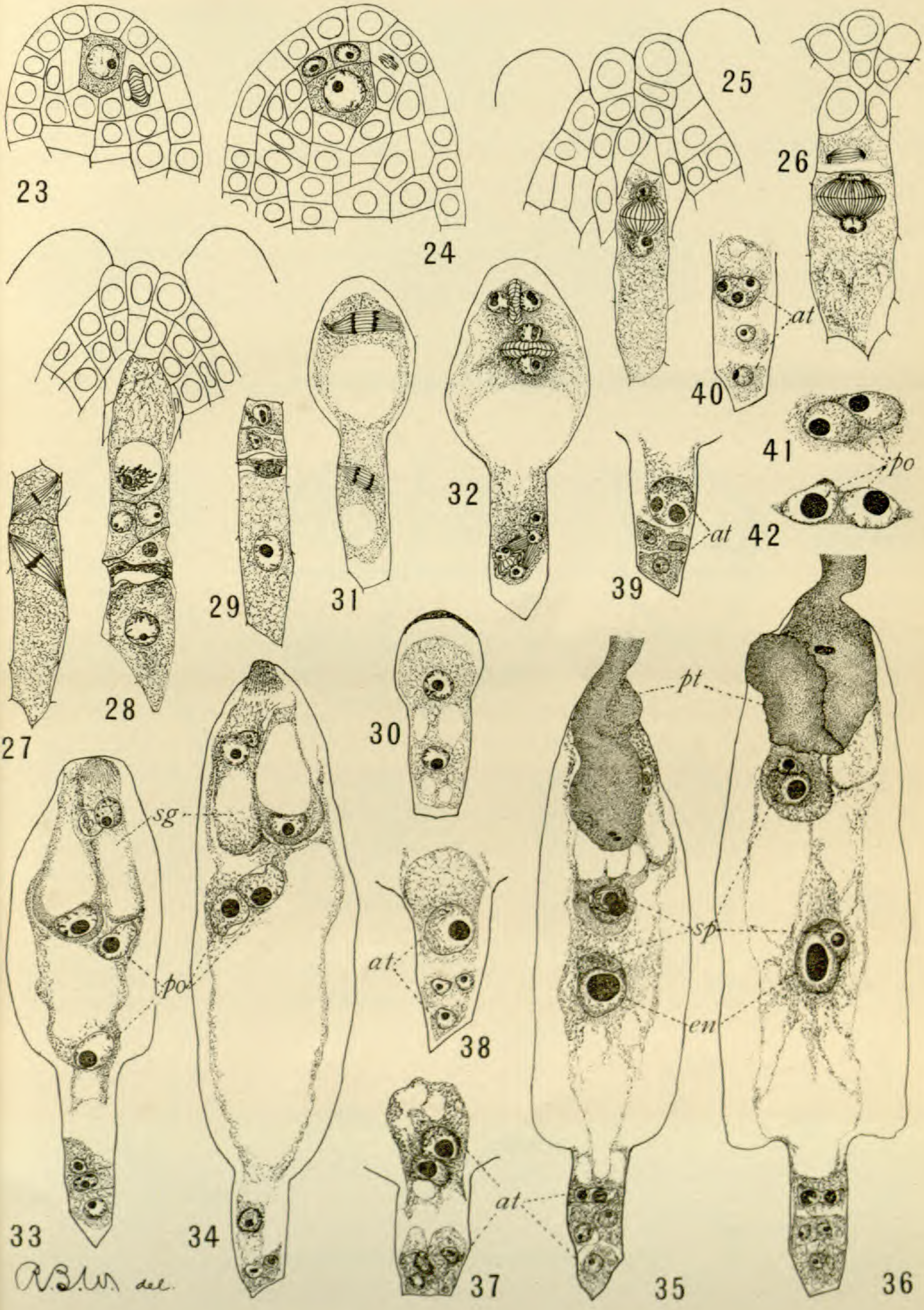
FIG. 32. Establishment of 8-celled embryo sac.

FIG. 33. Older embryo sac showing arrangement of cells. Polars approaching one another.

PLATE I



WYLIE on ELODEA



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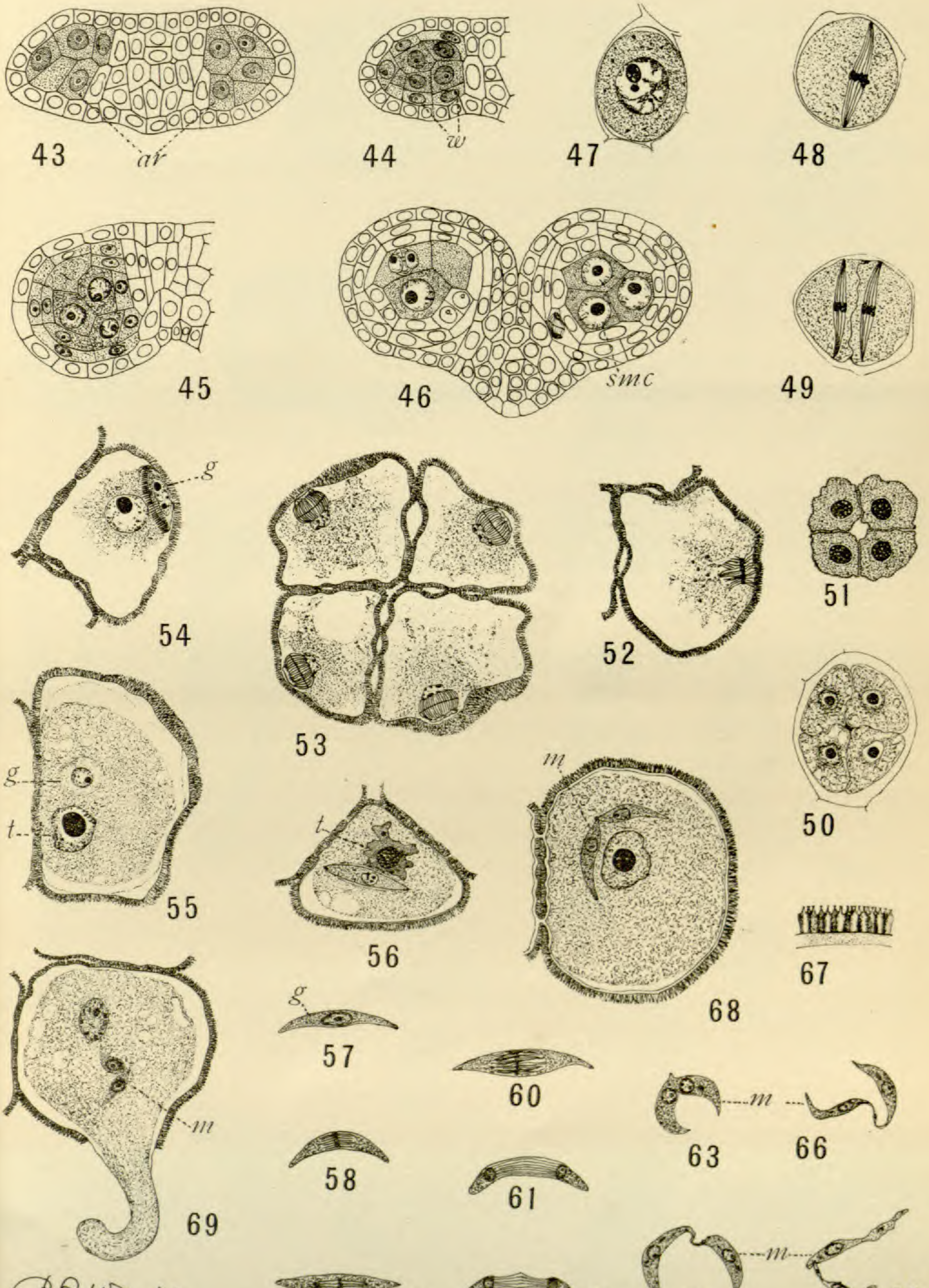
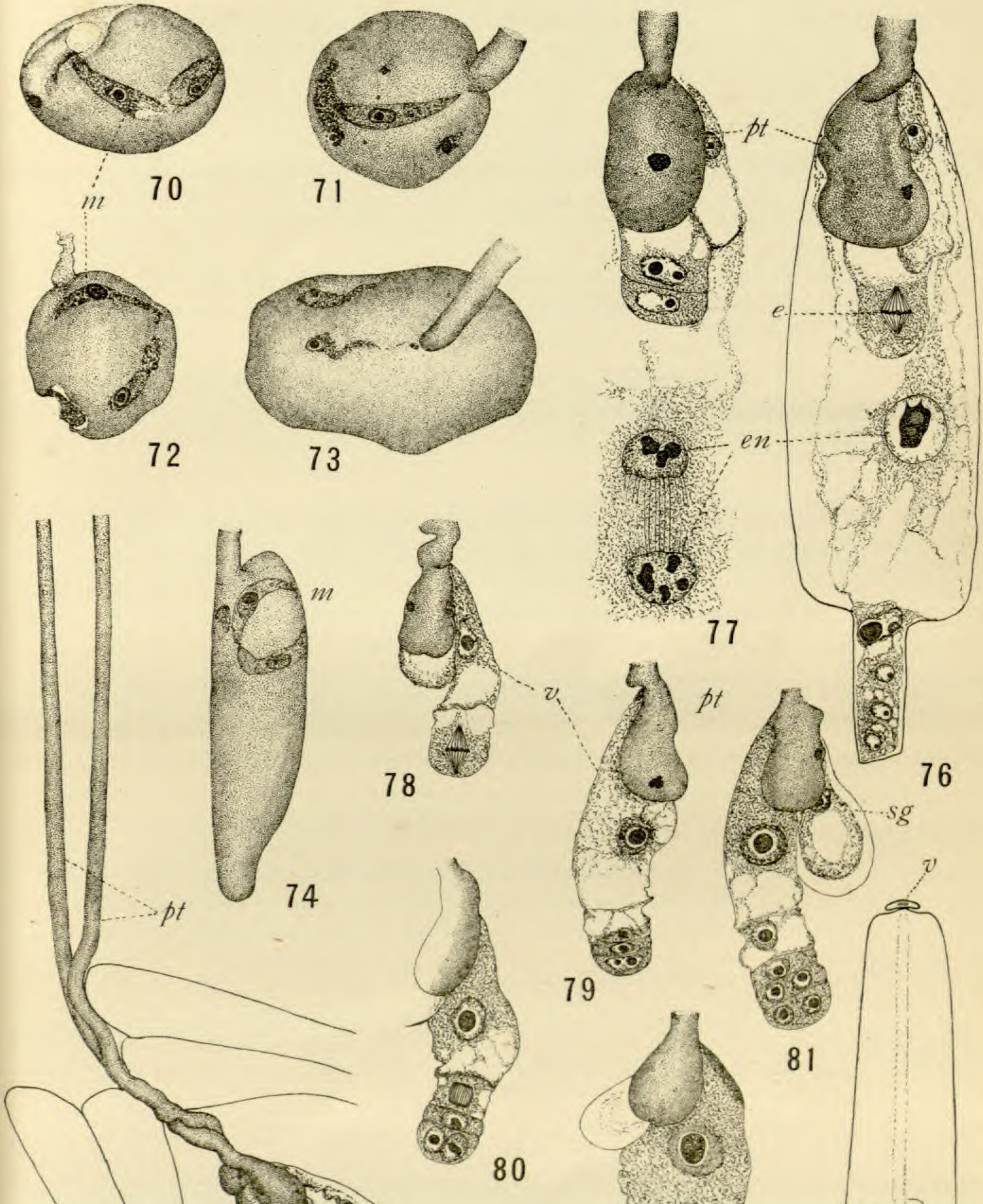


WYLIE on ELODEA

PLATE IV



WYLIE on ELODEA

FIG. 34. Embryo sac just before fertilization. The polars lie in contact.

FIG. 35. Embryo sac at time of fertilization. One sperm lies in contact with the endosperm nucleus; the other is uniting with the egg.

FIG. 36. A similar stage. The pollen tube contents have apparently burst out of the synergid.

FIG. 37. Antipodal group showing five nuclei.

FIG. 38. Antipodal group. The enlarged nucleus surrounded by dense cytoplasm which is bounded by a membrane.

FIG. 39. An antipodal group similar to *fig. 38* without membrane about enlarged cell.

FIG. 40. An antipodal group showing three nuclei.

FIGS. 41, 42. Polars as they lie in contact before fertilization.

PLATE III.

FIG. 43. Cross-section of stamen showing the archesporia of the two sporangia.

FIG. 44. Archesporium cutting off primary wall layer which nearly invests the primary sporogenous cells.

FIG. 45. Showing several wall layers and cells cut off the sporogenous tissue on the axial side of the sporangium.

FIG. 46. Cross-section of stamen after spore mother-cells are established.

FIG. 47. Spore mother-cell immediately before division.

FIG. 48. First division of spore mother-cell.

FIG. 49. Division of daughter-cells.

FIG. 50. Young tetrad enclosed by wall of mother-cell.

FIG. 51. Young tetrad free from wall of mother-cell.

FIG. 52. Division of microspore nucleus.

FIG. 53. Four spores of tetrad clinging together with their nuclei dividing simultaneously.

FIG. 54. Generative cell being cut off along wall of spore. The tube nucleus already enlarged.

FIG. 55. Generative cell has passed into the cytoplasm of the tube cell.

FIG. 56. Tube nucleus amoeboid in form, generative cell elongated.

FIG. 57. Generative cell as it appears before division into the male cells.

FIGS. 58–62. Stages in the division of generative cell.

FIGS. 63–66. Male cells joined in pairs by their elongated ends.

FIG. 67. The spore coats; the exine with spines.

FIG. 68. A pollen grain at time of pollination, showing tube nucleus and male cells.

FIG. 69. Pollen grain germinating on the stigma of a pistillate flower.

PLATE IV.

FIGS. 70–74. Cyst-like enlargements formed at ends of pollen tubes in ovarian cavity, showing male structures are still distinct cells.

FIG. 75. Embryo sac into which two pollen tubes have entered, showing course of tube and mode of entrance into sac.

FIG. 76. Division of fertilized egg. Endosperm nucleus still in resting condition.

FIG. 77. Division of primary endosperm nucleus in embryo sac with two-celled embryo.

FIG. 78. Two-celled embryo with lower nucleus in division.

FIG. 79. Four-celled proembryo.

FIG. 80. The end cell of embryo has divided by a vertical wall.

FIG. 81. Embryo with enlarged synergid.

FIG. 82. Later stage in development of embryo showing greatly enlarged vesicular cell.

FIG. 83. Diagram of longitudinal section of embryo from nearly ripe seed. Flattened vesicular cell at root end, lateral stem tip, and secondary roots from near base of stem.

CHEMOTROPISM OF ROOTS.[1]

FREDERICK C. NEWCOMBE and ANNA L. RHODES.

THE chemotropism of pollen tubes and of fungus hyphae and the chemotaxis of various unicellular organisms have received considerable attention in the great mass of work which has been done on the sensitive activities of plants. There is probably a well-defined notion that terrestrial roots, which are known to be hydrotropic, are also chemotropic. The unequal distribution of minerals in the soil, and of decaying organic matter, can be thought of as furnishing opportunity for the development of chemical response as a biological adaptation.

In literature there seems to be no record of work done to test the ability of roots to respond to a chemical stimulus by changing their direction of growth. This test has now been made, and the results are recorded in the following pages.

I. THE ONE-SIDED APPLICATION OF CHEMICALS IN TUBES.

The first method employed consisted in applying to the tips of roots immersed in a liquid a chemical diffusing from the open mouth of a horizontal tube.

A considerable quantity of the ordinary Sachs's culture fluid was made, containing all the ingredients except the potassium nitrate. A solution of potassium nitrate was then made of such a density that when a drop of it was placed in the solution of the other ingredients of the culture fluid, the potassium nitrate would neither rise nor fall. Rather large capillary tubes were now made, 1.5^{cm} long by 1^{mm} internal diameter and closed at one end. These tubes were then filled with the solution of potassium nitrate by the use of the air pump. Next, a row of seedlings, fastened by strips of blotting paper and rubber bands to a bar of glass, were suspended across a glass cylinder, the roots being immersed in the culture fluid containing no potassium nitrate. The tubes filled with the potassium nitrate solution were now introduced into the jar of liquid, and so adjusted that their open

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[1] Contribution 68 from the Botanical Laboratory of the University of Michigan.

ends were within a few millimeters of the root-tips, there being a tube for each root. Every few hours the position of the tubes of potassium nitrate was changed in order to follow the descent of the root-tips. This method will be recognized as an adaptation of that method first employed for other purposes by Pfeffer.[2]

Altogether eighty-seven seedlings of *Helianthus annuus* L. and seventeen seedlings of *Raphanus sativus* L. were employed, for periods ranging from twenty-four to forty-eight hours at 20° to 24° C., but without showing a response. The positive curves and the negative curves were no more numerous than one might observe in these roots growing in water.

Thinking that the amount of potassium nitrate might have been too small to act as a stimulus, glass vials holding 20^{cc} were used instead. The mouths of the vials were closed by plugs of cotton previously wet with the potassium nitrate solution. Here also the roots showed no curves that could be ascribed to the chemical.

The absence of response in the foregoing experiments might be ascribed to any of several conditions. It might be that the roots used were not chemotropic, though others might be. It might be that the sunflower and the radish were chemotropic to some chemicals, but not to the potassium nitrate; though the thought suggested itself at the outset that, if roots are chemotropic they are likely to respond to chemicals which form their necessary food. It might be that the potassium nitrate was not present in large enough proportion. It might be that the difference in chemical composition was not great enough on opposite sides of the root. It might be, finally, that, while the seedling had a full supply of all kinds of stored food, it would show itself indifferent, but would respond, when it needed mineral food from without. Manifestly the thing to do was to satisfy these conditions as fully as possible.

II. THE ONE-SIDED APPLICATION OF A CHEMICAL BY DIFFUSION THROUGH A MEMBRANE.

With a view to testing the roots of plants when the food stored in the seed had been exhausted, water cultures were

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[2] Ueber chemotactische Bewegungen, etc. Untersuch. Bot. Inst. Tübingen 1 : 367.

started in the plant house in a full culture solution, except for the absence of potassium nitrate. After the plants had produced secondary roots, fresh culture fluid of the same composition was exchanged for the old, and there was inserted in each jar a glass dish of solution of potassium nitrate, whose density was approximately the same as that of the other liquid, as determined by the means already described. These glass dishes of potassium nitrate, holding 30^{cc}, were closed by parchment paper, or by hardened filter paper, and the dishes were set with the membrane parallel with the main roots and 2 to 3^{mm} distant from them. The preparations were continued in the plant house for six weeks, or long after all stored food was exhausted, both fluids being renewed every ten days. The roots were shielded from the light to avoid heliotropic curving. The species used were *Raphanus sativus* L., *Fagopyrum esculentum* Moench., *Lupinus albus* L., and *Pisum sativum* L. There was, however, no chemotropism shown.

To make sure that the failure of potassium nitrate solution to act as a stimulus was not due to the relatively small quantity employed, the foregoing experiment was repeated in all its details, except that the two solutions employed were nearly equal in volume. The preparation was continued for three weeks, and the solutions were renewed in the middle of the period. The time of year was summer, and the growth was good.

It would seem as though this preparation would bring curves, if the seedlings employed were chemotropic. Here was a row of roots parallel with and within 2 or 3^{mm} of a parchment membrane 9^{cm} in diameter having different solutions on its opposite sides. It was as though the jar had been divided into halves by a parchment septum, and the roots suspended on one side close to the septum. One can hardly think that in nature conditions can be more favorable for the manifestation of chemotropism. And this preparation did show a certain response. Nine seedlings of *Lupinus albus* and forty-four of *Raphanus sativus* were used. The former showed no curves nor other response ; but the Raphanus showed a considerable number of primary and secondary roots bending toward the potassium nitrate, and a much greater growth of lateral roots on the same side. This greater growth on the side toward the parchment membrane was not mainly due to the effect of the curving of the roots into that position; but the lateral roots on that side had made a better growth than on the opposite side. This behavior recalls the similar results obtained with varying soils by Nobbe,[3] Stohmann,[4] Höveler,[5] and Frank,[6] who obtained a greater growth of lateral roots in richer soils.

Here at last was a result indicating chemotropism of roots. Yet the method left much to be desired. With some means to insure a greater inequality in chemical composition on the opposite sides of a root, much better responses might be obtained.

III. DIFFERENT CHEMICALS BROUGHT TO OPPOSITE SIDES OF THE ROOTS BY STRIPS OF FILTER PAPER.

The device next tried was to conduct liquids of different composition to the opposite sides of the root by means of narrow strips of thin filter paper. The seedlings were suspended from a bar of glass fastened horizontally across a damp chamber. In the bottom of the chamber were placed two little dishes, one containing distilled water, the other Sachs's culture solution. From one liquid a strip of filter paper, 2^{mm} wide, extended upward and adhered to one side of the root, while the opposite side was covered by a strip from the other liquid. The strips of paper were not allowed to touch one another. In some tests, the small dishes were placed above the level of the root tips, and the paper strips hung downward, touching the flanks of the root-tip and then diverging and ending in dishes of water below. Every few hours the strips of paper were adjusted so as to keep them in contact with the roots near the tip. In this form of experiment nineteen seedlings of *Lupinus albus* were used, but no curves resulted. The objection to this method is found in the difficulty of keeping the paper strips in contact with the sloping sides of the root-tip.

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[3] NOBBE: Landwirthsch. Versuchsstat. **4**: 222. 1862; and **10**: 100. 1868.

[4] STOHMANN: Jahresbericht über die Forschungen der Agriculturchemie 1868-69.

[5] HÖVELER: Jahrb. Wiss. Bot. **24**: 294. 1892.

[6] FRANK: Bot. Zeit. **51**: 153. 1893.

IV. THE APPLICATION OF CHEMICALS IN BLOCKS OF GELATIN.

The preceding methods all proved themselves unsatisfactory. Yet they are worth incorporating in this record, for they are methods which would probably suggest themselves to any one pursuing this subject, and it is worth while to show the unsatisfactory results they bring.

Another method was conceived which seemed to promise better control of the application of a chemical to only one side of a root. This was the employment of gelatin as a vehicle for the various chemicals. It was thought that gelatin blocks might be made with solutions of salts, and these blocks might be brought against the roots, a block on each side. There was, however, the question as to the behavior of roots growing in gelatin, and their ability to respond to stimuli. Wacker[7] determined the retardation in the growth of some roots in water, while Sachs[8] and Němec[9] mention the fact that roots inverted in air and water do not return completely to their usual geotropic position. Experiments in this laboratory have shown that there is a greater retardation of growth of roots in water than in air or earth, and a greater retardation in gelatin than in water. At the same time, it was found that geotropic response is not so great in gelatin as in water, and not so great in water as in earth or air. Still growth proceeds apparently normally in gelatin, except for retardation; and geotropic responses follow stimulation, though somewhat slowly. It was decided, therefore, to try the use of gelatin.

Large, rectangular, oblong glass jars were selected to serve as damp chambers. They were lined with filter paper, dipping into water in the bottom. Paper boxes of suitable size were then made, and these laid on glass plates, while their sides were held rigid with wooden frames. Into these boxes, as molds, the warm gelatin mass was then poured, and allowed to solidify. The gelatin mass had been made by dissolving the dry gelatin in a watery solution of the salt to be used on the roots. The

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[7] WACKER: Jahrb. Wiss. Bot. **32**: 71. 1898.

[8] SACHS: Arbeiten Bot. Inst. Würzburg **1**: 409. 1873.

[9] NĚMEC: Jahrb. Wiss. Bot. **36**: 89. 1901.

gelatin blocks as they came from the molds were 15^{cm} long, 9^{cm} wide, and 2.5^{cm} thick. The seedlings to be used were fastened in the usual way to a bar of white pine which was suspended across the damp chamber at a suitable height. In the bottom of the damp chamber a glass platform had been raised above the water, and on this the gelatin blocks were laid, each block with a glass plate for a backing. A little practice soon enables one, with a hand on each glass plate, to turn the gelatin blocks up against the row of roots; and while with one hand the two blocks of gelatin are held in place, with the other hand they are secured there by bringing against the glass plate supporting them bars of wood held in place by springs of rubber tubing.

A row of thirteen seedlings of *Lupinus albus* was first used between the blocks of gelatin, one of which was made with distilled water, the other with 0.28 per cent. dry salt of di-sodic phosphate (Na_2HPO_4). The seedlings were 5^{cm} to 7^{cm} long, the temperature 23°, and the period twenty-four hours. The dry gelatin was 6 per cent. of the whole mass.

At the conclusion of the experiment, all thirteen roots were found grown into the sodium phosphate gelatin, the angles of curvature being 45° on the average. The roots looked healthy, and growth had been good. Decisive as this result was, it did not demonstrate the precise cause of the curving. The result may have been traumatropism, or hydrotropism (osmotropism), or chemotropism.

The curves could hardly be due to the presence of copper or other metal in the distilled water, for water from the same bottle was used in the gelatin on both sides of the seedlings. Yet to make doubly sure, the next gelatin blocks were made with water twice distilled in flasks of Jena glass. In this test eleven seedlings of *Lupinus albus* were employed as in the preceding experiment. Here as before all roots turned positively into the gelatin containing the sodium phosphate, nearly all angles being 45° or over.

It might be thought that the curves were due to the injurious action of the sodium phosphate on the growing zone of the root, retarding growth there, and thus causing the tip to swing around to make the positive curve. This result would be the same as the effect of mechanically wounding a root in the elongating zone, as determined by Spalding.[10] It is to be noted, however, that to produce a positive curve by injury the sodium phosphate must act traumatically on the elongating zone, whereas we should expect it to act first on the more sensitive root apex, and produce a negative traumatropic curve. To test the relative sensitiveness of the root apex, and of the elongating zone toward a known injurious substance, a block of gelatin was made up with a 0.01 per cent. aqueous solution of crystals of copper acetate, while the gelatin used on the opposite side of the roots was made with distilled water only. Sixteen seedlings of *Lupinus albus* were used. After six hours, the temperature being 21° to 22°, the gelatin blocks were separated, and the roots were seen to be bending away from the side holding the copper salt. The gelatin was replaced and allowed to remain eighteen hours longer, when the experiment was ended. Thirteen of the sixteen roots were strongly negative toward the copper acetate, while the other three roots remained straight. All roots were living and had grown somewhat.

It is thus demonstrated that when an injurious substance is presented at the same time to both the elongating zone and the apex of a root, the negative traumatropism of the root will overcome the tendency to form a positive mechanical curve. It is thus demonstrated that the curves toward sodium phosphate in the former experiments were not traumatic.

There is still the possibility that the curves toward the sodium phosphate were due to a disturbance of the turgor of the root. The salt on the one side may have caused a shortening of the cells on that side by withdrawing water; or the low osmotic pressure of the water and the gelatin on the opposite side may have caused an inflow of water into the cells, and hence a lengthening on that side of the root.

To test the possibilities named in the foregoing paragraph, a gelatin block was made up with 3.5 per cent. watery solution of

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[10] SPALDING: Traumatropism of roots. Annals of Botany 8 : 423. 1894.

cane sugar, and brought against one side of a row of roots, while the gelatin block on the opposite side was made up with distilled water. Twelve seedlings of *Lupinus albus* were used in a temperature of 22°, and the duration of the experiment was twenty-four hours. All roots grew straight.

Since in the last experiment the roots had on each side a gelatin solution of equal strength, it follows that on the side of the sugar solution there was an excess of osmotic pressure corresponding to more than 183.4^{cm} of mercury. This, however, effected no bending.

Another set of sixteen seedlings of *Lupinus albus* was set up between gelatin blocks, the one side having a 3.5 per cent. solution of cane sugar, and the other a 0.28 per cent. solution on the dry salt Na_2HPO_4. When the preparation was taken down twenty-five hours afterward, every root had grown into the sodium phosphate, the angles running from 30° to 75°.

These two experiments certainly show that the curves toward the sodium phosphate are not to be explained as osmotropism nor ascribed to any mere physical disturbance of the water content of the cells. If the curves are due neither to injury nor to the osmotic action of the sodium salt (osmotropism or hydrotropism), there remains probably but one explanation: We have here a true case of chemotropism of roots.

Accepting the foregoing results as demonstrating the positive chemotropism of the roots of *Lupinus albus* toward sodium phosphate, it would be interesting to know whether with strong solution of the same salt the root would show itself negatively chemotropic.

A row of ten seedlings, having on one side a gelatin block made with distilled water, and on the other side a block made with 2 per cent. dry salt of di-sodic phosphate, had all their roots killed within a few hours. Another row of ten seedlings, similarly treated except that the gelatin on one side was made up with a 1.5 per cent. solution of the sodium salt, showed, after twenty-four hours, all the roots bent into the gelatin containing the chemical. All of the roots except one were dead. All had grown sufficiently, however, to make the curve before dying.

A third row of ten seedlings of the same species, set up between gelatin and distilled water on one side and gelatin and 1 per cent. di-sodic phosphate on the other, gave eight roots bent into the gelatin containing the chemical, while the other two roots were straight. None of the roots were dead. In the twenty-four hours of the last experiment, the roots had grown but about 10^{mm}, though the temperature was 20° to 23°. This shows a retardation of growth to about 50 per cent. of what it would have been in air or soil.

The last series of three experiments demonstrates that by strong solutions of sodium phosphate the roots of this plant unable to turn in negative chemotropism are helplessly lured on to certain death. The case is similar to that of several free-swimming organisms, mentioned by Rothert[11], which swim into solutions of lethal osmotic strength.

Though the roots of *Lupinus albus* are positively chemotropic toward di-sodic phosphate, they do not display a like behavior toward all salts that are absorbed by plants as food. Seedlings of *Lupinus albus* to the number of thirty-seven suspended between blocks of 5 per cent. gelatin, one block holding only distilled water, and the opposing one a 0.5 per cent. solution on the anhydrous nitrate of ammonium, showed when the preparations were taken down twenty-four of the roots grown into the block containing no chemical, while the other thirteen roots were straight.

A similar preparation with the same species was made with gelatin with distilled water on one side, and with gelatin and a 0.75 per cent. solution of water-free calcium nitrate on the other side. At the end of the experiment twenty roots were negative toward the salt, and the other eight roots were straight. Still another set of seedlings of the same species was prepared with roots between gelatin and distilled water on one side and gelatin and a 0.375 per cent. solution of the water-free calcium nitrate on the other. The result turned out as before, except that a smaller proportion of roots bent. Of the seventeen roots, eight

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[11] ROTHERT: Beobachtungen und Betrachtungen über tactische Reizerscheinungen. Flora **88**: 409. 1901.

turned into the gelatin holding distilled water only, while nine grew straight.

Used in experiments similar to the foregoing, a 0.5 per cent. solution of potassium nitrate caused nine roots of the lupin out of ten to turn slightly into the distilled water gelatin, while the tenth root bent into the potassium nitrate gelatin. The growth was good, the roots not distorted, and the curves were slight. A 0.6 per cent. solution of anhydrous magnesium sulfate caused very slight curvatures in the lupin roots, but all ten roots certainly bent into the distilled water gelatin.

The curves described above as following the use of ammonium nitrate, calcium nitrate, potassium nitrate, and magnesium sulfate may have been either negatively traumatropic or negatively chemotropic. In view of the behavior of the roots of this plant toward gelatin containing 3.5 per cent. of cane sugar, the curves last described could not have been osmotropic. The experiments certainly do show that *Lupinus albus* is not similarly chemotropically sensitive to all salts that it may absorb as food. Its roots are positive toward all solutions of sodium phosphate tried, but they turn away from solutions of corresponding osmotic strength of the other salts used.

During the course of the work it seemed of interest to test the behavior of the roots of the lupin when two unlike salts of the same osmotic pressure were brought at the same time against opposite sides of the roots. For this purpose isosmotic solutions were made of potassium nitrate (KNO_3), calcium nitrate ($Ca(NO_3)_2$), and magnesium sulphate ($MgSO_4$). The solutions were made by the specific gravity method to give a pressure equal to 130^{cm} of mercury, it being assumed that in these weak solutions ionization was complete. It was assumed also that KNO_3 gave two ions, $Ca(NO_3)_2$ three ions, and $MgSO_4$ two ions.

When these isosmotic solutions of potassium nitrate and of calcium nitrate were opposed on the flanks of a row of lupin roots, nine of the eleven roots grew into the potassium nitrate, two roots growing straight. When potassium nitrate and magnesium sulfate were opposed, ten of the eleven roots grew into the potassium salt, and one into the magnesium. When calcium nitrate and magnesium sulfate were opposed, ten of the fourteen roots grew into the magnesium salt, while the other four roots remained neutral.

When we remember that all of the four salts last used caused the lupin roots to bend negatively when these salts were severally opposed to distilled water gelatin, we may be certain the curves noted in the preceding paragraph were repulsion and not attraction curves. The magnesium sulfate therefore repels more strongly than the potassium nitrate, and the calcium nitrate more strongly than either the potassium nitrate or the magnesium sulfate. Whether this repulsion is chemotropic or traumatropic cannot be decided at this time.

To ascertain whether other plants are chemotropically sensitive as *Lupinus albus* has been found to be, seedlings of *Cucurbita Pepo* L. have been put to the test.

Isosmotic solutions of potassium nitrate, calcium nitrate, and magnesium sulfate were prepared with computed pressures equal to 130^{cm} of mercury at a temperature of 15°. With these solutions blocks of gelatin (6 to 10 per cent. of gelatin according to the general atmospheric temperature) were made up and brought against the roots of the seedlings suspended in rows in damp chambers. The results may be shown in tabular form, the chemicals in a horizontal row being in opposing blocks of gelatin, the column of figures to the left indicating the number of roots curving toward the salts to the left, the figures in the middle column indicating the neutral roots, and the figures at the right indicating the number of roots curving toward the salts there given.

		Curved	Neutral	Curved		
KNO_3	←	1	9	0	→	$MgSO_4$
KNO_3	"	2	16	10	"	$Ca(NO_3)_2$
$MgSO_4$	"	0	9	3	"	$Ca(NO_3)_2$

Through an error in reading the specific gravities of solutions as given in Gerlach's tables,[12] the stock solution of di-sodic phosphate was made with an osmotic pressure of 39^{cm} of mercury, instead of the same pressure as the solutions of the three salts

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[12] Zeitsch. Analyt. Chemie **8**: —. 1869.

last used. Before the error was discovered, *Cucurbita Pepo* had been tested as shown in the following table, the explanation of the columns of figures being the same as for the preceding table, and the salts held in gelatin blocks as before.

		Curved	Neutral	Curved		
KNO_3	←	3	19	7	→	Na_2HPO_4
$Ca(NO_3)_2$	"	2	9	1	"	Na_2HPO_4
$MgSO_4$	"	0	8	0	"	Na_2HPO_4

It is probable that the results would have been approximately the same in the last table if the solutions of salts on the opposite sides of the roots had been osmotically equal. *Lupinus albus* was tested in precisely the same way and with the same chemicals as given in this table, and the result showed thirty roots out of thirty-seven curved toward the sodic salt, and not one root curved toward the three other chemicals.

From the two foregoing tables, this result certainly stands out: *Cucurbita Pepo* is neither attracted nor repelled by the chemicals used as is *Lupinus albus*. If its direction of growth is controlled at all, it is but feebly so by the di-sodic phosphate and the calcic nitrate; but it is more probable that it is not chemotropic, at least toward the salts here used, and that the curves that came were due to disturbances of growth, not falling within the realm of chemotropism.

CONCLUSIONS.

The experimental results recorded in the foregoing pages show that the roots of *Lupinus albus* are chemotropically positive toward solutions of di-sodic phosphate, and that no concentration of solution of this salt will produce a negative curve. The stronger solutions used (1.5 per cent.), cause first a curving toward the salt and then death. The death of the roots in such a solution may be due to the osmotic strength of the surrounding medium. The osmotic strength of the salt solution plus that of the gelatin probably amounts to somewhat more than four atmospheres of pressure, and such a pressure is probably greater than that of the cells of the distal millimeter of the root-tip.[13]

[13] STANGE: Bot. Zeit. 50: 292. 1892.

The particular attractive component of the salt is not shown. It may be either the sodium or the phosphoric acid ion. Recalling the work of Stange[14] and of Buller[15] one might think the response to be due to the PO_4 ion. Experiments now being made in this laboratory will, it is hoped, determine this question.

The general indifference of the roots of *Cucurbita Pepo* toward the chemicals used indicates that we may expect further study of the chemotropism of roots to show the same specific differences in sensitiveness to chemicals as is shown in sensitiveness toward light; that is, there will be found chemotropic and non-chemotropic roots.

The behavior of all the roots tested gives no indication of osmotropism. *Lupinus albus* was indifferent to the one-sided application of a 3.5 per cent. solution of cane sugar, and the same plant gave no negative bends when a solution of the di-sodic phosphate concentrated enough (four atmospheres) to cause death was applied to one side only. Yet the roots of this plant are hydrotropic. The roots of *Cucurbita Pepo* were indifferent when chemicals plus the gelatin gave osmotic pressure of about 78^{cm} of the mercury on one side and 170^{cm} of mercury on the other.

From Rothert's[16] view one would regard osmotropism and hydrotropism as identical; yet it is not improbable that roots will be found which are not osmotropic though they are hydrotropic. Such is the indication in these experiments.

The behavior of the lupin roots in curving away from all chemicals used except the sodic salt, may be either traumatropic or chemotropic. Or may this not be a reaction where chemotropism and traumatropism lose their distinction?

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[14] STANGE: Bot. Zeit. **48**: 124. 1890.

[15] BULLER: Annals of Botany **14**: 558. 1900.

[16] ROTHERT: Flora **88**: 415. 1901.

BOTANICAL SURVEY OF THE HURON RIVER VALLEY.

II. A PEAT BOG AND MORAINAL LAKE.[1]

LEWIS H. WELD.

(WITH SIX FIGURES)

WHILE the general history of morainal lakes and the superficial relations of their plant societies have long been familiar both to botanists and geologists, there has been great lack of detailed information regarding changes now taking place and the effects of such changes on the distribution of plants and consequent vegetable accumulations. In fact, anything approaching a satisfactory comparative study, based on reasonably complete data, has thus far been out of the question. The evidence goes to show that the rate at which morainal lakes in southern Michigan are filling up has been extremely variable and that oscillations of water level and various other changes are in progress, directly affecting biological conditions. For future critical studies, therefore, it is essential that definite observations of present conditions should be permanently recorded. The large number of morainal lakes in the Huron River Valley and the numerous peat bogs accompanying them, some of which are reported to be as much as forty feet in thickness, offer excellent opportunity for scientific exploration and commercial enterprise to cooperate with mutual advantage.

The lake, or pond, which forms the subject of the present study, is the first and smallest of the so-called Three Sister Lakes, and lies three miles west of Ann Arbor, just south of the trolley line. It is oval, or ovate, in outline, with the long axis SSW by NNE, the larger end lying towards the south. Its greatest length is 600^{ft} (180^{m}) and its width 400^{ft} (120^{m}); on the west

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[1] This work, to which Mr. Weld gave a large part of his time for a year, was incomplete when he left the University of Michigan in July 1902. As the work was carefully done, it seems desirable to place his observations on record. With his approval, some necessary changes and additions have been made by V. M. Spalding, under whose direction the survey is in progress.

is a strip of tamarack swamp and low ground several acres in extent, through which flows to the southwest the outlet, a mere ditch, dry except in spring. Across the road, north of the present lake, is a small marsh, part of the same basin, cut off in the early days by a corduroy road and now by the high embankment of the trolley line. It had no drainage to the north. The general relations are shown in the view from the trolley embankment (*fig. 1*).

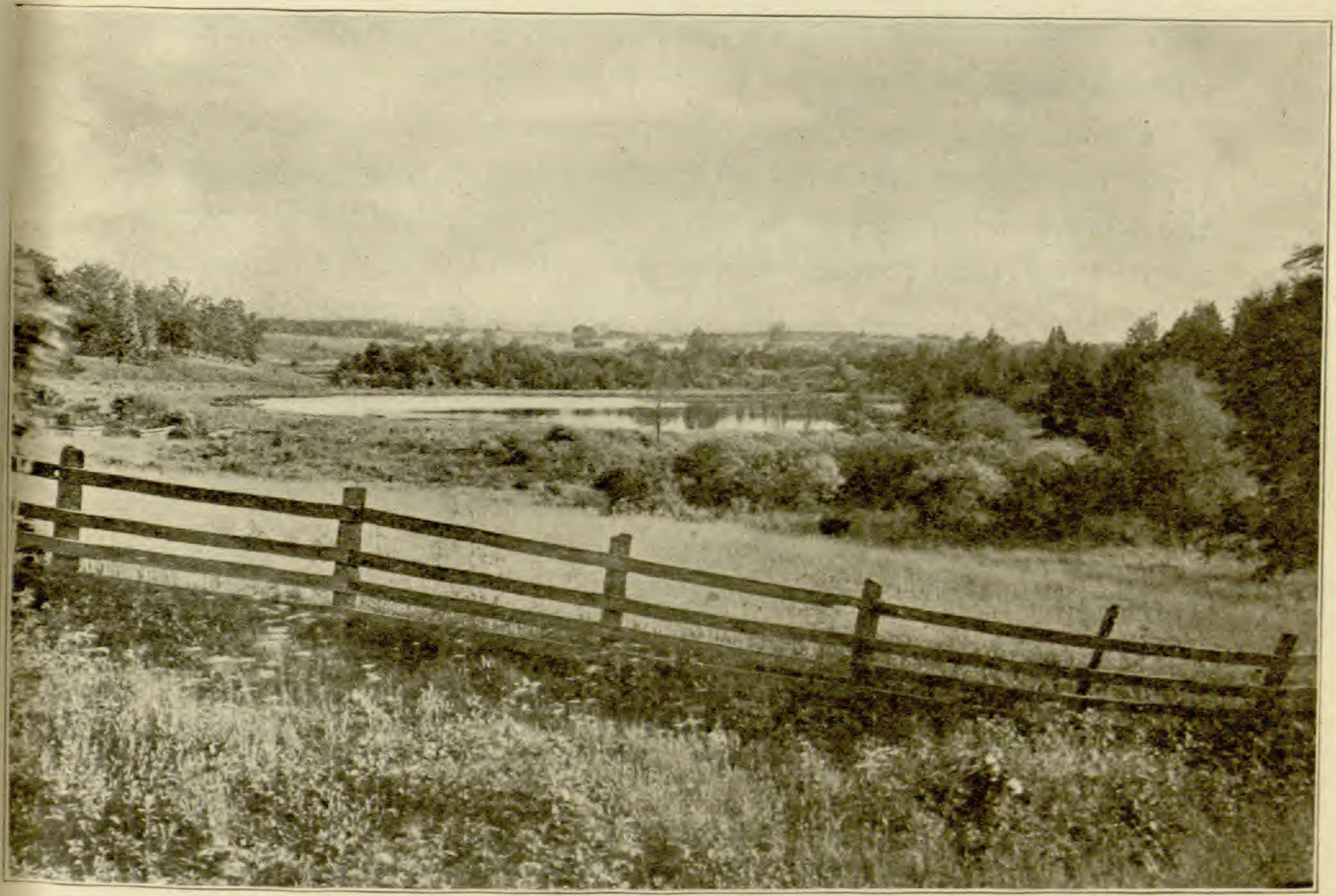

FIG. 1.—First lake from the N. W. on the trolley embankment.

About 1200$^{\text{ft}}$ (365$^{\text{m}}$) to the south lies a second lake, larger and nearly circular in outline, hemmed in except on the north and northwest by badly eroded hills. Its outlet is a ditch on the north side, which joins the outlet from the first, then flows straight west, crossing the road, through a low marsh, nearly to the woods beyond, and then turns to the northwest. West of the second, a quarter of a mile away, is the third lake, the largest and deepest of the group. It is not connected with the other two, a low, gravelly ridge separating it from the marsh just east of the woods, through which the other outlet flows. The outlet of this third lake flows through a bog at its western extremity, then to the southwest, where it makes a great bend through a level plain; then, after two or three miles, it turns north again, joining the outlet of the other two and forming a branch of Honey Creek which empties into the Huron River about a mile above Foster's.

The levels of these lakes are approximately the same, *i. e.*, 914^{ft} (278^{m}) above sea level or 33^{ft} (10^{m}) above the bench-mark on the library building of the State University, and 120^{ft} (36.5^{m}) above the Huron River at the outlet of Honey Creek. The summit of the divide east of the first lake is 955^{ft} (291^{m}) above the sea, or 41^{ft} (12.5^{m}) above the lakes. The corner on Liberty Street, one mile south of Huron is 979^{ft} (298^{m}) and the kame just south of Liberty Street rises probably 75^{ft} (23^{m}) higher. It was once proposed to derive the water-supply of Ann Arbor from the third lake, pumping the water to a reservoir on top of this kame, about 140^{ft} (42^{m}) above the lake.

Ordinarily the level of the three lakes remains nearly constant throughout the year, becoming, however, 6 to 8^{in} ($15–20^{cm}$) higher in the spring. In the fall of 1901 the lakes were said to be lower than they had been in years. It is popularly supposed that they are fed by springs, but careful testing with a thermometer, in the fall of the year, has thus far failed to detect the influence of such springs. It is a very common thing, however, for lakes of this sort to be sub-irrigated, that is, water percolating through the stony clay of adjacent hills makes its way to the lake, and, owing to the higher water-table on all sides, maintains the level constant in the lake basin. Another thing which helps to retain the water is the fact that the bottom of the lake basin is filled with a deposit of blue clay which prevents leaching. The depth of the lakes varies with the size, the first being 18^{ft} (5.5^{m}) deep, the second over 35^{ft} (10.5^{m}), and the third 55^{ft} (16.75^{m}).

This group of lakes is of glacial origin, like numerous other small lakes of Michigan. They lie on the western slope of the terminal moraine which was formed by the Erie lobe of the ice sheet, and which now extends northeast and southwest across the county. Just south of the second and third lakes is a high kame, and these lakes lie in some of those local depressions in the drift which are characteristic of a kame area. The present outlets follow the glacial drainage channels. These flowed away from the ice front to the north and northwest to the Huron River, which at that time had just formed in the re-entrant angle between the Erie and Saginaw lobes and flowed to the west through the Portage and Grand into Lake Michigan. All the region east of this terminal moraine, including Ann Arbor, was then occupied by the ice sheet, and the glacial drainage was to the west.

As is well known, such morainal lakes are destined sooner or later to become obliterated by the combined action of erosion and vegetation. The process goes on more slowly in some than in others, depending on size, depth, character of the shores, direction of winds, and the nature of the vegetation which gets a foothold. The first lake represents a fairly advanced stage in the process, the second and third occupying a far larger proportion of their original basins.

The characteristic zonal distribution of the vegetation is well marked in all three of these basins, especially in those of the first and third, the lake lying in the center with water lilies around its margin, then sedge and sphagnum, cassandra and other shrubs, and finally forest. It is noteworthy that the lake, as in many similar cases, is nearer the eastern than the western side of its basin, the bog and forest being better developed on the western side. This is not so evident in younger stages, but is very noticeable at the first lake.

Proceeding now to a more detailed account of the vegetation of the first lake, we may conveniently follow the zones in their natural order:

1. *Potamogeton zone.*—This is represented by *Potamogeton lucens*[2] in deep water, at the outer edge of the pond lilies, not at

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[2] The nomenclature is that of Gray's Manual.

all abundant, and by *P. zosteraefolius*, which is also sparingly present. The open water is 18$^{\text{ft}}$ (5.4$^{\text{m}}$) deep in the deepest place, which is near the south end. The bottom is of blue clay with a very thin film of black organic matter resting upon it. This clay bottom is derived from eroded material that has washed into the lake, chiefly before so much peat had accumulated around the borders of the basin, the finest of which, in turn, has been washed out into the middle of the lake and has settled in the deepest water. A section of the lake opposite the ice-house (*fig. 2*) shows that it is a flat-bottomed, saucer-shaped basin.

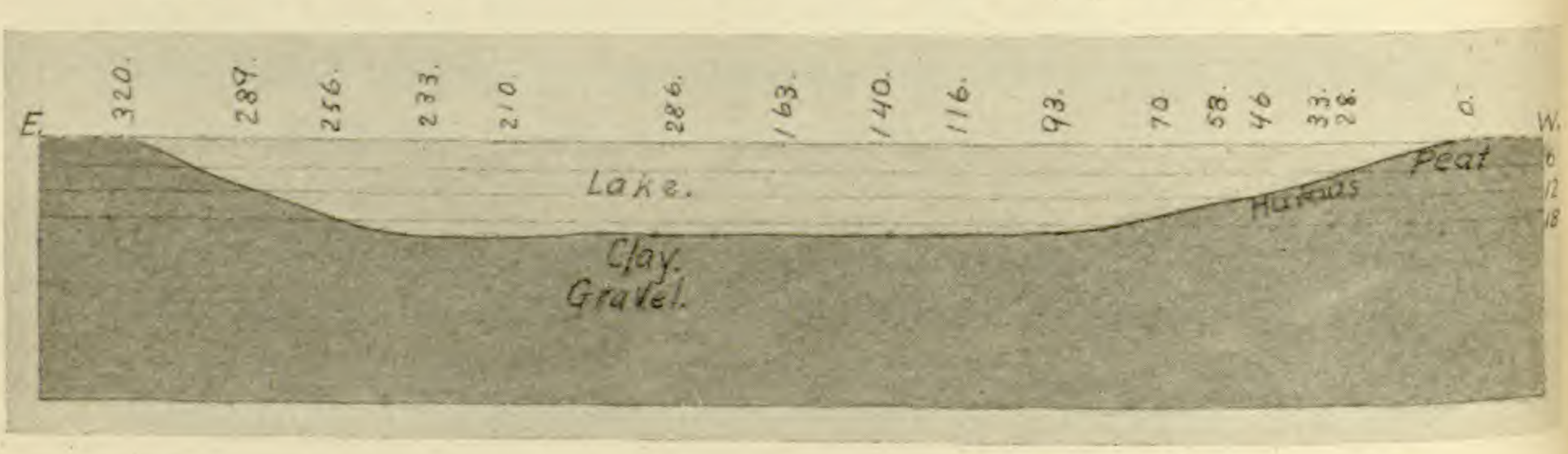

FIG. 2.—Section through lake opposite ice-house. Scale 1 : 900.

As we approach within 50 to 60$^{\text{ft}}$ (15–18$^{\text{m}}$) of the shore we come to the rather steep incline of the terrace formed by the border vegetation. This is composed of dead organic material in which sphagnum is conspicuous. Even though the lake is small, the waves probably stir it to the bottom, as it is so shallow. The water is highly colored, a yellowish-brown, by the decaying organic substances, and contains much solid matter in suspension.

2. *Nuphar zone*. The terrace just described is occupied by a very prominent and almost unbroken zone of yellow pond lilies from 20 to 30$^{\text{ft}}$ (6–9$^{\text{m}}$) wide, growing in water from 6$^{\text{in}}$ to 5.5$^{\text{ft}}$ (15–167$^{\text{cm}}$) deep. It is widest in the quiet water of the southwest end of the lake, while on the east there are a few short spaces where it is interrupted altogether; but on the whole it is an almost perfect zone. These lilies are most efficient agents in reclaiming a lake. Not only can they creep out with their stout rootstocks into 6$^{\text{ft}}$ (2$^{\text{m}}$) or more of water, binding together

the humus and contributing to it by their own decay, but their long petioles and large leaves break the force of the waves so that in the quiet water thus afforded a variety of less resistant forms can grow, adding the products of their decomposition to that of the lilies and to the débris which they collect.

The plants found growing here in the lily zone are :

Nuphar advena, giving character to the zone and preferring shallower and more quiet water than the next; Nymphaea odorata, in two isolated patches only, as if recently introduced; Brasenia peltata, replacing the lilies in two places; Potamogeton natans, a few specimens; Ceratophyllum demersum, scattering, not in dense beds; Utricularia sp., close to shore not abundant; Chara sp., two flourishing clumps near shore, each about a foot square, apparently recently introduced; Naias flexilis.

This zone then is made up almost wholly of Nuphar, which is replaced in spots by Nymphaea or Brasenia, while a very small number of other plants, represented by few individuals, grow on the soft, black, almost bare bottom. It would seem, therefore, that the yellow pond lily is an agent of prime importance in forming the soil in which various plants named in the following sections flourish. The relative importance of species in this and succeeding zones in the formation of peat should be investigated.

3. *Carex and sphagnum zone.* This is separated from the lily zone by a distinct though irregular line of demarcation. It presents a low, level appearance, being formed in great part of grasses and sedges uninterrupted by taller plants or shrubs (*fig. 3*). Its flora, however, is varied, consisting of about thirty species. Carex, with some six species, predominates; and, with several grasses, ferns, and other plants, forms a thick, tough, flexible mat resting on water or liquid mud beneath. This zone is less distinctly defined and the mat less compact, and hence less safe to walk upon, on the eastern than on the western side. Ordinarily, however, it will hold a man's weight clear to the edge, even when the water is high in the spring, without breaking. Some species of plants prefer the lakeward border, growing at or near the water's edge; among these are the sensitive and flowering ferns, swamp milkweed, Dulichium, Eleocharis, and certain other sedges, besides seedlings of Bidens and a mint, evi-

FIG. 3.—Zone of sedges. Taken at south end of lake, looking S. W.

dently from seeds that have floated to the places where they are growing. Others grow further back, among which are the cranberry, buck-bean, white violet, and sphagnum. Following is a list of the plants of this zone, as far as determined, somewhat in the order of their relative importance and abundance.

Carex filiformis, Glyceria nervata, Eleocharis palustris, Aspidium noveboracense, Viola blanda, Menyanthes trifoliata, Potentilla palustris, Equisetum limosum, on east side near edge of water, Vaccinium Oxycoccus on S. E. and N. W., Carex four species, Onoclea sensibilis, Osmunda regalis, Asclepias incarnata, Dulichium spathaceum, Eupatorium perfoliatum, Mentha canadensis, many seedlings of Bidens and Impatiens in spring, Cassandra calyculata, Salix myrtilloides, Eriophorum gracile, Scutellaria galericulata, Campanula aparinoides.

At the north end of the lake, in a particularly soft place, is a patch of *Typha latifolia*, but elsewhere there is a sharp transition between lilies and sedges, the Pontederia and Typha zones as commonly represented being wanting at this lake.

4. *Cassandra zone.* This zone is characterized by an advance of shrubs, of which cassandra is the most conspicuous. This, with the accompanying sphagnum, is active in raising the marsh and preparing it for tree growth (*fig. 4*). It is not present in all cases, but when present the succeeding forest floor is much drier. Its development here is weak. It is accompanied by Andromeda, chokeberry, small willows, huckleberry, low birch, and mountain holly. Around some lakes east of Whitmore this zone of shrubs is much better developed, consisting, however, of willows as dominant species, with no cassandra.

The plants of this zone at the first lake include: Cassandra calyculata, Sphagnum sp., Andromeda polifolia, Pyrus arbutifolia melanocarpa, Nemopanthes fascicularis, Gaylussacia resinosa, Salix myrtilloides, Viola blanda, Rumex Acetosella in the drier spots, Lycopus lucidus americanus, Glyceria nervata, Aspidium noveboracense, Osmunda cinnamomea, Solidago sp., Sarracenia purpurea growing half hidden in the sphagnum at the base of the clumps of cassandra, Drosera rotundifolia between clumps of cassandra with sphagnum and buck-bean at the northwest side of the lake, Arethusa bulbosa growing in the sphagnum, Habenaria lacera, Pogonia ophioglossoides, Calopogon pulchellus, Menyanthes trifoliata.

We are still at a loss to explain the distribution of these bog plants, particularly the orchids.

FIG. 4.—Young tamaracks; cassandra underneath.

5. *Forest.* Next comes the only tree that seems to be able to endure these conditions, the tamaracks, small ones advancing into the cassandra zone, in one instance even within 6^{ft} (1.8^{m}) of the water and farther back larger trees $12–16^{in}$ ($30–40^{cm}$) in diameter (*fig. 4*). This forms a forest of one species of tree, constituting the grove west of the lake. There the trees stand close together, and the shrub vegetation, cassandra in particular, is killed by lack of light. The forest floor is covered with dead brown needles, with only the occasional green of a moss, sedge, fern, or composite pushing through between the clumps of dead cassandra. This is one type of bottom vegetation in a pure tamarack woods. Where the growth of tamaracks is more open, particularly if the ground is rather wet, a great variety of leafy herbaceous undergrowth completely covers the ground. This is the case in a swamp near Cavenaugh Lake, where under the scattered tamaracks there is a rank growth of skunk cabbage, indian turnip, ferns, woodbine, grape, vervain, mints, elder, and juniper. In this case cassandra had not been present in the basin to dry the bottom. Another swamp near Whitmore, consisting of small trees close together, was found to be very wet, the roots of the trees creeping on top of the ground and densely covered with sphagnum, little else being present. No cassandra had been there.

Into the pure tamarack forest at the first Sister Lake, where the conditions permit, namely in the grove on the northwest, the following are now coming in:

Prunus serotina, Acer dasycarpum, Populus tremuloides, Rhus glabra, Quercus rubra, Rubus villosus, Osmunda cinnamomea, O. regalis, Pteris aquilina.

Leaving the basin level and the forest and going up hill on the west side, we pass to ground that has been cultivated, now in meadow. A few feet up the hillside we come to a distinct zone of white vervain, about 10^{ft} (3^{m}) wide, which winds around the foot of the hill, its position evidently determined by water supply.

The succession of plant societies as here described, which is ideally perfect on the north and northwest, has been modified elsewhere by conditions induced by human agency. Thus the area east of the lake, beyond the line fence, is characterized by an absence of forest and a scanty development of shrubs, though tamaracks once stood there within the memory of old settlers, and the stumps are still present. After they were cut, continued pasturing prevented their coming in again and favored the development of sod. West of the fence, however, where stock has been excluded, there is a good development of both trees and shrubs, and no sod has been formed. South of the ditch to the west of the lake the tamaracks were cut off, perhaps fifteen years ago, and cassandra and other shrubs have come in, with a multitude of young tamaracks which will eventually kill out the cassandra. A portion of this area, where the tamaracks were cut, was burned over in or near 1890. Following the burning, a dense growth of Marchantia covered the ground, but it has all disappeared since, and the ground is now occupied by

Populus tremuloides, Populus grandidentata, Salix rostrata, S. lucida, S. amygdaloides, S. cordata × sericea ?, Pyrus arbutifolia melanocarpa, Acer dasycarpum, Cornus stolonifera, Larix americana, Rubus villosus, R. strigosus, Rhus glabra, Pteris aquilina, Osmunda cinnamomea, O. regalis, Poa pratensis, Eupatorium perfoliatum, Typha latifolia, and other species, constituting a swamp clearing society. Occupation by a much wider range of species is possible and often occurs.[3]

The general topography and the extent of the vegetable deposits show at a glance that this lake was once much larger and its level some higher than at present. By digging a series of holes in the basin through the peat the bottom contour of the old lake is seen to conform to the present contour of the surrounding hills. It is thus found that the old lake included the marsh north of the road, for a boring in the road near the sluice shows 2^{ft} (61^{cm}) of till, washed in and brought in to build the road, and below that 7^{ft} (2.1^{m}) of peat. A series of borings 100^{ft} (30^{m}) apart (*fig. 5*) shows that to the east of the line fence the lake was comparatively shallow, shown by the 8 to 9^{ft} (2.4–2.7^{m}) of peat, with a gently sloping bank on the eastern side, as would be expected from the contour of the present hill.

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[3] The above lists were made in spring, and accordingly include few composites. The attempt has been made to give representative lists rather than complete ones.

West of the fence, however, the peat is over 20 ft (6 m) thick, and here was a deep part of the lake. In a few of these borings an attempt was made to determine the thickness of the blue clay, but there is no sharp separation between the clay and the gravel beneath. *Figure 6* shows a cross section of the basin in an east and west line through the north end of the lake. The western slope was not so steep at this place and the lake was more disk-shaped. How much deeper than 20 ft the peat may be in places near the lake has not been ascertained.

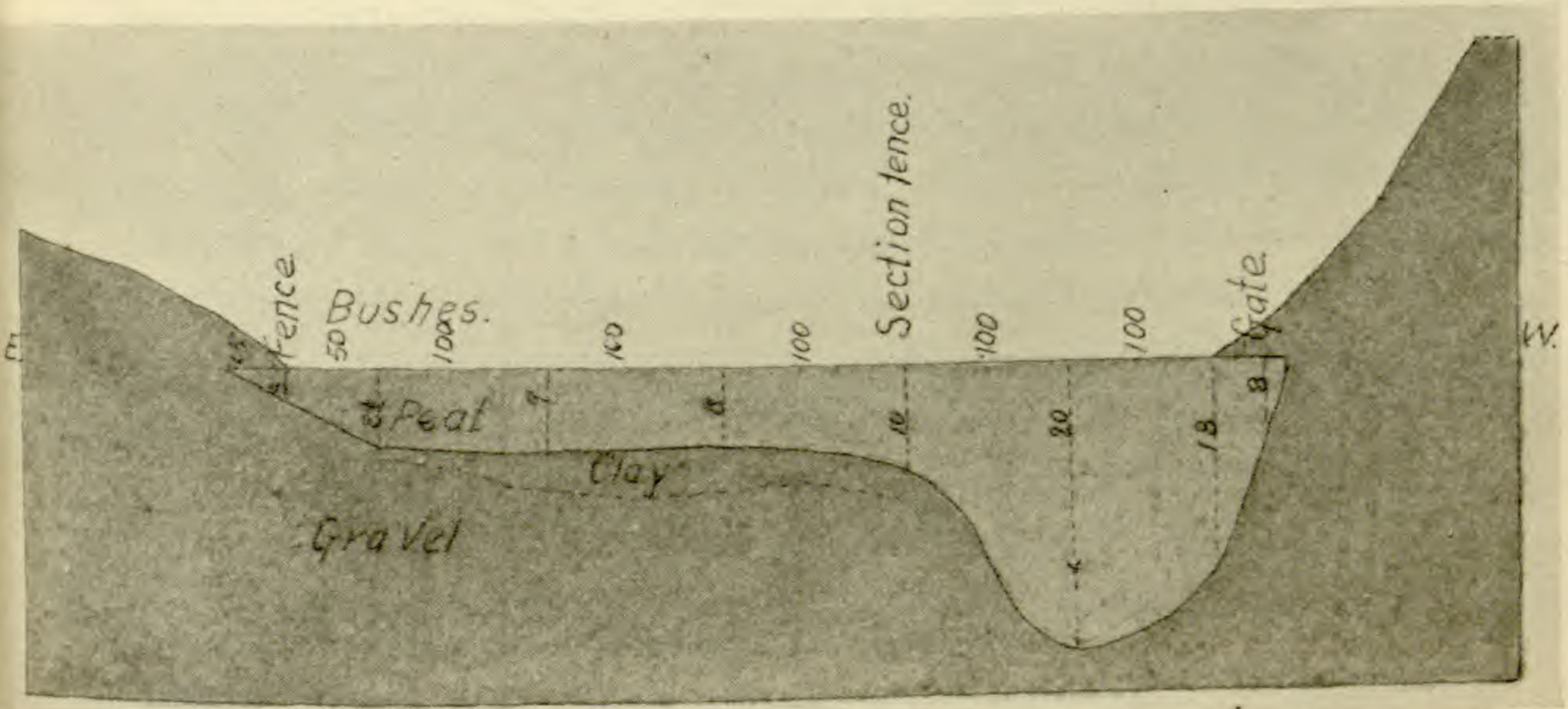

FIG. 5.—Section across lake basin from E. to W., halfway between lake and road, in line with fence. Hor. scale 1 : 2160 ; vert. scale 1 : 360.

Directly south of the lake is a shallow valley leading over to the second lake. A boring in the bottom of this at the fence shows 8 ft (2.4 m) of gravelly clay mixed with dark organic materials. This valley was once quite deep and formed a connection between the lakes, but being narrow was filled up by erosion rather than by vegetable deposits. West of this valley is a hill now under cultivation, and to the west of this is a broad valley in which runs the present outlet of both lakes. The peat in this valley is over 16 ft (5 m) deep, showing that here was a broad and deep connection with the second lake, the hill being at that time an island.

The Three Sisters were then originally two lakes, the third, which has always been separate, and one from which the first and second and the marsh north of the road have been derived. The original lakes were some 5 to 6^{ft} ($1.5-1.8^{m}$) higher than at present, as is shown by a beach or terrace north of the second lake, and by other evidence. Their lowering is apparently due in great part to better drainage since open ditches have been cut in the outlet channels.

It is very desirable that a complete enumeration and comparison of the fauna and flora of the first and second lakes should be made. Here are two lakes that once were one, but except for the connection through a ditch running only in the spring, have been isolated for a long period. The physical characteristics of the two lakes are now very different, and, assuming that they were both inhabited by the same forms when there was one uniform condition, it would be reasonable nevertheless to expect modifications or variations to arise, particularly in the aquatic life, following the changes in external conditions. Some differences in the present plant life of the two lakes are now very noticeable, the phytoplankton of the first being very different from that of the second. The latter contains an enormous number of blue-green algae, Oscillaria and others, or at least did all through the winter and spring, while the first lake had none. Desmids appeared in great abundance in a culture dish from the first lake, while the other gave few. More diatoms have been present in the second lake than in the first. The second contains many Volvox, not found at all in the first, and some Eudorina. Two representatives of the Peridineae, *Peridinium tabulatum* Ehrh. and *Ceratium hirudinella* O. F. Müller, occur in each lake. The paucity of higher plants is noticeable. The first lake has no Elodea or Myriophyllum, only three species of Potamogeton, little Ceratophyllum, and but two small clumps of Chara. The flora of the second lake, not yet sufficiently studied, is apparently quite as scanty. The presence or absence of flowering plants seems to be largely a matter of the chances of dispersal, but this certainly does not account for the differences in the phytoplankton of the two lakes. In seeking an explanation of this account must be made of their physical differences, among which the following are to be specially considered:

1. *Color.* The water of the second lake is clear, or would be if the blue-green algae were filtered out, while that of the first is highly colored, a yellowish-brown, due to the great amount of decomposed vegetable substances about the lake. This latter fact is the greatest difference between the two lakes, perhaps the cause of all others, but there is as yet no wholly satisfactory explanation of the antecedent fact that something like 95 per cent. of the work of filling one basin has already been done, while the process is but fairly started in the other. The greater depth of the second may have something to do with this. The ice in the first lake is clear as crystal. Freezing in winter and evaporation in summer serves to concentrate the amount of dissolved salts in the water and thus still further deepen the color.

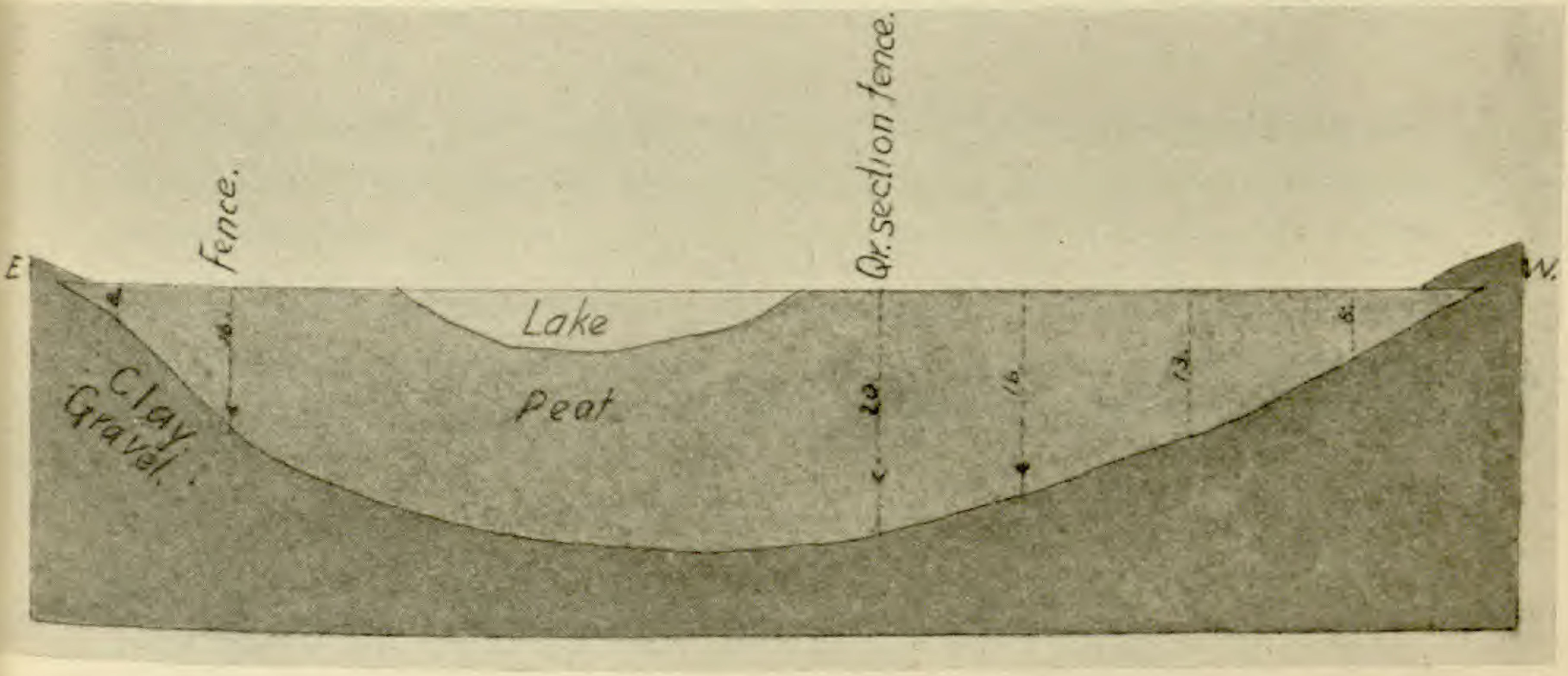

FIG. 6.—Section across lake basin from E. to W. at ditch. Scale as in *fig. 5*.

2. *Turbidity.* Absorption of light, as is well known, is much greater in colored than in clear water, and it is also occasioned by turbidity due to the presence of solid matter in suspension. Turbidity is most conveniently measured in the field by the wire method of Hazen, which consists in observing the depth at which a platinum wire 1^{mm} in diameter disappears when lowered horizontally into the water. The scale is furnished by the recip-

rocal of the depth in inches at which the wire becomes invisible. As recently modified by Whipple and Jackson, turbidities are read directly from the scale as parts by weight of suspended matter in a million of water, making this a very simple observation and worthy the attention of botanists engaged in the study of aquatics. November 12, 1902, a reading of 11.5 was obtained. No readings were taken on the second lake.

3. *Temperature.* This, coupled with depth, may account for periodic phenomena observable particularly in the case of diatoms. The first lake is so shallow that stagnation never occurs. The bottom is a little more than a degree cooler than the surface. The second lake is over 35^{ft} (10.6^{m}) deep in places, and, though no temperature readings have yet been taken, stagnation may occur, causing at the time of the spring and fall overturning an increase in the diatom flora. At all events the second lake showed many limnetic diatoms in the spring, more than in May, leading to the inference that stagnation does occur.

The chemical composition of the water, which may be the determining factor for the presence of blue-green algae in one lake and their absence from the other, has not yet been examined.

The facts here presented show plainly that the history of these morainal lakes, as regards their vegetation, is by no means identical. Differences of depth and contour, of soil and drainage, of water supply and the chances of seed dispersal, with other less conspicuous factors, have resulted in great differences in the rate of filling up and in the character of their plant life. The first lake stands as a representative of a large number in this valley that show essentially the same succession of plant societies. After the retreat of the ice the ground could hardly have been left bare for any considerable period. If this had been the case, the evidence would be seen in much greater erosion than has actually taken place. As it is, these areas, held by vegetation, show the even curves of ice- and water-formed topography. We are to think of forest-covered hills surrounding a newly formed lake basin. Aquatics and amphibious plants are already growing about its edge, and as the humus accumulates, sedges, bushes, and finally trees follow. As the basin becomes filled up with peat the lake first disappears from the center, then the bog, and so on until a tamarack woods fills the basin. Into this pure growth of tamarack there come in slowly elm, ash, maple, birch, basswood, and their accompanying undergrowth. A swamp near Cavenaugh Lake was observed where elms and ash a foot and a half in diameter had come in, overtopped the tamaracks, and killed them. This swamp had a very leafy undergrowth. Thus the final stage is a damp, rich-woods flora of soft woods; never does a hard-wood flora take possession, as far as my observations in this region extend, although an occasional oak or juniper may be found.

The history just outlined has been greatly modified in individual cases, as the remarkable differences between the first and second lakes plainly show, and future investigations should take full account of such differences. Thus far, critical comparisons of the flora of different lakes and bogs and the conditions affecting their plant life are wanting. The distribution of their phytoplankton presents many unexplained facts, and the factors determining the peculiarities of bog xerophytes are still an unsolved riddle. The deposition of peat is progressing with varying rapidity in numerous bogs and swamps in southern Michigan, but the processes involved in its formation and affecting not merely its fuel value but its fitness for further plant growth, and hence the composition of succeeding plant societies, are still very imperfectly known. The valley of the Huron River, with its great number of lakes and variety of conditions, offers a favorable area for more extended study of these problems.

SUMMARY.

1. These lakes were formed in the moraine at the front of the ice sheet when the Erie lobe extended 3 miles (5^{km}) west of Ann Arbor. The present outlets follow the glacial drainage to the west into the Huron River, which then flowed west into Lake Michigan.

2. The third lake never was connected with the others. The first and second were once one, with an island in the center. Subsequent lowering of water and filling of channels has made two lakes.

3. Since their separation the physical characters of the two lakes have become very different, leading to marked differences in the character of their plankton.

4. These differences appear to be due primarily to the greater depth of the second and the more rapid filling of the basin of the first lake. The reasons for the latter are not clear.

5. A luxuriant flora probably flourished on the terminal moraine at the time of retreat of the ice sheet. The lake was first invaded by aquatic and amphibious plants. As humus accumulated, there followed in turn sedges and sphagnum, shrubs, a pure tamarack, and then a mixed, soft-wood, deciduous forest.

6. Vegetation accumulated faster on the western than on the eastern side of the lake, due at least in part to the direction of prevailing winds. The ax, fire, and pasturage have obscured the order of succession in some places and prolonged the period required for the ultimate reclamation of the basin. Other causes, not yet sufficiently investigated, have resulted in marked differences in composition of the bog floras of this and neighboring lakes, and in the constitution and rapidity of formation of the vegetable substances with which they are becoming filled.

UNIVERSITY OF MICHIGAN.

SOUTHWESTERN PLANTS.

LESLIE N. GOODDING.

EARLY in the season of 1902 the writer visited the southern part of Nevada and Utah for the purpose of securing as large a representation of the flora as possible. On arriving at Calientes, the extreme southern point of the Oregon Short Line at that time, in the latter part of April, it was found that the plants were not yet in condition to collect. On that account the trip was extended southward along Meadow Valley Wash, the Muddy, and the Virgin to the Colorado River. From thence return was made along the Virgin to St. George, Utah, and directly across to Modena, Utah. Calientes was again visited and collections made of plants that had now come into condition. Returning northward through Utah, stops were made at every convenient point on the railroad, from which visits were made to some of the desert portions of central Utah and to several localities in the Wasatch Mountains. Leaving the railroad at Carter, Wyoming, with camp outfit, and traveling southward, the final work of the trip was done in the Uintah Mountains and on their southern slopes. Three weeks were spent here, and proved as profitable as any of the twelve that were spent in the field.

A large amount of material was secured, and among the several hundred species are many of great interest, either because of their meager representation in the herbaria, or because they are poorly understood, or finally because they have heretofore wholly escaped recognition. A discussion of a few of these is submitted in this paper.

CENTROSTEGIA Gray, DC. Prod. **14**:27; Pacif. R. Rep. **7**:19.

C. CRYPTANTHA (Curran); *Chorizanthe Thurberi cryptantha* Curran, Bull. Cal. Acad. **1**: 275.

C. LEPTOCERAS Gray, Proc. Am. Acad. **8**: 192; *Chorizanthe leptoceras* Wats., Proc. Am. Acad. **12**: 269.

C. THURBERI Gray, DC. Prod. **14**: 27; Pacif. R. Rep. **12**: 19; *Chorizanthe Thurberi* Wats., Proc. Am. Acad. **12**: 269.

The validity of the genus Centrostegia can hardly be questioned when one has both plants and descriptions at hand. The spurs on the involucre are so characteristic that the genus might well stand on these alone.

Eriogonum revolutum, n. sp.—Perennial, the low woody base rather intricately branched, the upright branchlets 7–10^{cm} long: leaves thick, linear, so strongly revolute as to be nearly terete, obtuse or acutish, 8–15^{mm} long, softly pubescent above, more densely so below, short petioled, fascicled near the ends of the branchlets: peduncles 5–8^{cm} long, slender, pubescent, leafy at the base only: involucres pubescent, short peduncled, in a compact head, turbinate, strongly 5-nerved and toothed, 10–20-flowered: bracts linear, scarcely exceeding the involucres; pedicels 4–5^{mm} long: calyx pubescent, pink, campanulate, slightly constricted in the middle, outer lobes oblong-oval, inner slightly narrower.

This excellent species is apparently not closely related to any described species, but undoubtedly belongs in § 3 of Watson's revision, Proc. Am. Acad. **12**: 262.

Collected by the writer in the mountains south of Bunkerville, Nevada (no. 753).

Cerastium variabile, n. sp.—A perennial cespitose herb with many erect stems 15–25^{cm} long, viscid pubescent throughout: leaves subcoriaceous, exceedingly variable in shape and size; the lower ones oblong-clavate, obtuse, 1–1.5^{cm} long; upper ones from narrowly oblong-linear to ovate-lanceolate, mostly acute, one-fourth to one-half the length of the internodes: sterile shoots very few, with internodes usually exceeding the oblong-linear acute leaves: flowers 5–12, in an elongated open cyme; the lower pedicels much elongated (often 25^{cm} long); upper ones considerably shorter, erect or recurved: the thick sepals narrowly oblong, acutish, 6–7^{mm} long, narrowed abruptly into a thin scarious margin and tip: petals 1–2^{mm} longer than the calyx, narrowly obcordate except for being *deeply* two-cleft: capsule one and a half times as long as the calyx, distinctly curved.

This very variable plant is most closely related to Dr. Greene's *C. occidentale*, from which it is easily distinguished by its more compactly cespitose bunches with very few sterile shoots, by its remarkably viscid pubescence, elongated cymes, broader and thicker calyx lobes, and much shorter and more deeply cleft petals.

Collected by the writer in the Uintah Mountains, Utah (no. 1246), where it grew in some profusion.

Draba valida, n. sp.—Perennial with a tap root: stem usually single but much branched from the base; stem and branches somewhat rigidly erect, the main stem 1.2–2^{dm} high, exceeding the branches by 4–5^{cm}; rather finely hirsute throughout: basal leaves numerous, 1.5–2^{cm} long, spatulate, obtuse, entire or coarsely toothed: stem leaves sessile, oblong, entire or occasionally coarsely two to four toothed, 1–1.5^{cm} long; calyx oblong, obtuse, 1.5–2^{mm} long, sparingly clothed externally with long hairs: petals white, oval to obcordate and attenuate at base, 2–3^{mm} long: pedicels erect, stout, 2–4^{mm} long: pods oblong, 4–7^{mm} long, clothed with short branched hairs: stigma almost sessile.

The type (no. 1402) of the above species was collected by the writer at Dyer Mines, Uintah Mountains, Utah.

AMELANCHIER RUBESCENS **cinerea,** n. var.—A peculiarly ashy-colored divaricate shrub, distinguishable from *A. rubescens* Greene by the much denser pubescence on the leaves and inflorescence, by the nearly obtuse oval leaves which are acutely serrate to the base, and by the shorter more broadly campanulate calyx with linear acute lobes.

Collected by the writer at St. George, Utah, May 13, 1902 (no. 780).

Cowania alba, n. sp.—A quite freely branched bush, 1.5–2.5^{m} high, with white bark and light colored wood: leaves 3–5-cleft at the ends and tapering to rather broad petioles, 8–11^{mm} long, dark green above, somewhat viscid and barely tomentose beneath, edges strongly revolute and resinous-dotted, crowded at the ends of small branchlets which are scaly from the persistent stipules of previous years: flowers white, about 15^{mm} in diameter: calyx tube very narrowly funnelform, clothed with short silvery pubescence, usually slightly resinous-dotted (not glandular-tipped pubescence), strongly veined; lobes narrowly oblong, obtuse, strongly net-veined, 3^{mm} long: petals oblong, obovate, very irregular in size and outline but usually long clawed: akenes normally two (rarely three), large, 8^{mm} long and 2^{mm} wide, with a prominent keel along the back; length of the tails unknown.

This elegant species cannot be said to be closely related to any other. The number and size of the akenes and the shape of the leaves are very characteristic.

Collected by the writer in the mountains south of Bunkerville, Nevada (no. 744).

Geranium longipes (Wats.).—Annual: stems usually simple below, branched above, one to several from the same root, sparingly strigose with short reflexed hairs; above, at the second or third whorl of leaves, the stem breaks up into three to six equal slender branches which in turn branch out into the two-flowered, much elongated, nearly filiform peduncles: pedicels slender and elongated; peduncles and pedicels quite densely glandular-pubescent: leaves broadly reniform in outline, $3–5^{cm}$ wide, deeply 5–7-cleft nearly to the base, the divisions narrowly lobed; radical leaves numerous, on slender petioles, $10–15^{cm}$ long: flowers white or pinkish, $2.5–3^{cm}$ in diameter: sepals narrowly oblong, ciliate, pubescent on the prominent veins, terminating in a long awn: petals a little shorter than the sepals, narrowly obcordate, deeply triangulate-notched: lobes of the ovary coarsely strigose-pubescent; filaments persistent, as long as the lobes of the ovary; beak 2^{cm} long, rather long-pointed: seeds oblong, pitted.

It is apparent from the meager description of *G. carolinianum longipes* Wats. that it must have been drawn from inadequate material. The "usually solitary peduncle" of Mr. Watson's description is true of occasional western plants, but these can by no means be separated from the other western forms. All the western material I have seen (except one specimen of true *G. carolinianum* from Idaho, which was doubtless an introduction) has the elongated peduncles and pedicels, and this has led me to think that all our western material comes under Dr. Watson's *G. carolinianum longipes*. The character of the pubescence as well as the elongated peduncles and pedicels, together with such minor points as the narrower calyx lobes, longer point on the beak, etc., easily separate the western plant from the eastern.

The writer's no. 1395 from the Uintah Mountains, Utah, is considered typical.

Rhus macrothyrsa, n. sp.—A tree-like shrub $1.5–2.5^{m}$ high, with glabrous stems (except the base of the young shoots which are clothed with a thick, light brown, woolly pubescence): leaves 20–25^{cm} long; rachis terete or often angled, with a narrow dorsal canescent line; leaflets 9–15, glabrous and green above and below, oblong-lanceolate, acuminate, acutely serrate, sessile: fruiting thyrse 15–25^{cm} long, open and quite strongly recurved; the rachis and its branches clothed with a rather coarse persistent pubescence; its branches often 8^{cm} long, ascending, subtended in the young thyrse by linear bracts 5–20^{mm} long: drupe slightly laterally compressed, about 3^{mm} in diameter, clothed with short, light red pubescence: stone nearly globular and smooth.

R. macrothyrsa is most closely related to *R. glabra*, from which it can readily be distinguished by its dark green leaves which are not at all glaucous on either side, and its long open recurved thyrse.

Collected by the writer (no. 988) at Calientes, Nevada.

Rhus utahensis, n. sp.—Shrub 1–1.5^{m} high, diffuse, rather slender: leaves simple, suborbicular or subreniform, truncate at base, coarsely and somewhat evenly crenate, 1.3–2^{cm} long: petioles terete, minutely pubescent, 4–8^{mm} long: inflorescence few-flowered: drupes rather large, 5–8^{mm} in diameter, clothed with a short pubescence.

R. utahensis is apparently the *R. canadensis simplicifolia* Greene, which name is untenable, however, on account of *R. simplicifolia* Salisb. *R. utahensis* is well worthy of specific rank, as it is very distinct from *R. trilobata*, its nearest ally.

Collected by the writer (no. 832) in Diamond Valley, Utah.

Apocynum nevadense, n. sp.—Glabrous throughout, stem 1–1.5^{m} high, freely branched above, the paired lateral branches far surpassing the central stem: leaves very smooth, subglaucous below, slightly darker above: the cauline sessile, semiclasping at base, 5–12^{cm} long, 2.5–4.5^{cm} wide, perfectly oblong, decidedly obtuse but tipped with a minute cusp, cordate at base; the rameal elliptic, acute, strongly murcronate, tapering below to the short petiole: cymes 1–3, usually terminal on the main stem, occasionally on the branches: peduncles 1–3^{cm} long; pedicels subtended by linear acute bracts: calyx segments linear-lanceolate: corolla white, cylindrical, exceeding the calyx segments by one-half: fruit 9–11^{cm} long.

This plant is probably most closely related to *A. oblongum* Greene, but the sessile cordate semiclasping base of the cauline leaves and long fruits are distinguishing characters of *A. nevadense.*

The type no. 986, was collected at Calientes, Nevada, by the writer, May 29, 1902.

Cressa depressa, n. sp.—A depressed, spreading, many-branched, very leafy perennial 10–15^{cm} high, usually much broader, widely divaricately branched from the base up and canescently villous throughout: leaves oblong, subacute at both ends, subpetiolate, 5–10^{mm} long, 3–4^{mm} wide: flowers pediceled (pedicel 2–4^{mm} long) in the axils of the leaves, forming long narrow racemes, the branches being floriferous nearly to the base: calyx composed of 4 or 5 equal, oblong to nearly oval sepals 5^{mm} long, subtended by two small (usually half the length of the sepals) foliar bracts: tube of the corolla campanulate, the length of the sepals; lobes 5, oblong, subacute, reflexed, clothed exteriorly with long silky pubescence: filaments scarcely exserted, broadly subulate, inserted on the middle of the corolla tube and united a little below the insertion by their expanded bases, forming nectariferous pits: styles filiform, nearly twice the length of the corolla tube; ovary broadly ovate, copiously silky-lanate at summit, four-ovuled.

C. depressa is most closely related to *C. truxillensis.* The latter apparently differs little from the foreign *C. cretica,* resembling it in habit and character of the inflorescense. The generic description and figure in Engler and Prantl's *Nat. Pflanz.* 4:15 show the spicate or even nearly capitate character of the inflorescence which forms a great contrast to the raceme of *C. depressa.* The generic description in Benth. and Hook. *Gen. Pl.* 2:881 calls for the inflorescence as described by Engler and Prantl. The generic descriptions all show that the previously described species have filiform filaments, whereas *C. depressa* has remarkably dilated filaments.

Collected by the writer (no. 726) from the salt swamp along the Virgin River of southern Nevada.

Langloisia punctata (Coville).—*Navarretia setosissima punctata* Coville, Contrib. U. S. Nat. Herb. 4:154.

The distinctions between *L. punctata* and *L. setossissima* are well brought out by Dr. Coville, and in the light of his discussion, in connection with good specimens of *L. punctata* recently collected by the writer at Rioville, Nevada, it seems proper to raise it to specific rank.

Phacelia foetida, n. sp.—Densely glandular-hispid throughout, light olive-green, 4–6^{dm} high, stout, erect, from a biennial root: leaves oblong, deeply toothed and occasionally slightly lobed; the lowermost short-petioled, 5–8^{cm} long, densely tufted about the base; the upper sessile and numerous along the stem: inflorescence a dense spicate thyrsus 1–2^{dm} long, composed of short dense scorpioid cymes (occasionally compound cymes at base): flowers sessile: sepals clavate, 4–5^{mm} long: corolla white or cream colored, narrowly campanulate, 5–7^{mm} long, slightly hispid without, the lobes short (1^{mm} long), ovate, obtuse: anthers ovate-oblong; filaments slender, exserted half their length, inserted low down in the corolla tube; appendages ovate, obtuse, united at the base of the filaments: style 2-cleft two-thirds its length: capsule globose, slightly 4-lobed, short glandular-pubescent, 4-seeded.

The above species seems sufficiently distinct from all other species of Phacelia to require no explanatory notes. It grows in the lava fields of southern Utah, where it was collected by the writer. It is characterized by a deathly sickening odor which may account for the fact that apparently it has not been collected or described before.

PHACELIA PALMERI Torr., Watson, Bot. King 251.—*P. integrifolia Palmeri* Gray, Syn. Fl. **2**: 160.

From a recent collection, made by the writer, at Kernan, Nevada, of *P. Palmeri*, it seems proper that the plant should stand as a species. *P. integrifolia* has entire crenately-toothed leaves, whereas *P. Palmeri* is deeply sinuately lobed and the lobes sinuately toothed. The former also has long exserted stamens, while the stamens of the latter are shorter than the corolla. There is also a marked difference in the internal appendages of the two species.

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BRIEFER ARTICLES.

SELECTED NOTES. III.

(WITH SEVENTEEN FIGURES)

EQUISETUM ARVENSE L.—Though Hofmeister[1] has described in detail the sprouting spores of *Equisetum limosum* and *E. arvense*, his figures of the latter are not so full but that another series might be of interest; especially as the method of development varies so greatly in this species. I have followed carefully the young prothallia of *E. arvense* during a month of growth, and the figures here given illustrate their progress from day to day. In both *E. limosum* and *E. arvense*, Hofmeister finds that almost without exception there is first cut off in the germinating spore a comparatively colorless basal cell, which generally gives rise to the first rhizoid. In *E. arvense*, however, he finds that there are numerous exceptions to this, the small basal cell often not elongating into a rhizoid, but remaining unchanged, while the large cell above produces the rhizoid. This variation was very rare in the spores sprouted by me, but such a case is shown in *fig. 8*. Sometimes (*fig. 6*) the small cell was not cut off, but the rhizoid came directly from the base of the large cell. The first rhizoid is usually the only one for a long time, and in no case did I find another, even in the oldest stages figured. The second wall is as a rule nearly parallel to the first in *E. arvense*, while in *E. limosum*, according to Hofmeister, it is generally perpendicular or strongly inclined to it.

Comparing *figs. 8* and *9*, it will be seen that the greatest possible variation is met with. Both plants shown are of the same age, twenty-three days. The filamentous form (*fig. 8*) is very rare, and is not described by Hofmeister. But Campbell[2] finds that in *E. telmateia* "the first wall may be either vertical or transverse, and sometimes, but not often, there are several transverse walls, and a short filament is formed."[3] *Figs. 10–14* represent plants about one month old. The largest is about old enough to produce antheridia. Later stages were not followed.

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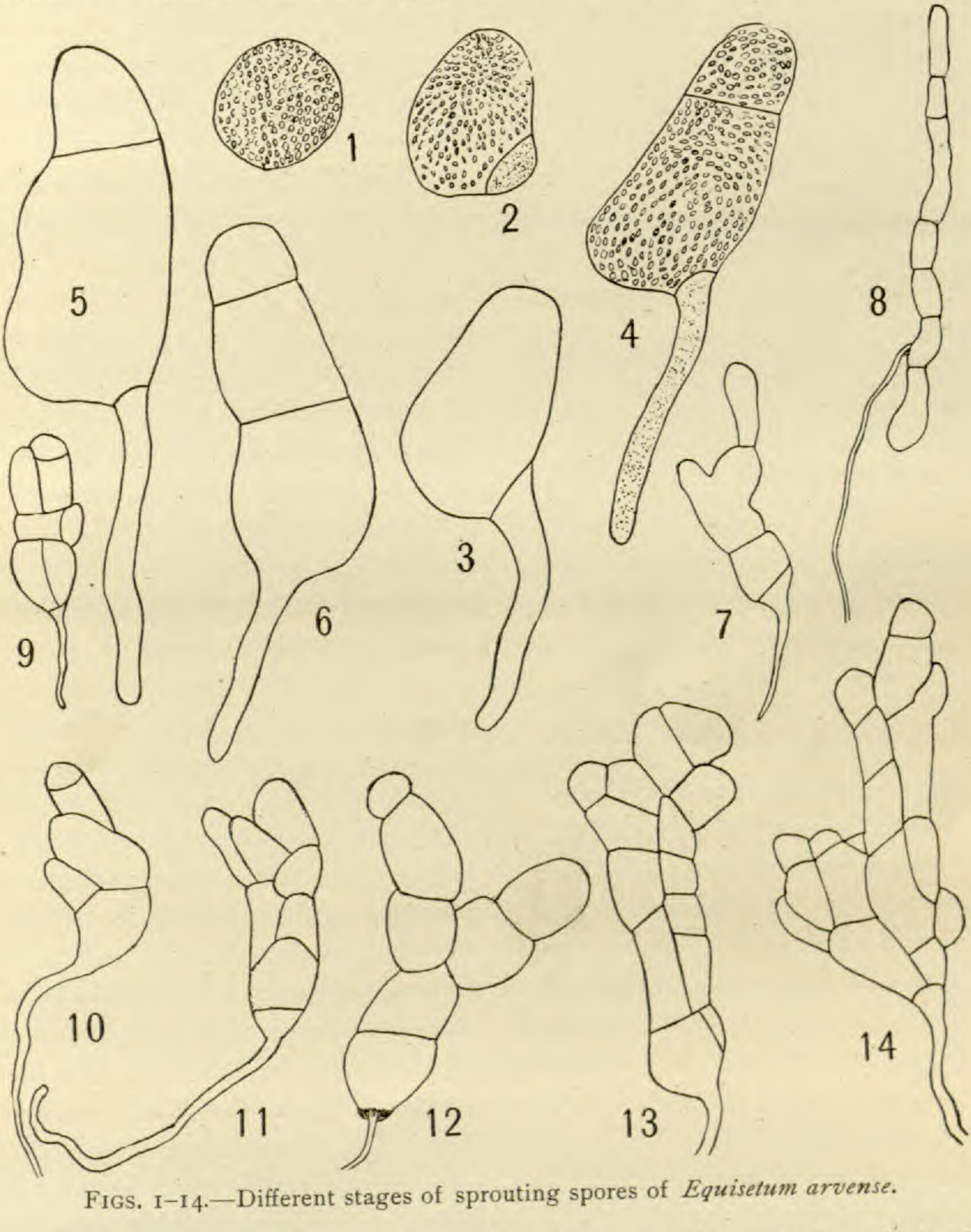
[1] Vergleichende Untersuchungen der höherer Kryptogamen, Leipzig. 1851.

[2] Mosses and Ferns 424.

[3] I have not been able to see the papers of Sadebeck and Buchtien on Equisetum.

MULTISEEDED ACORNS.—Acorns with more than one seed have been described before, but the following striking example may not be unworthy of mention. On the bank of a stream near Baltimore, Md., there is a rock chestnut oak (*Quercus Prinus* L.) that was found to bear acorns which almost invariably contained two or three seeds. One of these acorns is shown sprouting in *fig. 15*. All three young plants are strong and healthy, but one is slightly larger than the others. I have found two young plants coming from an acorn of *Quercus velu-*



FIGS. 1–14.—Different stages of sprouting spores of *Equisetum arvense*.

tina Lam., but other acorns from the same tree showed no such tendency.

Clavaria mucida Pers.—This pretty little species has an interesting habit that I have seen referred to only by Morgan,[4] who describes it as "usually growing on a thin greenish stratum, Chlorococcus." I have often found this plant, and it has always been associated with this alga.[5] It generally grows on dead, soggy wood, but often also on alga-covered soil. The habit is shown in *fig. 16.* Atkinson describes and gives a photograph of *C. mucida,*[6] but does not mention its association with the alga. Neither does Hennings in Engler & Prantl's *Pflanzenfamilien*, who says in reference to its habit, "Auf faulenden Holze, seltener auf Erde."

If the basal part of the fungus and the substratum be cut in paraffin or teased under the microscope, it will be seen that the delicate hyphae ramify from the base of the stalk and pass out in all directions among the alga cells. *Figure 17* illustrates the relation between alga and fungus. The hyphae do not enter the alga and have no haustoria, but show about the same loose relation with the alga as in the case of the lichen, Collema. From its constant occurrence and close association with this alga there seems scarcely a doubt that *Clavaria mucida* is in the initial stages of becoming a basidiomycetous lichen.

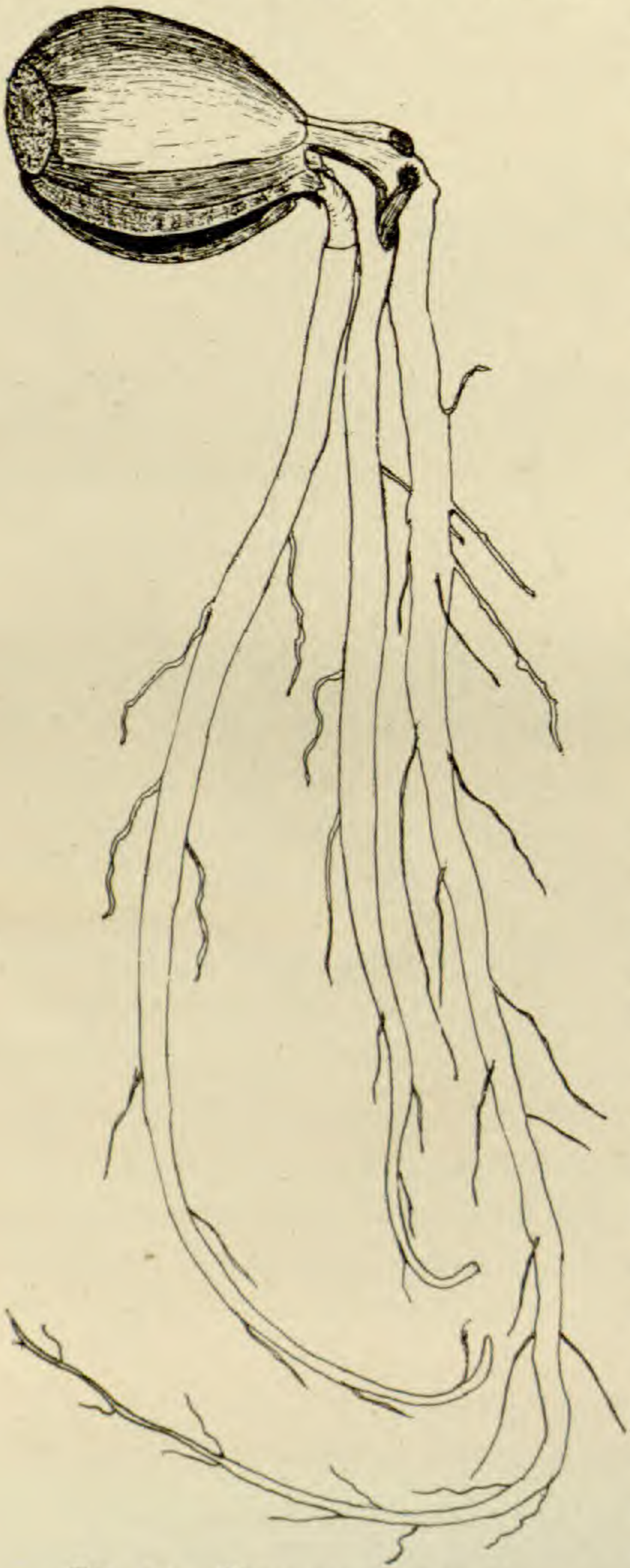


Fig. 15.—Three young plants from one acorn of *Quercus Prinus*. Natural size.

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[4] The mycologic flora of the Miami Valley, Ohio. Jour. Cincinnati Soc. Nat. Hist. **11** : 86–95. *pl. 2.* 1888.

[5] I have not carefully identified the alga, and cannot vouch for its being Chlorococcus.

[6] Mushrooms, edible, poisonous, etc. Ithaca. 1900.

SPORE DISTRIBUTION IN LIVERWORTS.—It has no doubt been noticed by all observers of the liverworts that, while terrestrial species have as a rule (Riccia and Sphaerocarpus are exceptions) their capsules raised on elongated stalks furnished either by sporophyte or gametophyte, those which grow on trees seldom elongate their stalks more than enough to free the capsule from the perianth. This difference is plainly due to the fact that the arboricolous species are sufficiently elevated to allow their spores to be well scattered without any special contrivance. It is interesting to note, however, the behavior of the fertile branches of *Porella platyphylla* Lindb. While the vegetative branches of the liverwort remain closely appressed to the bark of the tree, the fertile shoots bend away some time before the spores are ripe, and often project a centimeter or more from the substratum. This exposes the spores to the free play of the wind and no doubt prevents many of them from being caught by the leaves of the mother plant. This habit seems to show that even in arboreal forms it may be an advantage to have the capsule removed some distance from the substratum. It will be noticed here that Porella resembles the Marchantiaceae in giving over to the gametophyte the duty of lifting the capsules.—W. C. COKER, *University of North Carolina, Chapel Hill.*

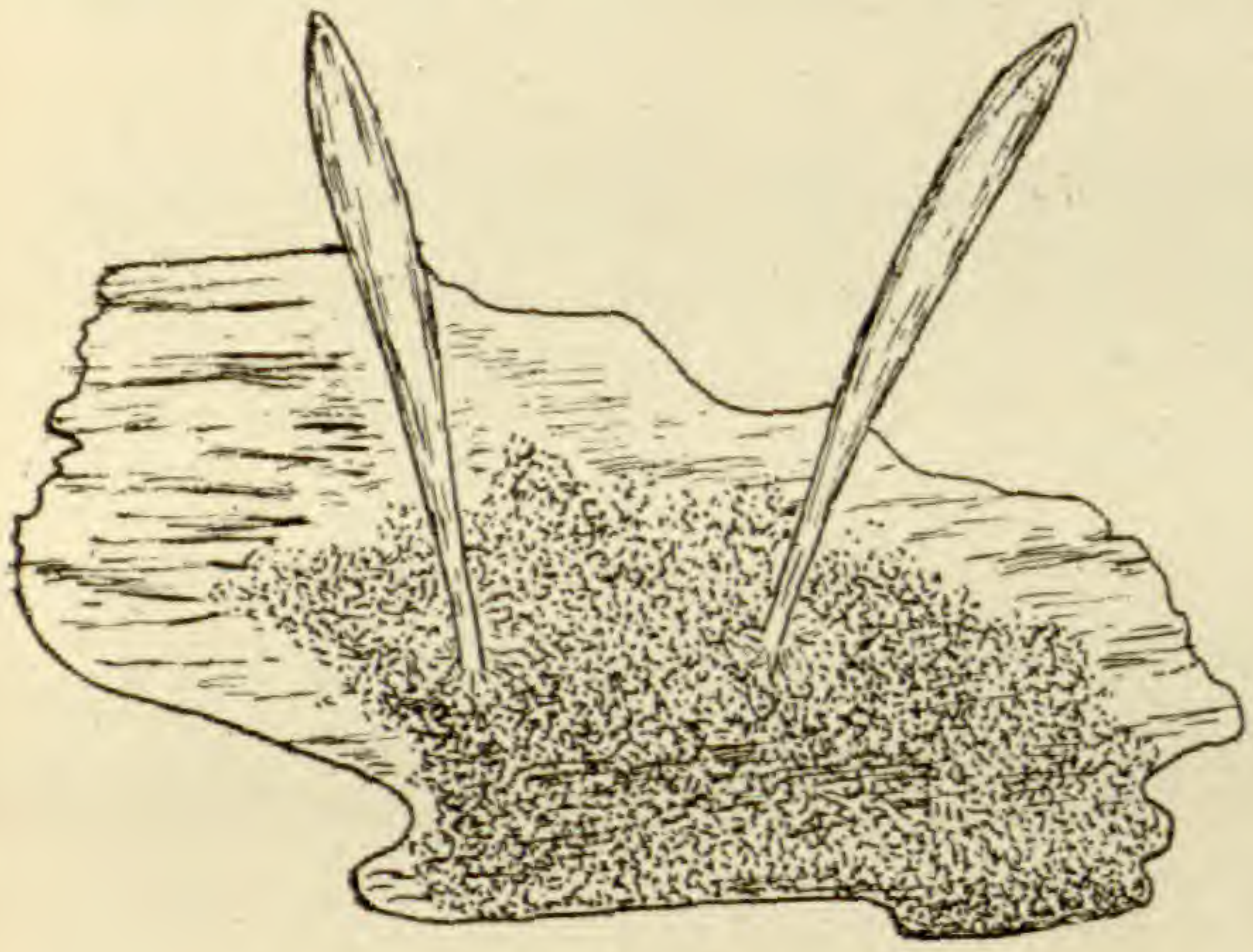

FIG. 16.—*Clavaria mucida*, growing on alga-covered wood. × 5.

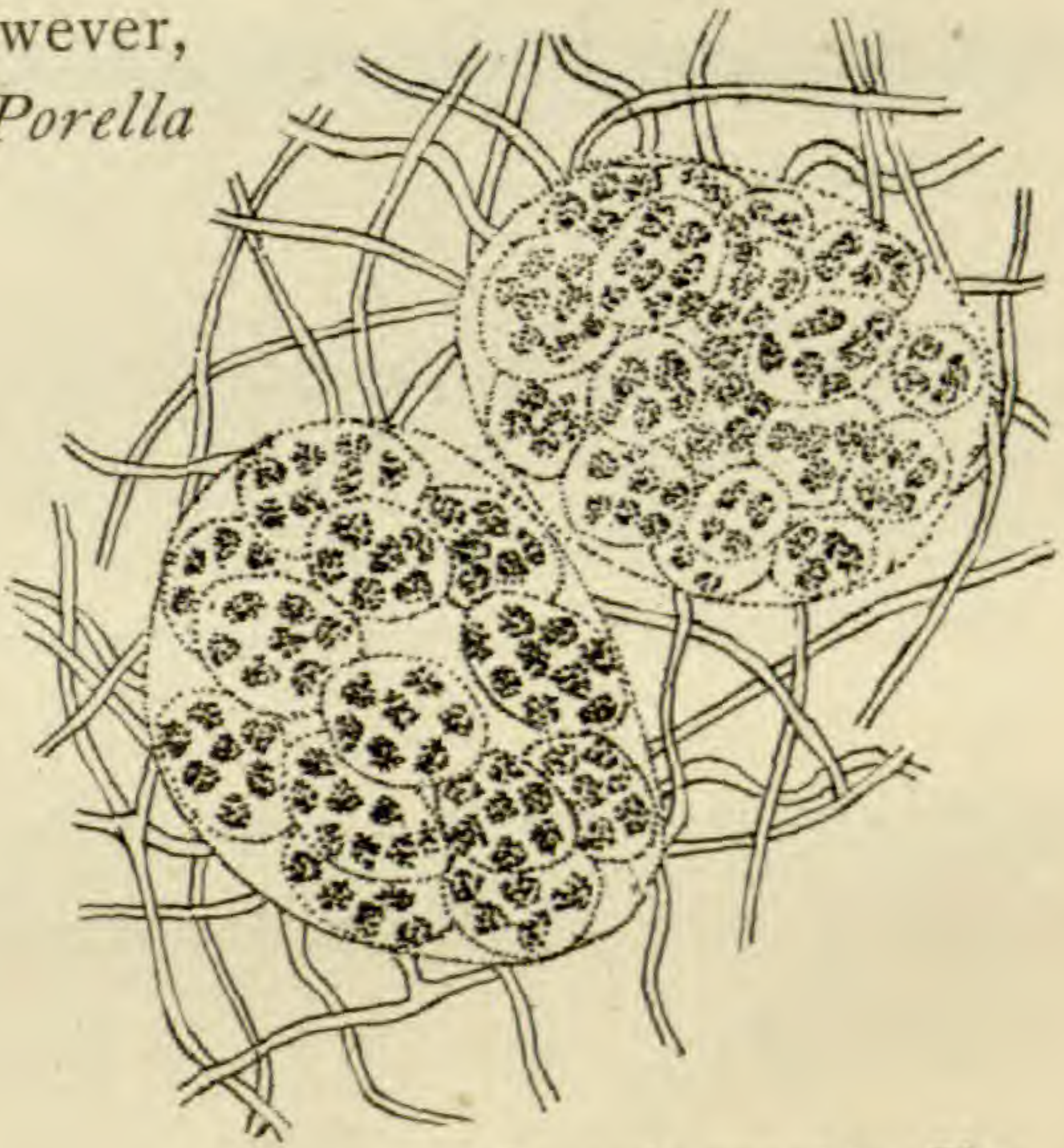

FIG. 17.—*Clavaria mucida*. Hyphae surrounding groups of algae. Highly magnified.

ON THE INTERPRETATION OF THE QUADRIPOLAR SPINDLE IN THE HEPATICAE.

SEVERAL papers have appeared recently bearing on the subject of the quadripolar spindle in the Hepaticae, particularly in connection with the genus Pellia. As the writers do not always seem to have apprehended the views I put forward in 1895 respecting this structure, or the degree of importance I attached to it, I may perhaps be permitted to explain the position I then took up, especially as I have seen no reason seriously to depart from it since that time. The structure in question was first seen by me in *Pallavicinia decipiens*. In this form the deeply lobed character of the spore mother-cell is marked in the highest degree, and I afterwards found the same structure in other Jungermanniales in which the spore mother-cells present similar characters.

Now I expressly regarded the appearance of four centrospheres, whether I was able to distinguish centrosomes (Fossombronia) or not as bodies contained within them, as a phenomenon *to be correlated with the lobed character of the cell taken as a whole*. But I certainly did not regard its persistence throughout the first mitosis as an essential condition. It does not so persist in Fossombronia, or in any other forms but *Pallavicinia decipiens*, and far less regularly in Pellia.[7] In summing up the body of evidence, I said (*l. c.*, p. 510): "The quadripolar spindles of these Hepaticae are really only the result of the special conditions imposed by the configuration of the spore mother-cell."

It is clearly, therefore, a misleading rendering of my position, as adopted in 1895, to suggest that the quadrupling of the primary chromosomes and their simultaneous distribution into four groups to form the daughter-nuclei constitute the "most remarkable features of Farmer's account of the activities of the quadripolar spindle."[8]

From the first, as soon as I began to extend my observations made on *Pallavicinia decipiens* to other species of Hepaticae, I recognized that this formed a very special case, and I correlated it with the unusually deep lobing of the spore mother-cell. I do not myself at all regard the quadrupling of the chromosomes and their simultaneous distribution as the point of central interest. It is even possible that future investigation, with the help of more modern methods, may show that the two divisions were not so much compressed as I thought in 1894, and that a cell plate may after all be formed during the first mitosis.

I may say in passing that I am not surprised that the character of the mitosis in *P. Lyellii*, described by A. C. Moore, should differ from that in *P. decipiens*. He depicts a slightly four-lobed cell, somewhat recalling that of Fossombronia, or Aneura, and I am much interested to see that, as one would have anticipated, the general features of the karyokinesis resemble those presented by the species of the latter genera with which I am familiar. A. C. Moore is right in supposing that I should interpret his *fig. 1* as indicating a less pronounced stage of

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[7] Annals of Botany 9:475. [8] MOORE, A. C., BOT. GAZ. 35: 388. 1903.

what in *P. decipiens* becomes a very well marked four-rayed figure. I observe he does not figure centrosomes or centrospheres, such as are easily seen at the corresponding stage in Aneura or Fossombronia. I fancy these bodies are not always identically developed, perhaps even in closely related forms. I have become convinced that in many liverworts there are often present within the centrosphere, where it can be distinguished, one or more particles that may be looked on as representing a centrosome. The number is, I think, of no great moment. The existence of the *substance*, whether in one or more granules, is the essential point. A nucleolus does not cease to be a nucleolus because several of them may be present in a nucleus which more frequently only contains a single one, and the same argument applies, I think, to the centrosome substance where it can be identified at all.

And as to the quadripolar spindle, whether we choose to restrict the term "spindle" to that portion of the achromatic apparatus that has become continuous from pole to pole, or whether we prefer to extend it so as to include the fibers or substances that are differentiated between the centrospheres and the nucleus during the prophase, irrespective as to whether these retain their positions later or not, is a matter of individual taste. Personally, seeing that they form a stage in the differentiation of the interpolar spindle (with or without fusion in pairs or otherwise), I embrace the latter alternative; and so include the four-rayed figure, independently of its degree of development or permanence as part of the spindle apparatus. I do not think much is gained by limiting the term "spindle" to the later stages, or restricting it purely to bipolar forms.

I should like to take this opportunity of correcting a statement in the memoir on nuclear division to which I have already referred in this note. At the time that paper was written the terms "heterotype" and "homotype" had not acquired that definite meaning that now attaches to them. At the present time I should certainly not regard the second division of the spore mother-cell as in any case in essential characters being really of a heterotype nature. The small size of the objects makes an exact appreciation of their evolution and final form a matter of some difficulty. I have, however, no reason to suppose that those few instances in which a renewed examination of the question has not resulted in definitely settling their homotype character, do really in any way differ in this respect from the many forms in which the nature of the second mitosis can be satisfactorily ascertained.—J. B. FARMER, *London, England.*

CURRENT LITERATURE.

BOOK REVIEWS.

Evolution and adaptation.

UNDER THE ABOVE TITLE the author has published a critical examination of the current ideas regarding the origin of adaptations.[1] His extended work on regeneration showed very plainly the insufficiency of the natural-selection theory as an explanation of the phenomena of that field. The present work is an extension of the same idea to the whole biological field, as the result of a study of the general problem from the same point of view. The appearance of De Vries's *Mutationstheorie*, and the republication of Mendel's experiments in heredity, with the correlated work of the last three years, have greatly strengthened the stand which the author is able to make; for antagonism is shown towards the principle of selection only in so far as it claims to be an active agent in the origin of adaptations. While there may be some doubt, especially in his later writings, as to the extent to which Darwin really meant to imply that the selective agent involved in the survival of adaptations is also directly involved in their origin, it is certain that the idea of the activity of natural selection in the *production* of adaptations has been carried to an absurd extreme by some of Darwin's followers. It is especially against this extreme position that the author takes a stand, for the usefulness or non-usefulness of a structure can have nothing to do with its origin. The selective factor, however, may be of value on one side of the problem of adaptation, "for," to use the author's words, "while we can profitably reject much of the theory of natural selection, and more especially the idea that adaptations have arisen because of their usefulness, yet the fact that living things must be adapted more or less well to their environment in order to remain in existence, may after all account for the widespread *occurrence* of adaptation in animals and plants."

This statement gives the prevailing point of view throughout the book, though the book is by no means merely a development of the above idea. It is especially marked by its judicious treatment of the different phases of the question, and by its careful exposition of opposing views. As examples may be mentioned the exposition of Nägeli's view of a perfecting principle throughout organic nature and of Fleischmann's criticism of the theory of evolution. The numerous original ideas may be represented by the following example chosen at random. In the discussion of the recapitulation theory the author gives the details of his interesting theory of embryonic repetition,

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[1] MORGAN, T. H., Evolution and adaptation. 8vo. pp. xiii+470. New York: Macmillan Co. 1903.

in which he holds that we cannot compare an embryonic characteristic with an *adult* ancestral one, but that embryonic characters only can be compared. "Their resemblances are explained on the assumption that there has been an ancestral adult form having these embryonic stages in its development, and these stages have been handed down to the divergent lines of its descendants."

The wide scope of the work may be indicated best by an enumeration of the titles of the different chapters. There is a chapter on the problem of adaptation, two on the theory of evolution, three are devoted to a criticism of the theories of natural selection and sexual selection, then come successively, the inheritance of acquired characters, continuous and discontinuous variation and heredity, evolution as the result of external and internal factors, the origin of the different kinds of adaptations, tropisms and instincts as adaptations, sex as an adaptation, and finally a summary with general conclusions.

The book is a valuable one both for its clear statement of the problems under discussion and for its many new ideas. It will undoubtedly be read by a wide circle of biologists and others interested in questions of evolution and adaptation.—CHARLES ZELENY.

The cell of the Cyanophyceae.

IN REGARD to the structure of the cell of the Cyanophyceae, observations, interpretations, and theories have long been conflicting and often contradictory, some observers describing a nucleus and chromatophores, and others denying the existence of such structures, while only less difference of opinion has been manifested in regard to other cell contents, the membranes, gelatinous envelopes, and the heterocysts. Kohl has just published a book[2] in which he first gives a critical discussion of previous literature, paying particular attention to the work of Bütschli, Hegler, Palla, Fischer, Zacharias, and Brand. He then describes his own work in great detail, with full illustrations on ten colored lithograph plates. Tolypothrix, Nostoc, and Anabaena are the principal forms studied and nearly all of the figures are from *Tolypothrix lanata* and *Nostoc coeruleum*.

The following topics are treated: central granules, cyanophycin granules, oil, chromatophores, glycogen, membrane and partitions, protoplasmic connections, "Verschlusskörper," vacuoles, chromatic substance, heterocysts, concave cells, central body; with some remarks on the relationship between the Cyanophyceae and bacteria. There is also a valuable table containing the most important tests and staining reactions. Without attempting to separate original views from confirmations and contradictions, the author's results, as gathered from the summary and body of the work, are about as

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[2] KOHL, F. G., Ueber die Organization und die Physiologie der Cyanophyceenzelle und die mitotische Teilung ihres Kernes. 8vo. pp. 240. *pls. 10.* Gustav Fischer, Jena, 1903. *M* 20.

follows. The protoplast of the Cyanophyceae does not differ essentially from that of other plant cells, having a nucleus and peripheral cytoplasm with chromatophores. There is always a single nucleus, organized as an independent organ and consisting of a relatively faintly staining ground mass in which the chromatin is imbedded and a larger or smaller number of "central granules" which are not found outside the nucleus. The nucleus differs from that of the higher plants (1) in the absence of a nuclear membrane,[3] (2) in the absence of nucleoli, and (3) in its form. The cytoplasm contains chromatophores, oil drops, cyanophycin granules, glycogen, and vacuoles. The chromatophores contain chlorophyll, carotin, and phycocyanin. The product of assimilation is glycogen, starch not being demonstrable, and the cyanophycin granules represent reserved albumen. The membranes of the vegetative cells are not cuticularized but consist principally of chitin, while those of the heterocyst are mostly cellulose. There are innumerable small chromatophores. The oft discussed central body is a genuine nucleus. During mitosis a spirem is formed which breaks up into chromosomes, and the various phases bear so striking a resemblance to those of higher plants that the author does not hesitate to designate them as *spirem, equatorial plate, diaster,* and *dispirem.* Threads resembling a spindle are shown in several figures. Protoplasmic connections between vegetative cells have been demonstrated in many cases. Chromatin is said to be a constant constituent of the cells of the bacteria as well of those of the Cyanophyceae, and Kohl believes that the two groups are very intimately related.—C. J. CHAMBERLAIN.

Handbook of systematic botany.

THE SECOND PART of Wettstein's handbook,[4] which has just appeared, deals with bryophytes, pteridophytes, and gymnosperms; the remaining section, which is to treat of angiosperms, will contain the index and will complete the work. The author proposes a complete system of classification, the main features of which were given in the review of the first part.[5] The taxonomic characters of the larger groups, of families, and sometimes of the most important genera, are given and the classification determines the order of treatment. However, the book is of equal interest to the morphologist, for development and embryology are carefully treated and are constantly used to support the author's views of relationships. The illustrations representing the development of organs from the standpoint of comparative morphology are particularly instructive, as is also the plate illustrating the evolution of plants, from the algae to the angiosperms. Considering the able

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[3] No reference is made to the work of Lawson, who, in the BOTANICAL GAZETTE for May 1903, discussed the absence of the nuclear membrane in the Cyanophyceae.

[4] WETTSTEIN, R. v., Handbuch der systematischen Botanik. II. Band, Theil I. 8vo. pp. 160. 1 colored plate, figs. 100. Leipzig and Wien: Franz Deuticke. 1903. *M* 4.

[5] BOT. GAZ. 32:61–62. 1901.

manner in which the morphological part of the work is treated, one is hardly prepared for the statement that in gymnosperms there is no alternation of generations, although traces of alternation are demonstrable, while in angiosperms the reduction of the prothallium has proceeded so far that sure homologies can no longer be shown and the alternation of generations has entirely disappeared. Of particular interest are the introductory pages on the evolutionary composition of groups, the homologies between them, and the causes of the changes in the homologous organs of the cormophytes.

The bryophytes are subdivided, as usual, into Musci and Hepaticae; in the pteridophytes three groups are recognized, the Filicinae, Equisetinae, and Lycopodinae; the gymnosperms are subdivided into six classes, Cycadinae, Bennettitinae, Cordaitieae, Ginkgoanae, Coniferae, and Gnetinae.—C. J. CHAMBERLAIN.

NOTES FOR STUDENTS.

RENAULT[6] concludes from the study of a number of plant sections that vegetative activity was greater in the Carboniferous age than at present. An extraordinary development of vascular and other tissues is recounted and figured.— H. C. COWLES.

ARBER[7] has recorded *Glossopteris Browniana* Brongn. from Sisi in Rhodesia, the containing formation being probably Permo-Carboniferous. A species of Calamites is recorded from the Tuli coalfield; and the Sengwe coalfield in northern Matabeleland yields an undetermined specimen of wood and two stems of the Eu-Sigillarian Rhytidolepis type.—E. W. BERRY.

MOLLIARD finds[8] that in pure cultures of *Ascobolus sp.* perithecia are not developed, although there is a considerable development of the vegetative mycelium. In all cases of fruiting individuals bacteria are present in abundance. He thinks that this is a fact of large significance, though he has no suggestion as to the exact office of the bacteria in this interesting case of symbiosis.—H. C. COWLES.

SEWARD[9] describes a new species of Dictyozamites from a low horizon in the Estuarine series of the Inferior Oolite of Yorkshire. The genus and its distribution in Jurassic times are discussed somewhat fully, and a comparison is instituted between the lower Mesozoic floras of Japan, Bornholm,

[6] RENAULT, B., Sur l'activité végétative aux époques anciennes. Compt. Rend. **136**: 401–403. 1903.

[7] ARBER, E. A. N., Notes on some fossil plants collected by Mr. Molyneux in Rhodesia. Quart. Jour. Geol. Soc. Lond. **59**: 288–290. 1903.

[8] MOLLIARD, Rôle des bactéries dans la production des périthèces des Ascobolus. Compt. Rend. **136**: 899–901. 1903.

[9] SEWARD, A. C., On the occurrence of Dictyozamites in England, with remarks on European and eastern Mesozoic floras. Quart. Jour. Geol. Soc. Lond. **59**: 217–232. *pl. 15.* 1903.

India, and England, with the result that they show only minor differences facts contrary to the usually accepted view. The paper, which is an important one, concludes with a complete bibliography.—E. W. BERRY.

R. G. LEAVITT[10] has accumulated some interesting data in reference to what he calls reversionary stages in *Drosera intermedia*, stages that he has experimentally induced. These data support the general statement "(1) that reversions, in either an ascending or a descending direction, are sometimes occasioned in plants by a deficiency of the food materials supplied to developing parts; and (2) that reversions in either direction are sometimes occasioned by a superabundant food supply in developing parts."—J. M. C.

BALL[11] has recently reinvestigated the influence of strains upon the formation of mechanical tissue. His results do not agree with those of Hegler on the same subject, for by a gradual increase in the pull exerted upon young stems Ball was able to produce neither an increase in the ability to resist mechanical pulling nor any thickening of the tissues. He substantiates the results obtained by Wortmann and by Elfving that when a stem is inhibited by force from bending geotropically there arises a marked one-sided development of bast fibers and collenchyma on the upper side; and also when an organ is prevented by force from bending phototropically there is a notable increase in the tissues on the side toward which it would bend. An increased thickening was also obtained on the convex side of stems bent over mechanically with gravity neutralized by the clinostat.— W. B. MACCALLUM.

THE DEHISCENCE of sporangia[12] of gymnosperms is definitely related to their form and position, and favors the distribution of the spores. The nearly related Picea and Abies differ in the dehiscence of their sporangia, the dehiscence in Picea being longitudinal while in Abies it is transverse. The upright staminate strobilus of Picea requires a longitudinal dehiscence for a thorough discharge of the pollen, while a transverse dehiscence is more effective in discharging pollen from the drooping strobilus of Abies. The peculiar dehiscence in Taxus is adapted to a rapid discharge of the pollen. In Ginkgo the lines of dehiscence of the two sporangia face each other and lie at such an angle that the pollen is easily shed. Ginkgo is the only known gymnosperm which has an endothecium. The Cupressineae are not considered, because their small, rather spherical sporangia are not so definitely oriented as in the other groups.—C. J. CHAMBERLAIN.

NOEL BERNARD has added further data[13] in the line of his interesting

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[10] LEAVITT, R. G., Reversionary stages in *Drosera intermedia*. Rhodora **5**: 265–272. 1903.

[11] BALL, O. M., Der Einfluss von Zug auf die Ausbildung von Festigungsgewebe. Jahrb. Wiss. Bot. **39**: 305–341. *pls. 6–7*. 1903.

[12] GOEBEL, K., Morphologische und biologische Bemerkungen: 13. Ueber die Pollenentleerung bei einigen Gymnospermen. Flora **91**: 237–263. *figs. 19*. 1902.

[13] BERNARD, NOEL, Conditions physiques de la tubérisation chez les végétaux. Compt. Rend. **135**: 706–708. 1902.

tuberization studies.[14] E. Laurent had shown that buds from aerial stems of the potato may develop into tubers, when placed in a sufficiently concentrated solution of saccharose, even when the latter is thoroughly sterilized; which seemed to call in question Bernard's theory that tuberization is due to an infection by parasitic fungi. Bernard confirms Laurent's results and extends them considerably, showing that a number of solutions produce like results. In these cases the chemical nature of the solution is shown to be of but little moment as compared with osmotic pressure. Bernard therefore enlarges his theory as follows: the state of hypertrophy which we call tuberization may be induced by various agents, which bring the cells into contact with substances of relatively high osmotic pressure. Among these substances in nature the products of fungus activity are perhaps the most important.—H. C. COWLES.

IN HIS second paper on the solenostelic ferns Gwynne-Vaughan [15] extends his observations to a large number of genera which he treats in a comparative way. His studies have led him to abandon Van Tieghem's term polystelic, for he finds that the meristeles are in all cases segments of a vascular ring, the lacunae in which are caused by the exit of leaf traces. The term solenostelic is applied to those cases where the foliar lacunae do not overlap, and this condition is derived from one in which the stele is solid. Evidence is adduced to show that the intrastelar parenchyma is merely cortex which has intruded through the leaf-gaps. Thus Gwynne-Vaughan's view of the fern stele coincides with that already advanced by Jeffrey, although rather strangely no mention is made of this fact, and is opposed to that of many English writers. The internal vascular strands found in Cyatheaceae are considered to be derived from elaboration of a local thickening of the xylem ring at the margin of the leaf gaps. The present system of classification is considered to receive support from the anatomical data presented, since nearly all the genera regarded as primitive by Prantl have a primitive vascular structure.—M. A. CHRYSLER.

THE SPERMATOGENESIS of hybrid peas [16] appears as the second paper in Dr. Cannon's studies in plant hybrids. Two hybrid peas were used for the present investigation, one a hybrid between the pure races Fillbasket and Debarbieux, and the other between Express and Serpette. Both hybrids are fertile and show variation according to the law of Mendel. Spermatogenesis was studied both in the pure races and in the hybrids. In the cells of the gametophyte the number of chromosomes is seven in all the pure forms and

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[14] See BOT. GAZ. 33: 75. 1902.

[15] GWYNNE-VAUGHAN, D. T., Observations on the anatomy of solenostelic ferns. II. Ann. Botany 17: 690–742. 1903.

[16] CANNON, W. A., Studies in plant hybrids: the spermatogenesis of hybrid peas. Bull. Torr. Bot. Club 30: 519–543. *pls. 17–19.* 1903. For review of the first paper see BOT. GAZ. 35: 445. 1903.

also in both hybrids. The number of chromosomes in the sporophytes of all the forms is fourteen. In the sporogenous division immediately preceding the formation of the mother-cells in both hybrids and in the pure form Fill-basket, the chromosomes were associated in pairs which may be related to the chromatin rings of the succeeding heterotypic division. Spermatogenesis in the hybrids proceeds just as in the pure races, and no abnormal mitoses were observed; consequently, abnormalities and irregularities of nuclear divisions do not form the basis for the variations of these hybrids. It is suggested that a thorough study of the sporogenous divisions preceding the heterotypic division may afford some explanation of variation.—C. J. CHAMBERLAIN.

AN INTERESTING account of the reproductive processes in Araiospora is presented by King.[17] Zoospores are formed through cleavage with the aid of vacuoles, and the outer plasma membrane is the last connecting film ruptured. The oogonium contains from 35 to 55 nuclei, which pass to the periphery simultaneously with the formation and fusion of patches of fine meshed cytoplasm in the center of the ooplasm. There is probably a general mitosis before the periplasm is differentiated from the ooplasm. A receptive papilla from the ooplasm pierces the antheridium and establishes the canal for the entrance of the sperm nucleus. There is no antheridial tube, the wall of the canal being of oogonial origin. This is a very interesting point, in which Araiospora appears to differ from all other oosporic Phycomycetes. The periplasm divides by anticlinal walls into hexagonal cells which invest the egg. The egg is uninucleate and a single sperm nucleus enters the ooplasm. These gamete nuclei approach in the central region of denser ooplasm and extend toward one another, later rounding off and lying side by side. They were not observed in process of fusion and this event, if it occurs, must be greatly delayed, for the pair may be found in the oldest oospores. The development and structure of the sexual organs indicates a closer relationship of Araiospora to the Peronsporales than to the Saprolegniales.—B. M. DAVIS.

THE REDUCTION of chromosomes, development of the embryo sac, and fertilization in *Paris quadrifolia* and *Trillium grandiflorum* have been investigated by Ernst.[18] The number of chromosomes in Paris is 24 in the sporophyte and 12 in the gametophytes, while in Trillium the numbers are 12 and 6 respectively. Since the two genera are so closely related, it is suggested that the double number of chromosomes in Paris may be due to an extra splitting of the chromatin thread. At the equatorial plate stage of the heterotypic division a second longitudinal splitting of the chromosomes is already

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[17] KING, C. A., Observations on the cytology of *Araiospora pulchra* Thaxter. Proc. Boston Soc. Nat. Hist. 31: 211. 1903.

[18] ERNST, A., Chromosomenreduction, Entwickelung des Embryosackes und Befruchtung bei *Paris quadrifolia* L. und *Trillium grandiflorum* Salisb. Flora 91: 1–46. *pls. 1–6.* 1902.

evident, so that there can be no reduction division in Weissmann's sense. The statement that Trillium (with Naias) has the smallest number of chromosomes yet known in phanerogams reveals another oversight of American literature,[19] since the numbers in Canna are 6 in sporophyte and 3 in the gametophyte. In a few cases the embryo sac of Trillium showed ten nuclei instead of eight, the two extra nuclei having arisen through fragmentation of two of the eight nuclei.

Double fertilization occurs in both genera. In the union of the sperm nucleus with that of the egg, the fusion is complete, a resting nucleus being formed. The second sperm nucleus and also the two polar nuclei pass into the spirem condition before uniting, so that there can be no real fusion of chromatin in the formation of the endosperm nucleus. How long the chromatin of these three nuclei remains independent was not determined.—C. J. CHAMBERLAIN.

ALL ECOLOGISTS are acquainted with Bonnier's great contributions to experimental anatomy, especially in his studies of alpine plants. He has recently[20] presented a second communication dealing with his Mediterranean cultures, which were established near Toulon in 1898. Fifty perennial species were selected, each plant being split in two, so that cultures of the same individual were conducted at Toulon and Fontainebleau. The plants used were obtained at Fontainebleau, while the soil for the parallel cultures was taken from Toulon. The external characters of the Toulon individuals were noted in the first communication;[21] these characters have been only accentuated in the succeeding seasons, and the experimental plants have become quite like plants of the same species native about Toulon. The early secondary wood at Toulon contains vessels of larger caliber than at Paris, while on the other hand the later wood is more fibrous at the former place. Again, in autumn the Toulon wood contains vessels of large caliber. Bonnier thinks that the large early and late vessels at Toulon are to be correlated with the two rainy periods, while the fibrous wood of summer is correlated with a dry period. Paris, on the other hand, has a more uniform climate, which is moister in summer than that of Toulon. The annual ring is thicker at Toulon. Many differences in leaf structure are also noted; for the most part the Toulon leaf characters are the more xerophytic. The immense importance of this type of study is obvious; it escapes on the one hand the errors arising from hasty field generalizations, and on the other hand it is free from the untenable inferences often drawn from experimental

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[19] BOT. GAZ. **30**: 25–47. *pls. 6–7.* 1900. See review in Jour. Appl. Micros. **3**: 1064–1065. 1900.

[20] BONNIER, GASTON, Cultures expérimentales dans la région méditerranéenne pour le modifications de la structure anatomique. Compt. Rend. **135**: 1285–1289. 1902.

[21] Compt. Rend. **129**: 1207–1213. 1899.

work conducted wholly in the artificial conditions of the laboratory or greenhouse.—H. C. COWLES.

IKENO has published his full account of spermatogenesis in *Marchantia polymorpha*,[22] following his preliminary announcement in the *Comptes Rendus*. He finds a centrosome beside each nucleus previous to the mitoses in the spermatogenous tissue. The centrosome divides, and its products, passing to opposite sides of the nucleus, become the poles of the spindle. He gives evidence that the daughter centrosomes sometimes divide again when at the poles of the spindle in anaphase. The centrosome cannot be found at the side of the daughter nucleus after the mitosis is completed, but it appears when the nucleus is ready for the next division. Ikeno believes that the centrosome is formed within the interior of each nucleus as a deeply staining body among the linin threads. This body moves to the nuclear membrane and is thrust from the nucleus. Outside of the nucleus it becomes the centrosome, functioning in the mitosis as described above. This account of the intranuclear origin of a centrosome is extraordinary. Intranuclear centrosomes have been reported in several animal forms, but they do not leave the nucleus in the manner described by Ikeno.

After the final mitoses in the spermatogenous tissue the centrosomes remain, to become the blepharoplasts of the sperms. Each blepharoplast passes to the plasma membrane of its sperm cell and develops two cilia. There is formed at this time another deeply staining body in the cytoplasm considered by Ikeno a *Nebenkörper*. The nucleus begins to elongate, this accessory body takes a position between it and the blepharoplast, and in this manner the much attenuated sperm is organized from the mother-cell.

Ikeno reasserts the blepharoplast to be the homologue of a centrosome, a position which he and Hirasé held in Cycas and Ginkgo respectively. In this they have the support of Belajeff's studies on Marsilia. Of an opposite view are Webber, Strasburger, and Shaw, who hold that there is no genetic relationship between the blepharoplast and the centrosome. The opinions of these authors cannot be discussed in a brief review, but the problem rests on disputed questions of fact as to the origin and behavior of blepharoplasts in all of the great groups of plants, from the processes of zoospore formation to the complications of spermatogenesis in the gymnosperms. There is no agreement on the events in any one type; which is eloquent of the desirability of cell studies of this character.—B. M. DAVIS.

ITEMS OF TAXONOMIC INTEREST are as follows: THEO. HOLM (Am. Jour. Sci. IV. **16**:369–376. 1903), has made a morphological and anatomical study of *Hypericum virginicum*, often called Elodea, and has reached the conclusion that it represents the obscure but valid genus Triadenum of Rafinesque. Accordingly he writes the name *Triadenum virginicum* (L.) Raf.—THEO.

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[22] IKENO, S., Die Spermatogenèse von *Marchantia polymorpha*. Beihefte Bot. Centralbl. **15**:65–88. *pl. 1*. 1903.

HOLM (*idem* 445–464), in his 20th "Studies in the Cyperaceae" has presented a natural classification of *Vigneae* and *Carices genuinae*, illustrating it by numerous species from various parts of the world which have been studied by the author, and were represented by sufficient material. In the *Vigneae* 15 sections are named, all excepting one being new; and in the *Carices genuinae* 24 sections are recognized, 11 of which are new. The classification follows the principles suggested by Drejer.—A. A. EATON (Fern Bull. **12**: 108–114. 1903) has described three new varieties of *Equisetum hiemale*.—H. DE BOISSIEU (Bull. Herb. Boiss. II. **3**: 837–856. 1903), in a paper presenting the Umbelliferae of China, describes *Netopterygium* (Symrnieae) as a new genus with two species, and also new species under Pimpinella, Seseli, Ligusticum, Selinum, Pleurospermum, Angelica, Peucedanum, and Heracleum.—M. L. FERNALD (Rhodora **5**: 247–251. 1903) has described a new Kobresia from Maine.—A. A. EATON (*idem* 277–280) has described three new varieties of Isoetes from Massachusetts.—R. MAIRE and P. A. SACCARDO (Ann. Mycologici **1**: 417–419. 1903) have described a new genus (*Didymascella*) of Phacidiaceae.—GEO. V. NASH (Torreya **3**: 101–102. 1903) has described a new Aletris from Florida.—G. N. BEST (Bull. Torr. Bot. Club **30**: 463–482. *pls. 15–16.* 1903) has published a revision of the North American species of Leskea, recognizing 15 species and varieties, four of which are new.—MARCUS E. JONES (Contrib. Western Bot. 11) has described a new species of Leucothoe, has discussed western Nyctaginaceae, describing a number of new species under Eriogonum, and has presented his views concerning several western Chenopodiaceae, describing new species under Atriplex.—ALICE EASTWOOD (Bull. Torr. Bot. Club **30**: 483–502. 1903), in a paper entitled "New species of western plants," has described new species under Zygadenus, Allium, Fritillaria, Iris, Chorizanthe, Spraguea, Silene, Eschscholtzia (2), Arabis, Cleomella, Wislizenia, Lathyrus, Clarkia, Scutellaria (3), Fraxinus, Convolvulus, Sphacele, Monardella, Lappula, Symphoricarpos (4), Echinocystis, Nemacladus, Agoseris, and Crepis.—O. VON SEEMEN (*idem* 634–636) has described three new species of Salix from California and Nevada.—J. M. C.

RECENT CONTRIBUTIONS CONCERNING MYCORHIZA. Fungi have long been associated with certain liverworts, but NĚMEC[23] was among the first to make a careful study of the subject; it was his belief that they characterize the Jungermanniaceae rather generally, but that they are rare or absent in the Marchantiaceae. STAHL,[24] supposing this distinction to be true, applied his mycorhiza theory to the liverworts, considering the Jungermanniaceae to have weak transpiration, abundance of sugar, and mycorhiza, while the Marchantiaceae have strong transpiration, abundance of starch, and no mycorhiza.

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[23] Ber. Deutsch. Bot. Gessells. **17**: 311–317. 1899.

[24] Jahrb. Wiss. Bot. **34**: 539–668. 1900. See BOT. GAZ. **30**: 68. 1900.

GOLENKIN, however, finds[25] that several of the Marchantiaceae, such as Marchantia, Preissia, Fegatella, have typical mycorhiza, although many species appear to be autotrophic. The fungus cells are localized, and in some cases are red in color. Starch is much more abundant in the cells that are free from fungi. BEAUVERIE[26] has made an experimental study of the mycorhiza of *Fegatella conica*, which he thinks to be of benefit to the host. Cultures in which the fungus (a Fusarium) occurs are more luxuriant than sterile cultures. Photosynthesis is weak, and the fungus is believed to obtain some of the necessary carbon. CAVERS[27] has made yet further studies of liverwort mycorhiza, but he adds little to our knowledge.

MÖLLER has been studying[28] the mycorhiza of pine roots, and obtains some results which differ from those of Frank. The well known ectotropic mycorhiza develops in connection with the roots of *Pinus sylvestris* in sand but not in humus, whereas Frank supposed the reverse to be the case. Where the fungus occurs, many of the roots, especially the main roots, are free from it; these roots are abundantly provided with hairs, which presumably have an absorptive function. Pines without mycorhiza are said to thrive quite well in humus soils. In raw humus soils a hitherto undescribed endotropic mycorhiza is found. Möller doubts if we yet know the physiological significance of mycorhiza; especially does he doubt whether it is proven that root fungi increase the supply of available nitrogen. TUBEUF,[29] on the other hand, though differing from Stahl, adheres in general to the prevalent mycorhiza theory. He thinks the chief value of the fungus to the host is in making nitrogen more available; atmospheric nitrogen in endotropic forms, humus nitrogen in ectotropic. Seven types of mycotrophic plants are recognized: (1) plants with occasional, and presumably non-essential, endotropic mycorhiza; (2) plants with strong endotropic mycorhiza, and with fully developed photosynthesis, transpiration, and absorption; (3) as in 2, except that the above-named functions are poorly developed (as Neottia), hence the fungi are probably of more consequence; (4) plants with occasional, and presumably non-essential ectotropic mycorhiza; (5) plants (as Pinus) with abundance of ectotropic mycorhiza and also of root hairs; (6) plants (Mono-

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[25] GOLENKIN, M., Die Mycorhiza-ähnlichen Bildungen der Marchantiaceen. Flora **90**: 209–220. 1902.

[26] BEAUVERIE, J., Étude d'une hépatique a thalle habité par un champignon filamenteux. Compt. Rend. **134**: 616–618. 1902.

[27] CAVERS, F., On saprophytism and mycorhiza in Hepaticae. The New Phytologist **2**: 30–35. 1903.

[28] MÖLLER, A., Ueber die Wurzelbildung der ein- und zweijährigen Kiefer im märkischen Sandboden. Zeits. Forst- und Jagdwesen 1902–1903 (Bot. Centralbl. **89**: 583, **93**: 257; Bot. Zeit. **61**: 329).

[29] TUBEUF, C. VON, Beiträge zur Mycorhizafrage. Naturw. Zeits. Land- und Forstwirthschaft **1**: 67 ff., 284 ff., 1903 (Bot. Cent. **93**: 430, 520).

tropa) with ectotropic mycorhiza and no root hairs, all food-stuffs being supplied by the fungus; (7) plants with ectotropic and endotropic mycorhiza. Tubeuf discounts some of Möller's work by showing that *Pinus sylvestris* has luxuriant ectotropic mycorhiza in moors; *P. cembra* has similar root fungi in alpine humus.

Cytological mycorhiza studies have been made by SHIBATA[30] and HILTNER.[31] Shibata has confirmed the general results of W. MAGNUS,[32] and has gone into greater detail along similar lines. The infested cells of Podocarpus show enlarged and amoeboid nuclei, which divide amitotically; upon the death or resorption of the fungus ordinary mitosis occurs again, though without normal spindles and nuclear plates, the nucleus, too, soon disorganizing. Shibata agrees with Frank and Magnus that the fungus is digested by the host, in a manner analogous to the digestion of insects by carnivorous plants. He regards amitosis as another type of cell activity, not necessarily pathological. Hiltner's results agree with the above. He thinks that only certain portions of the fungus—Janse's sporangioles—are digested by the host. He regards nitrogen enrichment as proven in the case of Podocarpus.

NEGER[33] combats the well-known view of Stahl that there is a struggle for food salts in the soil between root hairs and fungi, in which the latter are most successful. Stahl supported his contention by showing that autotrophic plants grow better in sterilized soil than in soil permeated by fungi. Neger claims that this is due to the greater abundance of foodstuffs in sterilized soil. *Lepidium sativum* and *Triticum vulgare* were grown in (*a*) non-sterilized forest mold, in (*b*) similar but sterilized soil, and in (*c*) a mixture of *a* and *b*. The plants grown in *a* were far less luxuriant than in *b* or in *c*, though the roots were equally developed in all cultures. The equal development of cultures *b* and *c* shows that the presence of fungi scarcely restricts the activity of root hairs, as Stahl supposed.—H. C. COWLES.

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[30] SHIBATA, K., Cytologische Studien über die endotrophen Mykorhizen. Jahrb. Wiss. Bot. **37**: 643–684. 1902.

[31] HILTNER, A., Beiträge zur Mycorhizafrage. Naturw. Zeits. Land- und Forstwirthschaft **1**: 1903 (Bot. Centralbl. **92**: 250).

[32] See BOT. GAZ. **32**: 377. 1901.

[33] NEGER, F. W., Ein Beitrag zur Mycorhizafrage: Der Kampf um die Nährsalze. Naturw. Zeits. Land- und Forstwirthschaft **1**: 372 ff. 1903 (Bot. Centralbl. **93**: 542).

NEWS.

PROFESSOR JOHN M. COULTER, after an absence of nine months, most of which was spent in Europe, has returned to his duties at the University of Chicago.

CHARLES L. POLLARD has left the U. S. National Museum to become a member of the scientific staff of the G. & C. Merriam Company, a publishing house of Springfield, Mass. His relation to *The Plant World* remains unchanged.

NATURE for November 5 gives an account of the eighty-sixth meeting of the Swiss Association for the Natural Sciences at Locarno. Mr. E. Fischer of Berne read an interesting paper on the origin of species, especially as illustrated by the Uredineae.

WITH REGRET we announce that the December number of the *Journal of Applied Microscopy and Laboratory Methods*, established by the Bausch & Lomb Optical Co. in January 1898, will terminate its existence. The *Journal* has been of much service to biologists in disseminating information as to methods and equipment of laboratories.

AMONG THE papers of botanical interest at the Cassel meeting of the German Association for the Advancement of Science and Medicine may be mentioned Professor Drude's account of his experiments on mutation, in which he gives results differing from those of DeVries. He thinks there is no sharp line between variation and mutation.

WITH ITS SECOND VOLUME the *Forest Quarterly* becomes an independent journal, being published privately under the direction of a board of editors, with Professor Fernow as editor-in-chief. The board well represents the profession of forestry and includes men from the various centers of professional forestry work. The journal deserves the support of all those interested in this great and growing subject.

DR. J. N. ROSE, of the National Museum, returned last fall from his fourth journey to Mexico, having made an unusually large collection of plants, comprising over 1500 distinct numbers. He also sent to Washington more than 200 living plants, mostly Crassulaceae, probably representing the richest collection of such plants ever sent from Mexico. The type locality of nearly every species of north Mexico was visited, and living material was obtained from most of them.

THE new way of extracting turpentine, introduced two years ago by Dr. Charles H. Herty, working under the direction of the Bureau of Forestry, is resulting in a complete change of methods by turpentine operators all over the south. The economic saving of this new method is enormous. Not only is there a great increase in the amount of turpentine produced, but it is an important factor in saving the pine forests of the south. Trees from which turpentine has been extracted by the old method soon die from the wounds inflicted on them. The new system, on the other hand, is not fatal to the tree, and does very little damage to the timber.

THE LAST ISSUE of *Science* for 1903 publishes the list of grants made by the Carnegie Institution. Those for botany are as follows: W. A. CANNON, New York Botanical Garden, for investigation of plant hybrids, $500.—H. S. CONARD, University of Pennsylvania, for study of types of water-lilies in European herbaria, $300.—DESERT BOTANICAL LABORATORY (F. V. Coville and D. T. MacDougal, directors), $8,000.—E. W. OLIVE, Crawfordsville, Ind., researches on the cytological relations of the Amoebae, Acrasieae, and Myxomycetes, $1,000. — JANET PERKINS, working at the Royal Botanical Gardens, Berlin, for preliminary studies on the Philippine flora, $1900.—G. R. WIELAND, Yale University, for continuation of his researches on living and fossil cycads, $1,500.

TESTS to determine the strength of the principal American timbers used for construction purposes are now in progress at Washington, at Yale University, at Purdue University, and at the University of California. The Bureau of Forestry, under whose direction these tests are made, plans to make tables of the strength of different American woods in cross bending and breaking, compression with and against the grain, and shearing. No complete and satisfactory series of tests on large sticks of timber has ever been made in this country. Lumber manufacturers in the south and the Pacific coast states are especially interested in this work, and have contributed gratis much of the material. The chief timbers now being tested are the southern pines and the red fir of the Pacific coast. In the laboratories at Washington tests are now in progress on loblolly pine sticks 17 feet long and 8 by 14, 8 by 8, and 8 by 4 inches. Special attention is given to the effects of moisture on the strength of wood. The timbers tested are of the usual grades offered in the market and are not selected pieces. At the laboratory of the Yale Forest School small selected pieces of longleaf pine, without knots or other defects, are being tested as to the ultimate strength of the fibers. At Purdue University tests are being made with hardwood timbers.

IN THE early morning of December 11, Marsh Hall, occupied by the Yale Forest School, was seriously damaged by fire, which started in the basement and involved the entire four stories of the building. The damage was chiefly to the furnishings and the interior finishing of the building, though the various collections and the laboratory equipment of the Forest School also suffered. Fortunately the library, the equipment of the botanical laboratory, and the herbarium were but slightly damaged. A large collection of South American woods and a collection of west American conifers, all of which were in large blocks, were destroyed. The specimens of domestic woods were discolored by smoke but not otherwise injured. Many tools and much apparatus, the greater part of which can be replaced on short notice, were totally destroyed. The technological laboratory was badly injured, but much of the machinery can be repaired. One of the heaviest losses was the complete data, covering six months' work by an expert and two assistants in the technological laboratory, where in cooperation with the Bureau of Forestry a study is being made on moisture and volatile oil in relation to the strength of timber. A large force of men is already at work in repairing the interior of the building and all classes will be resumed without interruption at the opening of the term on January 9.

THE NEW YORK BOTANICAL GARDEN has secured a lease of the group of buildings at the Cinchona Botanical Garden belonging to the Colonial Government of Jamaica and will maintain them as a botanical laboratory under an agreement with the Colonial Government, and with the cooperation of the Department of Public Gardens and Plantations of Jamaica. Sufficient land for experimental purposes and for a nursery is included in the leasehold privileges. The buildings include a residence known as Bellevue House, three laboratories, two ranges of glass, and small buildings suitable for lodging. Investigators are there offered the use of tables in the laboratory buildings; lodging in Bellevue House or in one of the other buildings at Cinchona; the use of land for experimental purposes; privileges to study the plantations at Cinchona, and also those at Hope and Castleton Gardens; privilege to consult the botanical library of the Department of Public Gardens and Plantations at Hope Gardens, and to take books therefrom to Cinchona under such conditions as may be imposed by the Director of Public Gardens and Plantations; easy access to an immense number of indigenous species in the primitive forests adjacent to Cinchona.

All persons who may apply for permission to study at Cinchona must submit such evidence as the Director-in-Chief of the New York Botanical Garden may require that they are competent to pursue investigations to advantage. While in residence at Cinchona they will be under the supervision of the Hon. William Fawcett, Director of Public Gardens and Plantations, to whose interest and advice the establishment of this American tropical laboratory is largely due. A laboratory fee, payable to the New York Botanical Garden, will be required of persons granted the above privileges.

Upon approval by the Scientific Directors of the New York Botanical Garden, any other institution, society, or individual, may be assigned the use of a table at Cinchona by the payment of $100 annually, which will entitle them to nominate investigators without the payment of fees; but not more than one person may be granted the use of any such table at the same time. The necessary expenses for a month's residence at Cinchona, including traveling expenses to and from ports on the Atlantic seaboard of the United States, are from $140 to $200; for two months' residence $160 to $230.

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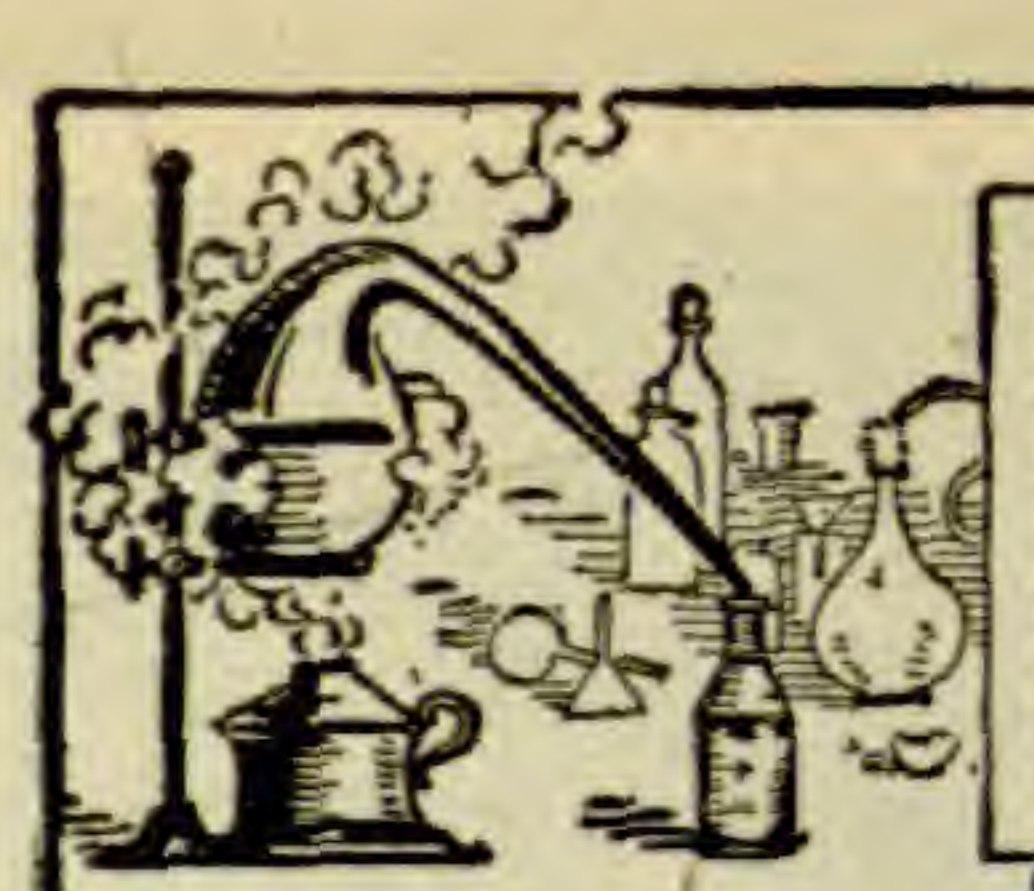

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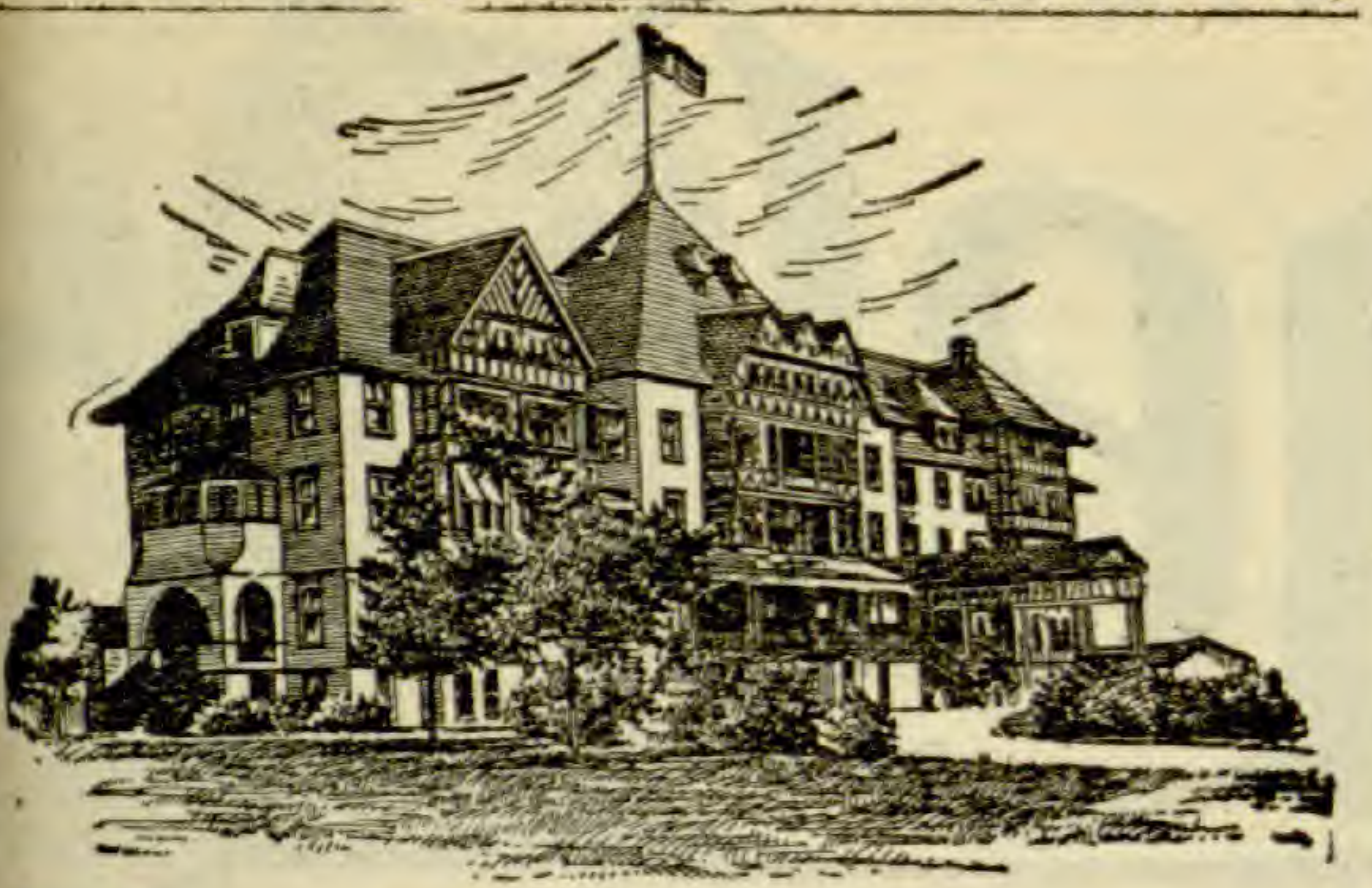

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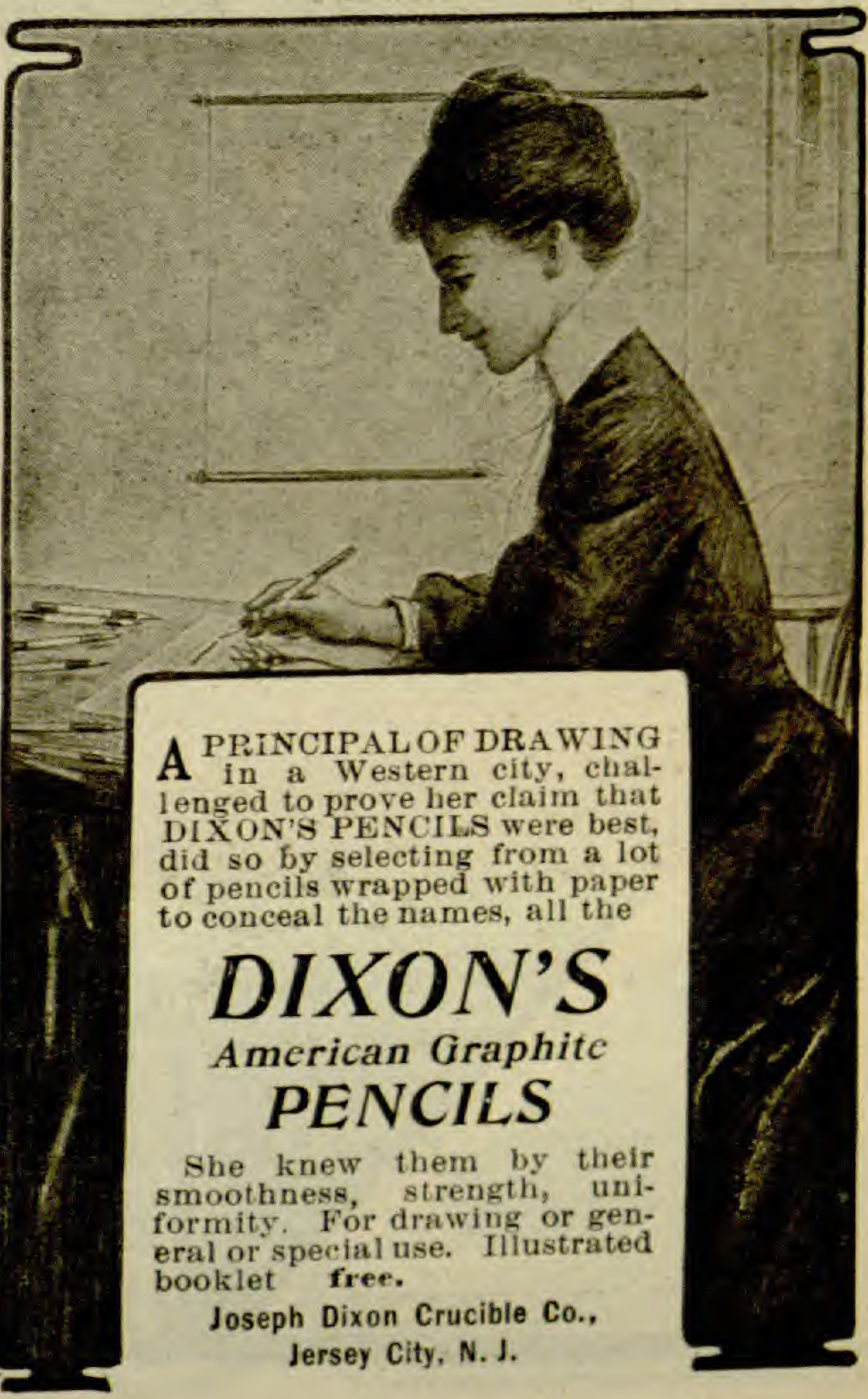

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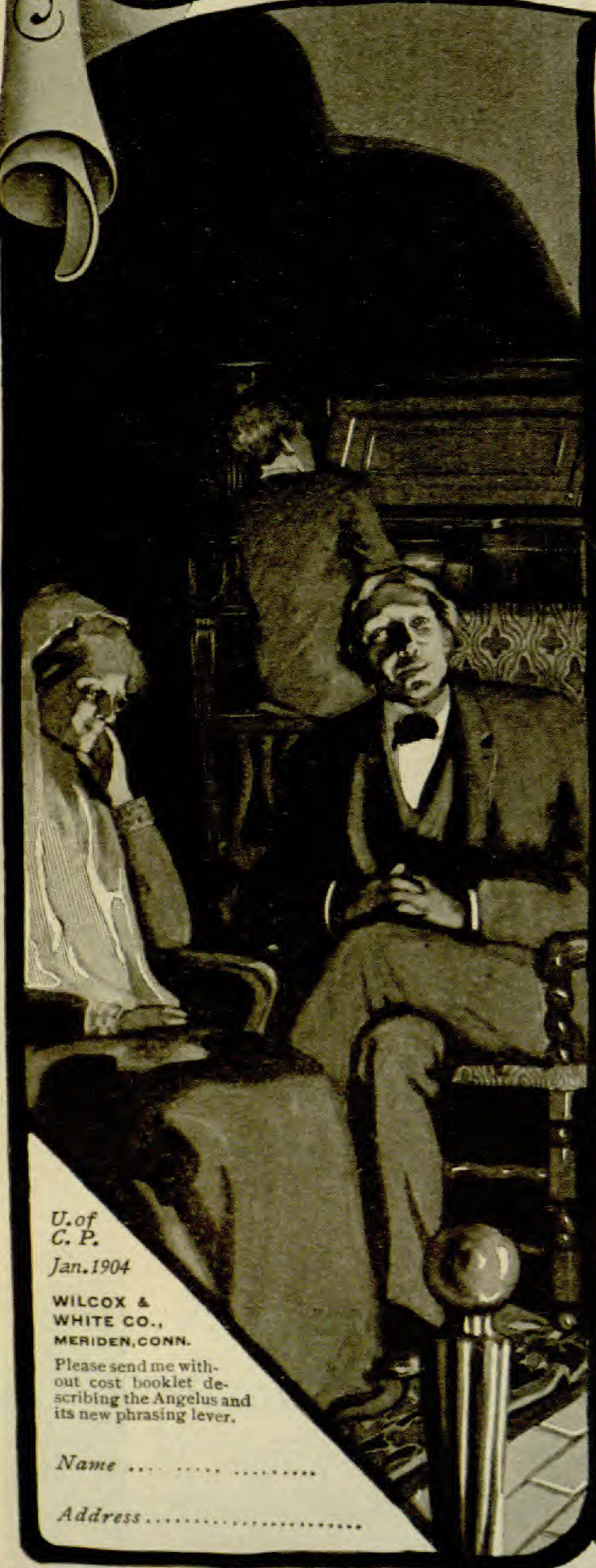

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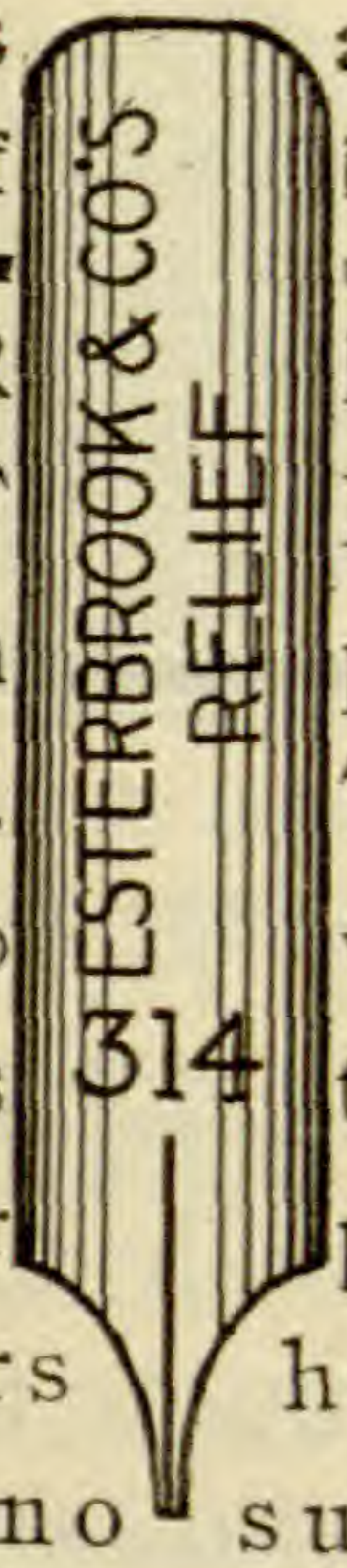
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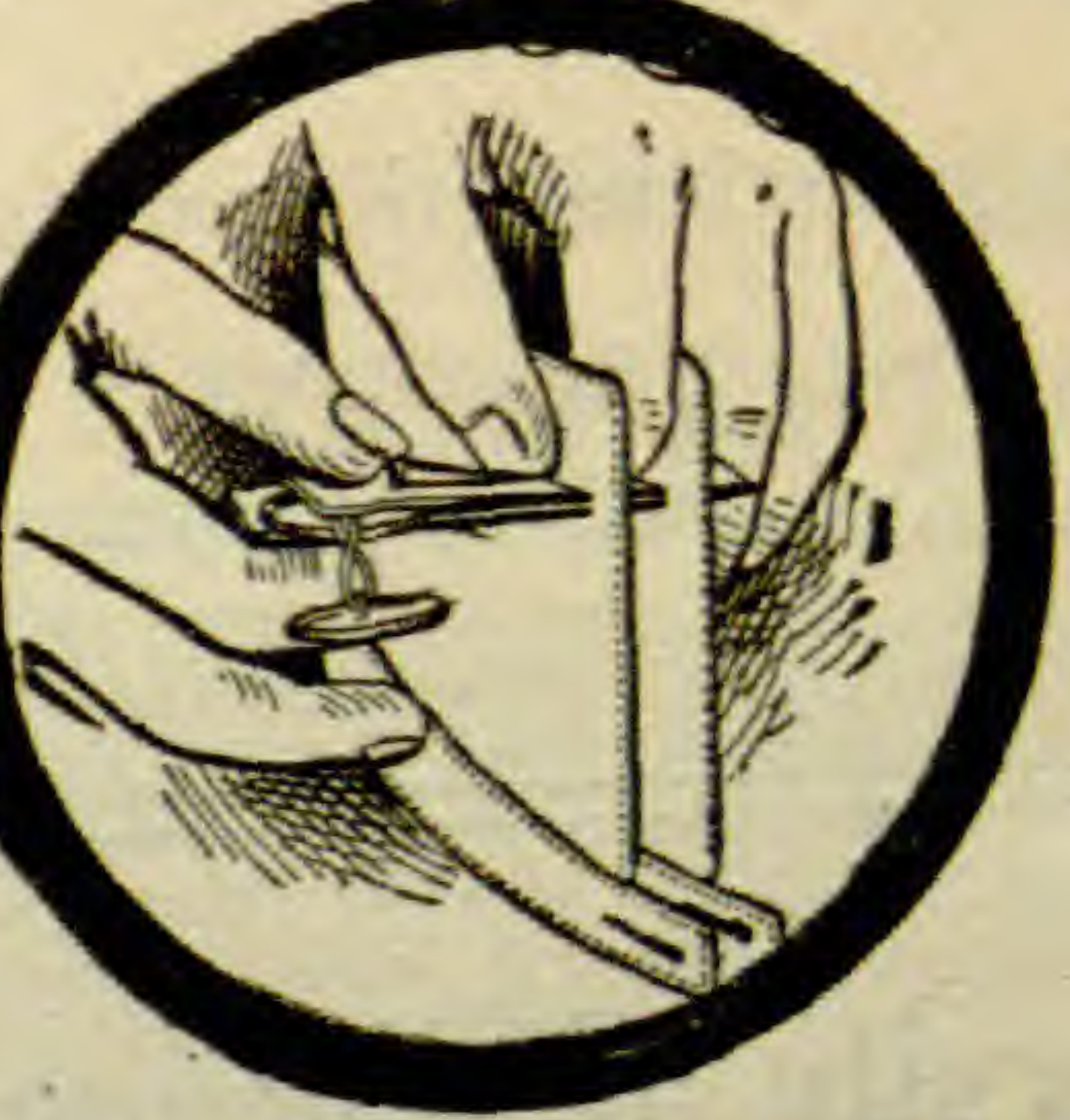


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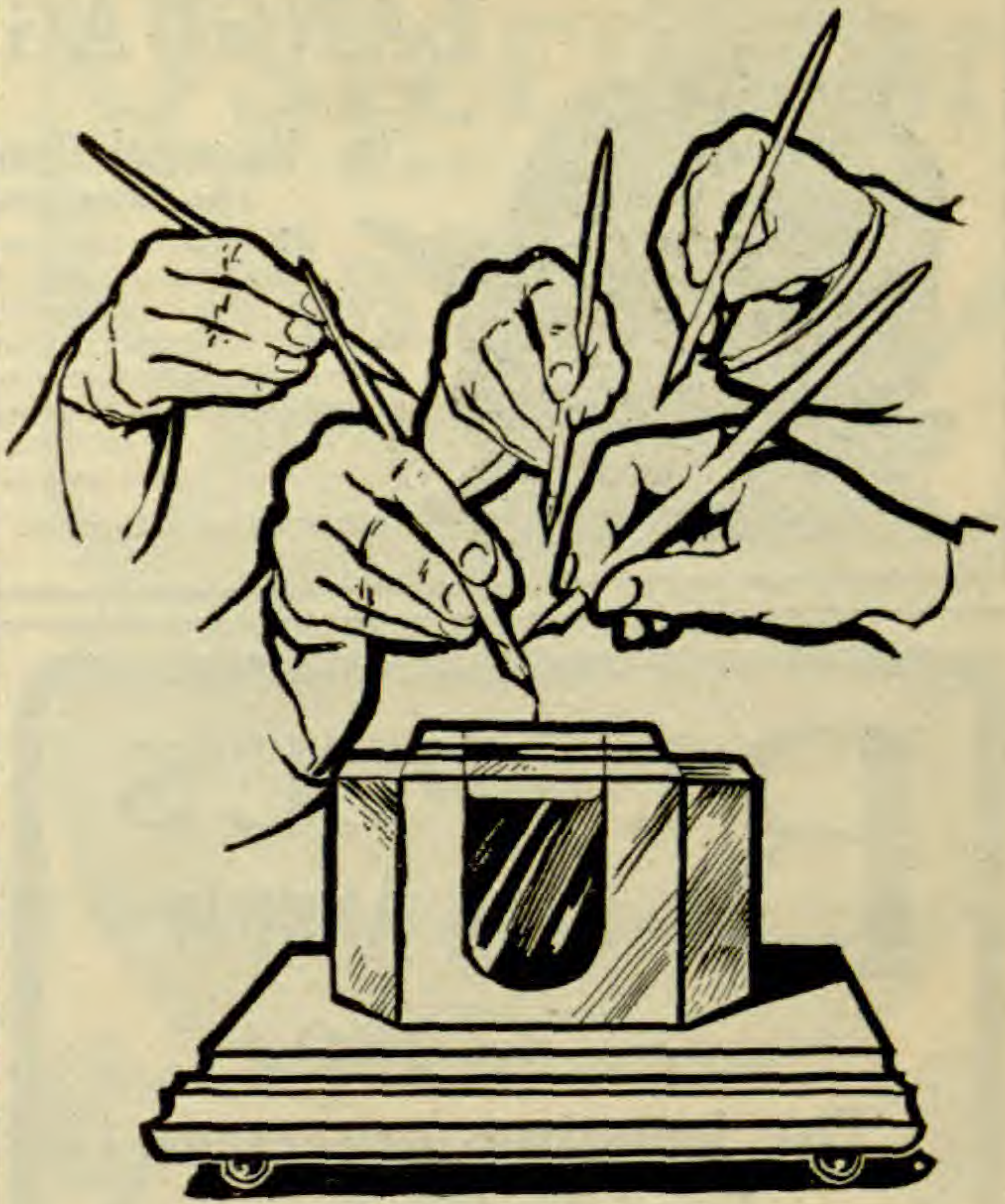

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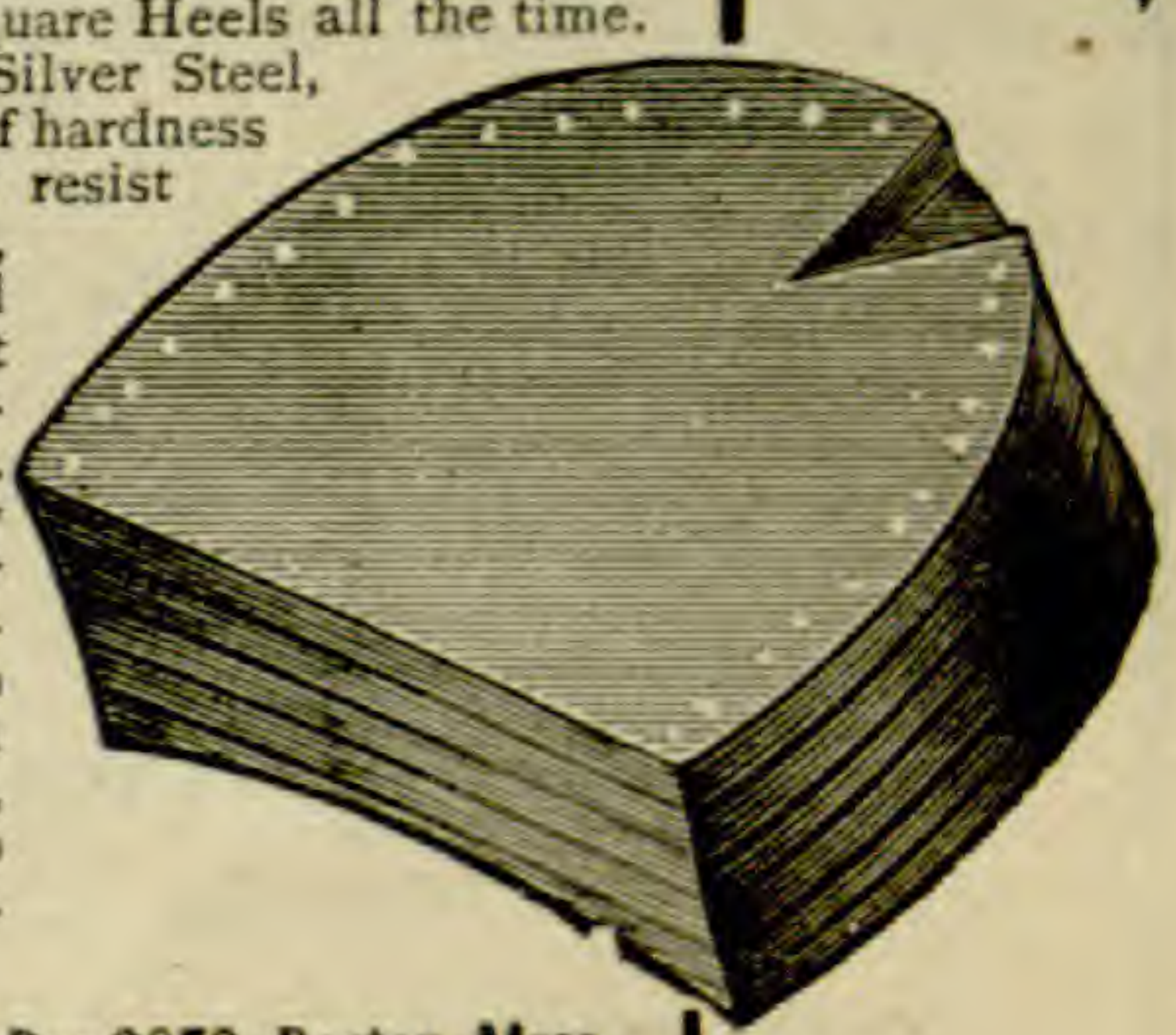

Vol. XXXVII FEBRUARY, 1904 No. 2

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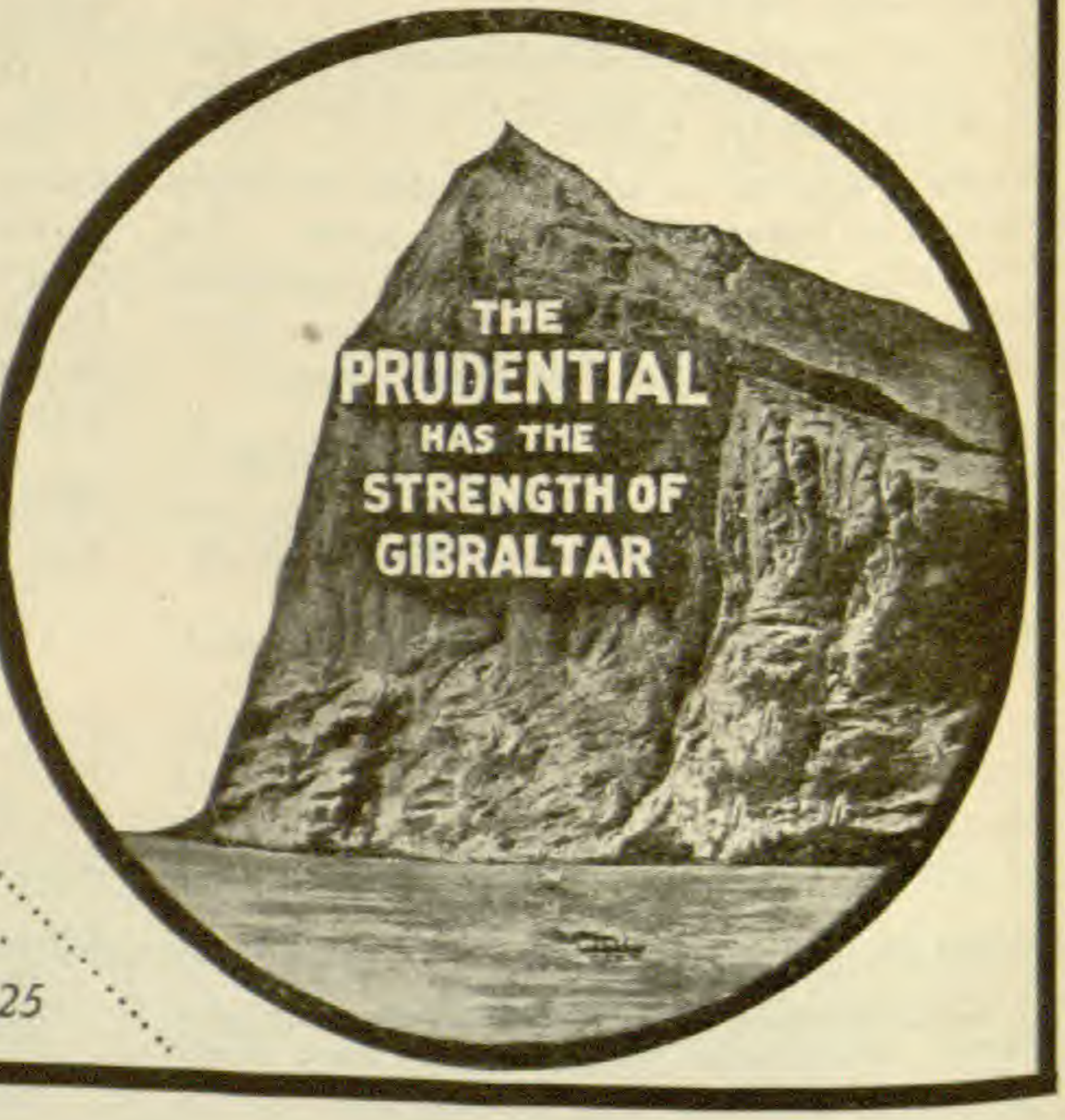
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VOLUME XXXVII NUMBER 2

BOTANICAL GAZETTE

FEBRUARY, 1904

ON A SELF-RECORDING METHOD APPLIED TO THE MOVEMENTS OF STOMATA.

FRANCIS DARWIN.

(WITH FIFTEEN FIGURES)

In my paper on stomata[1] it was incidentally shown that the temperature of a leaf varies, other things being equal, with the condition of the stomata. Thus if there are two leaves, in one of which (O) the stomata are open, while in the other (C) they are closed, it is found that O is cooler than C. It is evident that this must be so because the evaporation from O is greater than that from C; in fact, one corresponds to the wet bulb, and the other to the dry bulb of a psychrometer. In the experiments above referred to the leaves employed were those of Tropaeolum, C being a leaf in which the stomata were closed by separating it from the plant, and thus allowing it to wither; while O was a leaf still attached to the plant, with normally open stomata. As the stomata of O closed in the evening, its temperature approached more and more to that of C, and to that of the dry bulb thermometer, while the temperature of an aquatic leaf (of a species in which the stomata are open at night) remained cooler than the dry bulb thermometer.

These experiments suggested that the changes in the temperature of a leaf might be used, with certain precautions, as an index of the condition of the stomata. It was hoped that by the use of this method it would be possible to check and control

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[1] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London B. 190: 582. 1898.

observations made by the horn hygroscope, as given in the above-quoted paper.

METHOD.

The apparatus employed was one of Callendar's recorders, a platinum thermometer,[2] or resistance thermometer, in which the difference between the temperatures of two fine platinum wires is recorded on a revolving drum.[3] In the experiments illustrated by *figs. 1, 2, 3, 5, 6, 12, 13, 14, 15*, the resistances were so arranged that a vertical fall of 24^{mm} in the tracing made represents a difference of 1° C. But as some of the figures have been reduced in scale it is simpler to state that the distance between the horizontal lines represents one-sixth of a degree C. In *figs. 4, 7, 8, 9, 10, 11*, the value of 1° C. is uncertain, owing to an omission in my notes. In these figures the distance between the horizontals represents either 0.1° or 0.2° C.

The fine platinum wires, the difference of whose temperature is recorded, are disposed in fine zigzags on plates of talc 10×3^{mm}, which will be referred to as "bulbs." The leaf is inverted, so that its stomatal surface is free, and its astomatal surface is in contact with the wire. It is generally necessary to hold the petiole in a clamp, and to press the leaf against the bulb by a pair of springs, or by a thread having weights at each end. An unavoidable drawback of the apparatus is that, owing to the current run-

---

[2] The instrument was made by the Scientific Instrument Company at Cambridge. I am much indebted to my brother, Horace Darwin, for help in management of the apparatus.

[3] A resistance thermometer, or, as it is often called, a platinum thermometer, consists of a fine platinum wire, which is exposed to the temperature it is desired to measure. As its temperature alters, its electric resistance also alters, and by measuring this resistance the temperature is found. These thermometers are usually made of platinum, but this is not necessarily the case; a fine wire of copper or of other metal can be used in many cases with equally good results. The resistance is usually measured by a Wheatstone bridge; the Callendar recorder is an automatic Wheatstone bridge, which is continually measuring the resistance, and at the same time moves a pen so that its distance from a fixed point is proportional to the temperature. This pen marks a line on a drum driven by clock-work, and thus a curve is drawn giving a continuous record of the temperature of the thermometer. By the use of two resistance thermometers a curve can be made representing the difference of their temperatures, and this is the arrangement which I have employed. See Callendar Electric Recorders, a pamphlet published (1901) by the Cambridge University Press.

ning through the wires, the bulbs are warmer, by roughly 2°, than the surrounding air. Thus the leaf under experiment is not in strictly natural conditions, being constantly warmed; in spite of the artificially increased transpiration[4] due to this condition, the leaf behaves normally in showing a marked rise in temperature as the stomata shut. Nor does the warming of the leaf,

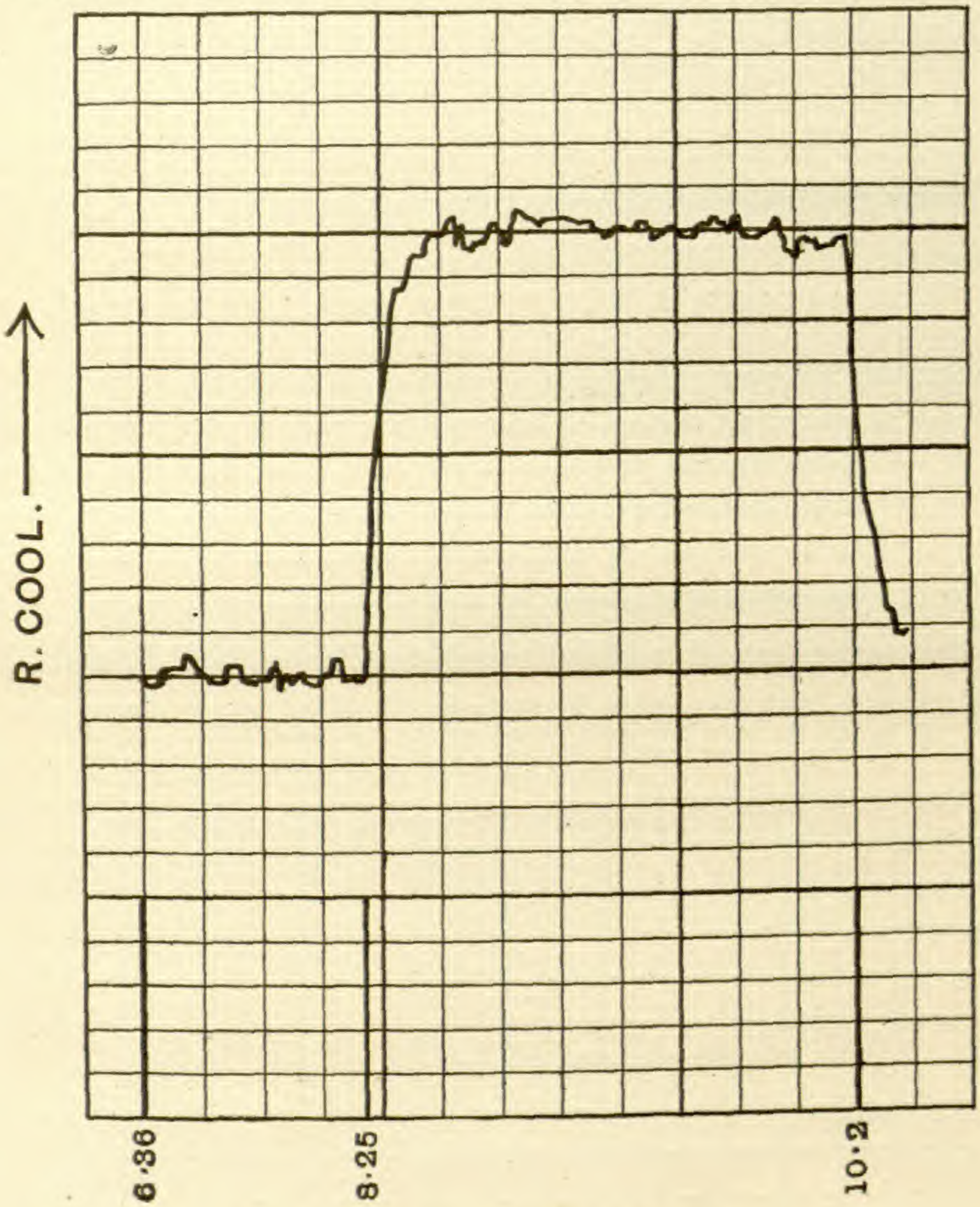

FIG. 1.—See Experiment 83 B, p. 84.

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[4] By the use of the horn hygroscope it is possible to show that the part of a leaf in contact with the recorder bulbs transpires more than the unheated parts of the same leaf. The following are readings taken on a tulip leaf, February 22, 1901, B being the transpiration of the part of the leaf in contact with the bulbs, N of the normal parts of the leaf.

P. M.	N	B
4:53	30	40
10:43	23	30

generally speaking, prevent the stomata showing normal behavior, *e. g.*, in closing at night, or by artificial darkness during the day, or again when the petiole is divided and the leaf begins to wither.

The purely physical results of the warmth of the bulbs have also to be considered. Supposing the apparatus is in equilibrium, and the pen therefore is running along the zero line, indicating equality of temperature in the bulbs; if a bad conductor, such as a flock of cotton wool be placed on one bulb, the pen will instantly be deflected, as shown at 8:25 P. M., *fig. 1.*

EXPERIMENT 83 B, *fig. 1. July 2, 1900.* COTTON WOOL.

P. M.	
6:36–8:20	Nothing on either bulb. · The battery turned off, and a thick pad of cotton wool placed on bulb B; this prevents loss of heat from B, and therefore gives an R-cool[5] movement when the battery was turned on.
8:25	Battery on: result, an R-cool rise of about 1.7° C.
10:2	Wool removed: result, an R-warm fall.

In the same way, if a good conductor, *e. g.*, a thin metal plate or a withered leaf, is placed on bulb R, the result shown at 5:56 in *fig. 2* will be seen; the effect of its removal is seen at 8:28.

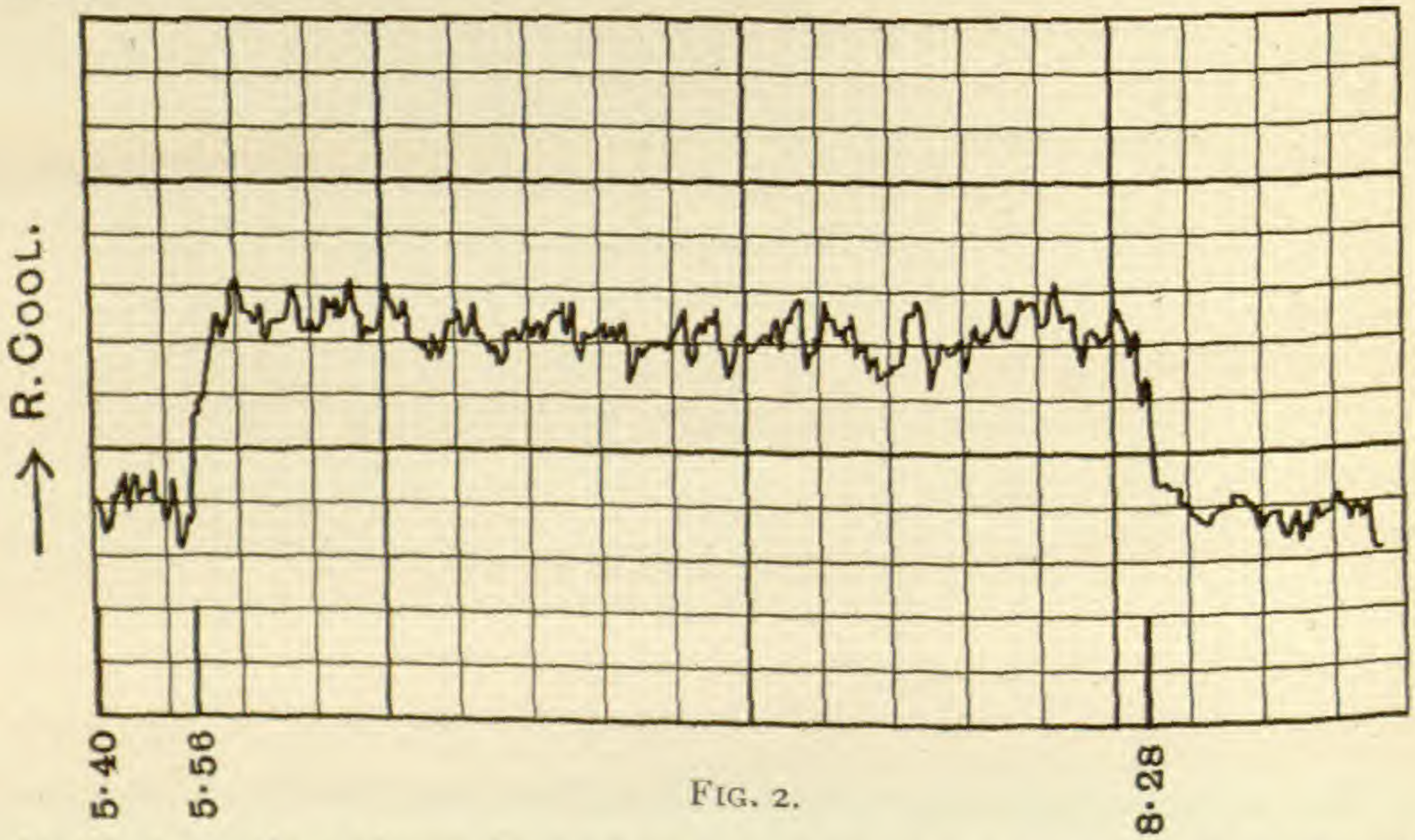

FIG. 2.

It is clear that these facts must be taken into account in experiments on leaves. This difference in temperature would not in

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[5] The two bulbs of the thermometer are distinguished as bulb B and bulb R. When the pen is deflected from the zero line it indicates a difference of temperature between B and R which may be called a "B-warm" or "R-cool" effect; while a ontrary effect would be described as either "B-cool" or the equivalent "R-warm."

any way indicate the cooling effect of transpiration, because the leaf used is one cut from the parent plant, in which the stomata had closed; the leaf simply acts as a good conductor.

In most experiments a leaf with stomata shut was placed on the control bulb, the experimental leaf being on the other. This has not merely the advantages pointed out, but it has the more important effect of protecting the control bulb from draughts of air, and therefore from changes in temperature. The effect is evident when both bulbs are covered with cotton wool. The line drawn is then quite free from the zigzags so evident in the figures published. The following experiment shows that it is important to choose carefully the body placed on the control bulb.

EXPERIMENT 46, *fig. 3, Dec. 18, 1899.* DRY AND WET GYPSUM.

A small block of dry gypsum wrapped in tin-foil on bulb R; a similar block soaked in water on bulb B; the tin-foil was pierced with pin holes so as to allow only a moderate degree of evaporation.

A. M.
11:7 Battery on to balance, and then turned off so that the blocks of gypsum might be placed on the bulbs.
11:25 Battery on: the B-cool fall is owing to the evaporation and conducting power of the damp gypsum (B).
P. M.
12:14 Doors and windows of the greenhouse opened, producing the following changes:

	Dry bulb, °C.	Wet bulb, °C.	Humidity of air, per cent.
12:13	15.0	12.2	70
12:18	11.3	7.8	58
12:27	8.5	6.0	66
12:43	7.8	6.0	75

The air was thus cooled, and was at first rendered drier; the increased evaporation should therefore have cooled B still more, but the curve shows that it became relatively warmer; this must be due to the fact that the block of damp plaster (B) took longer to cool. It was clearly a temporary effect, since at 12:43 the curve returned to nearly the position occupied before the temperature was lowered.

At 12:43 (about) the windows and doors were shut, and a reverse movement of the same temporary character followed.

The experiment was repeated with an Alisma leaf on bulb B and the damp block of plaster on R. When the temperature fell, the leaf, in spite of its smaller volume, cooled more slowly than the plaster; there was therefore a relative warming of the leaf lasting about 15 minutes, and the reverse effect occurred as the air became warmer again on the door and windows being closed.

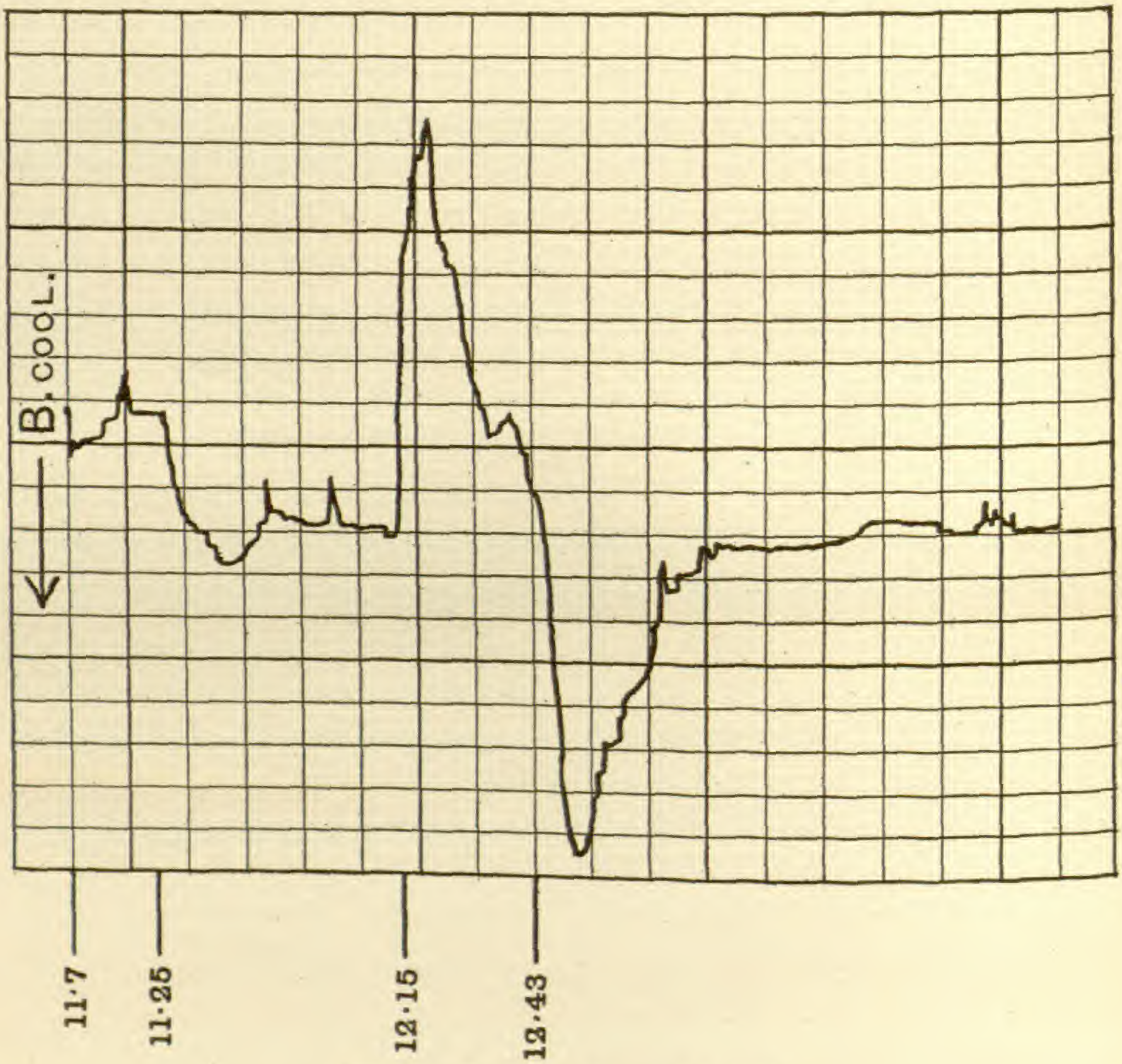

FIG. 3.—See Experiment 46, p. 85.

These experiments show clearly the necessity of using for the control bulb a body equaling in volume and conductivity that on the experimental bulb. A cut leaf with closed stomata answers this purpose well enough.

Another element of some importance is the condition of the air. It is obvious that, if the air becomes drier, the evaporation from the experimental leaf will increase, and the curve might be interpreted to mean that the stomata had opened more widely. This is not of great practical importance, since the method is used chiefly to demonstrate sudden changes in the condition of the stomata. But in taking readings of the closure of the stomata occurring naturally at night, it would be necessary to take account of the effect of the dampness of the night air. One way of counteracting the error is to place on the control bulb a leaf of a species whose stomata do not close at night. Another method, which is more easily managed, is to use for a control a wet strip of linen.[6] Any change in the moisture of the air will affect both leaf and linen in roughly the same way, and thus an increase in the leaf temperature may be put down as practically all due to closure of the stomata. It should be noted that the effect of moist air is not nearly so great in a resistance thermometer as in an ordinary wet and dry bulb thermometer, no doubt because the temperature of the bulbs is maintained above that of the air. It follows that the error against which the use of a wet bulb is meant to guard is not nearly so great as might be expected.

EXPERIMENT 106. *March 14, 1901.*

Bulb B was covered with a strip of wet linen, while bulb R was exposed to the air. By watering the floor and the hot pipes, the air was made damp, as shown by the following readings:

P. M.	°C.	°C.	Per cent.
4:0	15.7°	12.7°	68
	Watered floor		
4:5	15.8	13.2	
4:7½	15.8	14.0	83
4:12	16.0	15.0	89
4:19½	16.0	15.2	91
5:11	14.9	12.8	77

Between 4:0 P. M. and 4:19½ P. M. the difference between the wet and dry bulb mercury thermometers decreased from 3.0° C. to 0.8°, *i. e.*, by 2.2°. If the resistance thermometers behaved like an ordinary wet and dry bulb psychrometer, the difference

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[6] It must be separated by a layer of oil-silk from the surface of the bulb, lest the thermometer wire should be wetted through a crack in the varnish by which it is covered.

between their temperatures, as seen on the curve, should have diminished by 53^{mm}. As a fact it only diminished by 14^{mm}, *i. e.*, the effect as measured by the Callendar recorder is only 26.4 per cent. of the actual change. Between 4:19½ and 5:11 the difference between wet and dry bulbs increased (as the air grew drier again) from 0.8° to 2.1°, *i. e.*, by 1.3° C. This should have given a change on the recorder-curve of 31^{mm}. The recorded change was not at any rate more than 8^{mm}, *i. e.*, 25.8 per cent. of the actual psychrometer effect.

EXPERIMENT 108. *March 16, 1901.* NARCISSUS.

In this experiment the effect of damp air is shown with a Narcissus leaf on bulb R and with nothing on bulb B. The floor and hot pipes were watered, with the following result:

P. M.	Dry, °C.	Wet, °C.	Per cent.
2:11 - -	17.9	12.7	52
	Watered floor and pipes.		
2:22 - - -	18.3	16.8	85
2:27 - -	18.2	17.2	90
2:56 - - -	Opened door.		
3:1 - -	16.8	13.5	67

Thus, between 2:11 and 2:27, the difference between the wet and dry bulb mercury thermometers decreased from 5.2° to 1.0°, *i. e.*, by 4.2°. This would mean a fall in the curve of 100.8^{mm}. The actual change in the curve was a drop of 22^{mm}, or in round numbers 22 per cent. of the psychrometer difference. The stomata were wide open throughout the experiment. Between 2:27 and 3:2 the difference between wet and dry mercury thermometers increased by 1.7°, which would equal 41^{mm}; the change in the curve was 12^{mm}, or 29 per cent. of 41^{mm}.

It should be added when an ordinary thermometer is converted into a wet bulb by wrapping it in a leaf, the difference between it and a dry bulb is considerably less than that between the wet and dry bulbs of a psychrometer.[7]

It is not obvious why the leaf when wrapped around the bulb of a thermometer behaves so differently from the wet gauze with which the psychrometer is covered. But the cause, whatever it

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[7] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London. B. **190:** 583. 1898.

is, should affect the recorder bulbs in the same way. On the whole, we may conclude that the effect of variations in the humidity of the air on the temperature of a leaf fitted to the recorder is comparatively small, especially when counteracted by the use of a layer of damp linen on the control bulb of the instrument. And this must be some advantage in experiments like the present, in which it is sought to estimate the opening and shutting of the stomata by temperature changes.

A possible source of error, in long-continued experiments, is that a leaf will transpire less in darkness than in light, quite apart from the closure of the stomata. This is believed to be due to the fact that the radiant energy absorbed by the chloroplasts is in part made evident as heat. It follows that a relative rise of temperature occurring at night might be put down to closure of the stomata, when it might in reality be due to the checking of "chloro-vaporization" by darkness. The following experiment, however, shows that this is not a serious source of error.

EXPERIMENT 102. *February 22, 1901.*

A tulip leaf (attached to the plant) was placed on bulb R, an "artificial leaf" made of wet linen on bulb B. Readings with the horn hygroscope showed that the stomata were open from 4 P. M., when the experiment began, until 10:32 P. M.; a slight closure had occurred, but the nocturnal reading corresponds to a fair amount of transpiration. The temperature of the air fell during the same period from 18.2° to 16.6°, but the relative moisture of the air remained the same, *i. e.*, 60 per cent. The reading of the resistance thermometer remained almost constant.

As far as one experiment may be trusted, it would seem therefore that darkness, apart from its effect on the stomata, need not produce any serious check to transpiration.

THE EFFECT OF WITHERING.

One of the points investigated in my work on stomata (*loc. cit.*, p. 548) was the phenomena which occur when certain leaves are severed from the plant. The first effect is that the stomata open more widely, and this "preliminary opening" is followed by a gradual closure of the stomata. This seemed a good subject for the recording method, since the effects occur rapidly, and errors from changes in external circumstances are not likely to obscure the result.

The following diagrams give some of the results obtained. It will be seen that the effect of cutting the leaf stalk is a practically instantaneous fall of temperature, corresponding to the preliminary opening of the stomata, followed by a gradual rise toward the zero line. The results, in fact, absolutely confirm the observations made with the horn hygroscope.

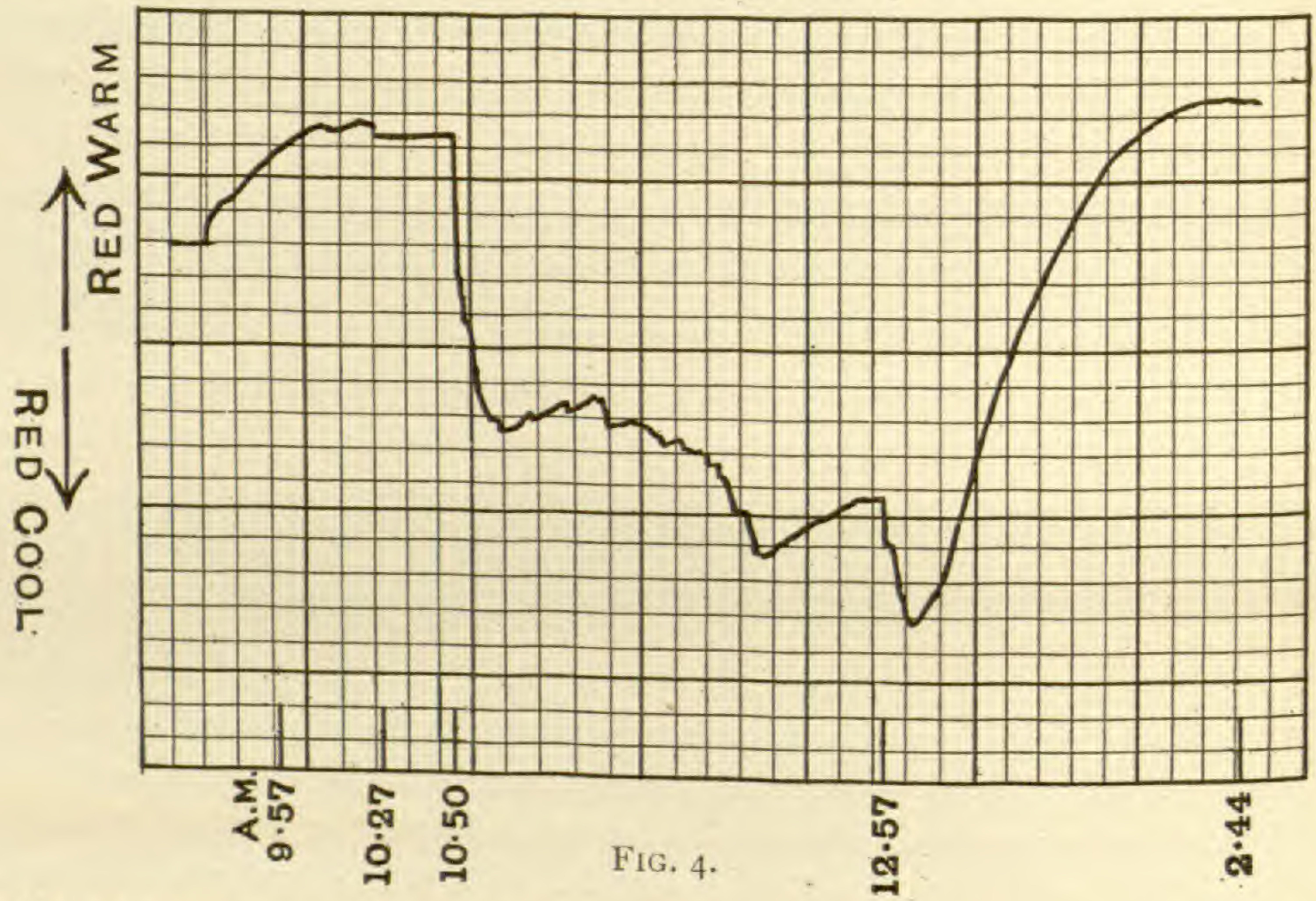

FIG. 4.

EXPERIMENT 27, *fig. 4*. *April 24, 1899*. CAMPANULA PYRAMIDALIS.

A. M.

9:57–10:27 Zero-line drawn, *i. e.* nothing on either bulb. Battery turned off and an attached leaf placed on the bulb R, a withered leaf being placed on the bulb B.

10:50 Battery turned on; the R-cool fall in the curve indicating the difference between the transpiring and withered leaf.

10:50–12:57 An irregular R-cool fall due to the stomata on the attached leaf (R) opening, as indicated by the horn hygroscope. Between 10:48 and 12:54 the moisture of the air decreased from 70 per cent. to 61 per cent., so that the whole of fall in the curve was not due to the opening of the stomata.

P. M.

12:57 Leaf on bulb R severed: a sudden R-cool fall lasting for about 10 minutes, followed by R-warm rise lasting for 1 ½ hours. It will be noticed that the preliminary opening of the stomata (12:57) takes place during a slight rise in the curve (R-warm) and is thus rendered distinct.

EXPERIMENT 51, *fig. 5. December 25, 1899.* EUPATORIUM WEINMANNIANUM.

An attached Eupatorium leaf on the bulb R; an attached Alisma leaf on the bulb B.

12:21 Eupatorium severed; rapid R-cool rise lasting 6 or 7 minutes, followed by an R-warm fall, lasting 24 minutes.

The following experiment shows the same result occurring slowly in an aquatic plant, in which class the stomata, as is well known, close much less effectively or in some species not at all, as the leaves wither.

EXPERIMENT 52, *fig. 6. January 16, 1900.* ALISMA.

Attached Alisma on bulb B; withered Eupatorium on R.

A. M.

10:28 B-cool fall showing difference between the transpiring Alisma and the partially withered Eupatorium leaf.

11:54 Alisma cut: an immediate B-cool fall showing opening of stomata, lasting for about half an hour, followed by gradual closure (B-warm) lasting more than 3½ hours.

The following readings of the horn hygroscope show that the Alisma stomata were not fully shut even towards the end of the period of closure. In this experiment the stomata of the Eupatorium leaf were not quite shut at the beginning of the experiment, though the low reading (10) of the horn hygroscope shows that they were nearly shut, nor were they quite shut even at 3 P. M. The withering of the leaves of this species is, I think, somewhat capricious.

READINGS WITH THE HORN HYGROSCOPE.

A. M.	Alisma	Eupatorium	Difference
11:53 - - -	32	10	22
11:54 - - - -	Cut Alisma.		
11:56 - - -	40	11	29
12:23 - - - -	40	9	31
12:42 - - -	35	9	26
P. M.			
2:11 - - - -	25	8	17
2:57 3:00 - - -	22	7 (avg. of 2)	15

The difference between the horn hygroscope readings of the two leaves is given in the dotted line (*fig. 6*) and agrees fairly with the temperature curve.

It should be noted that the closure of the Eupatorium stomata would not increase but slightly diminish the long B-warm rise; on the other hand the fall of the curve from 11:54 to 12:24 is to a very slight degree increased by the change in the Eupatorium leaf during that period.

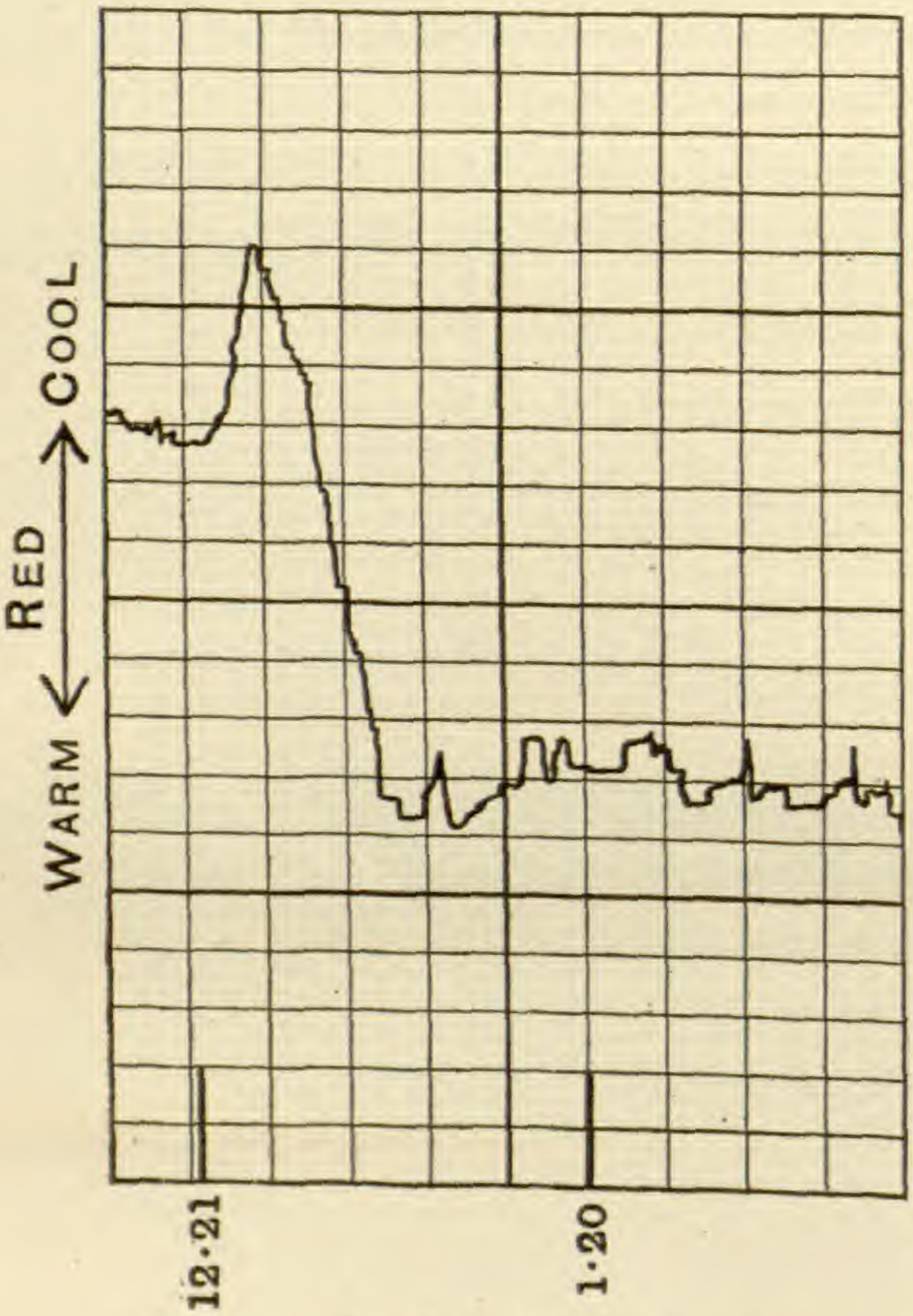

FIG. 5.—See Experiment 51, p. 91.

THE EFFECT OF DRY AIR.

Stahl[8] has published experiments from which he draws the conclusion that the closure of the stomata in dry air does not depend on the general diminution of the store of water in the leaf, but rather on the loss of water by the guard cells, which may, in his opinion, be independent of the general withering of the leaf. I have discussed this difficult question in my *Observations*,[9] where I have tentatively given the theory that the guard cells lose turgor "spontaneously," *i. e.*, "not by simple evaporation, but in response to a stimulus. And this stimulus may be the slight flaccidity of the rest of the leaf." This point of view, though it does not harmonize with Stahl's facts, has nevertheless some probability. According to my view, there must be, whenever the stomata close, a slight, though it may be an imperceptible, general detergescence of the leaf. The repetition of certain experiments with the horn hygroscope confirms me in my belief that the first stage in the closure of the stomata is a slight general withering,

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[8] STAHL, Bot. Zeitung, Einige Versuche über Transpiration und Assimilation. Bot. Zeit. **52**^{1}: 121. 1894.

[9] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London B. **190**: 617. 1898.

and not a direct specialized reaction of the stomata to dryness of the air. I undertook these experiments in consequence of reading Aloi's papers,[10] with which I was unacquainted when I wrote my *Observations on stomata.* The point of Aloi's work is his proof that leaves exposed to a very dry atmosphere may have widely opened stomata, if the plants are well watered.

My experiments were carried out as follows: A plant is placed under a water-sealed bell jar, *i. e.*, in a very moist atmosphere. The bell is removed, and a reading with the horn hygroscope taken at once; the plant is then left in the dry air of a room, and it is found that the stomata gradually close, in spite of the illumination remaining practically unchanged. This is the class of experiment recorded in *Observations on stomata.* The new fact brought to my notice is that the result often fails with plants growing in well-watered soil, while it succeeds more uniformly with plants in which the soil is dry. This points to the conclusion that the closure of the stomata depends on the loss of water in the plant as a whole being greater than the intake. Analogous

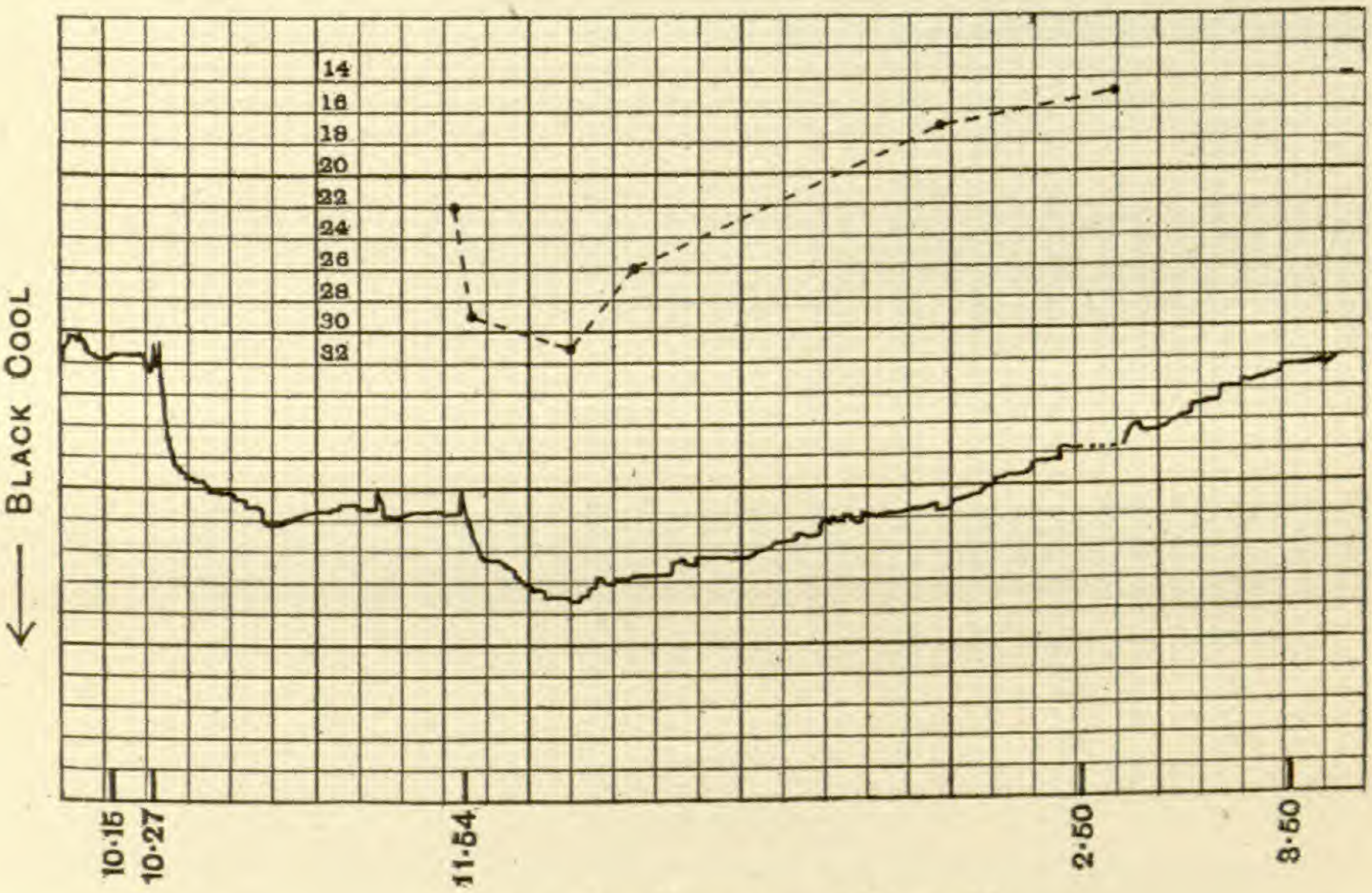

FIG. 6.—See Experiment 52, p. 91.

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[10] ALOI, La traspirazione delle pianti terrestri, etc. Catania, 1891. ALOI, Influenza dell' umidità del suolo sulla traspirazione, etc. Naturalista Siciliano 13: —. (Ni. 4–9.)

results were also obtained with the recorder (see *fig. 12*), but it will be convenient to preface them by the simpler experiments in which the condition of the soil is not taken into account.

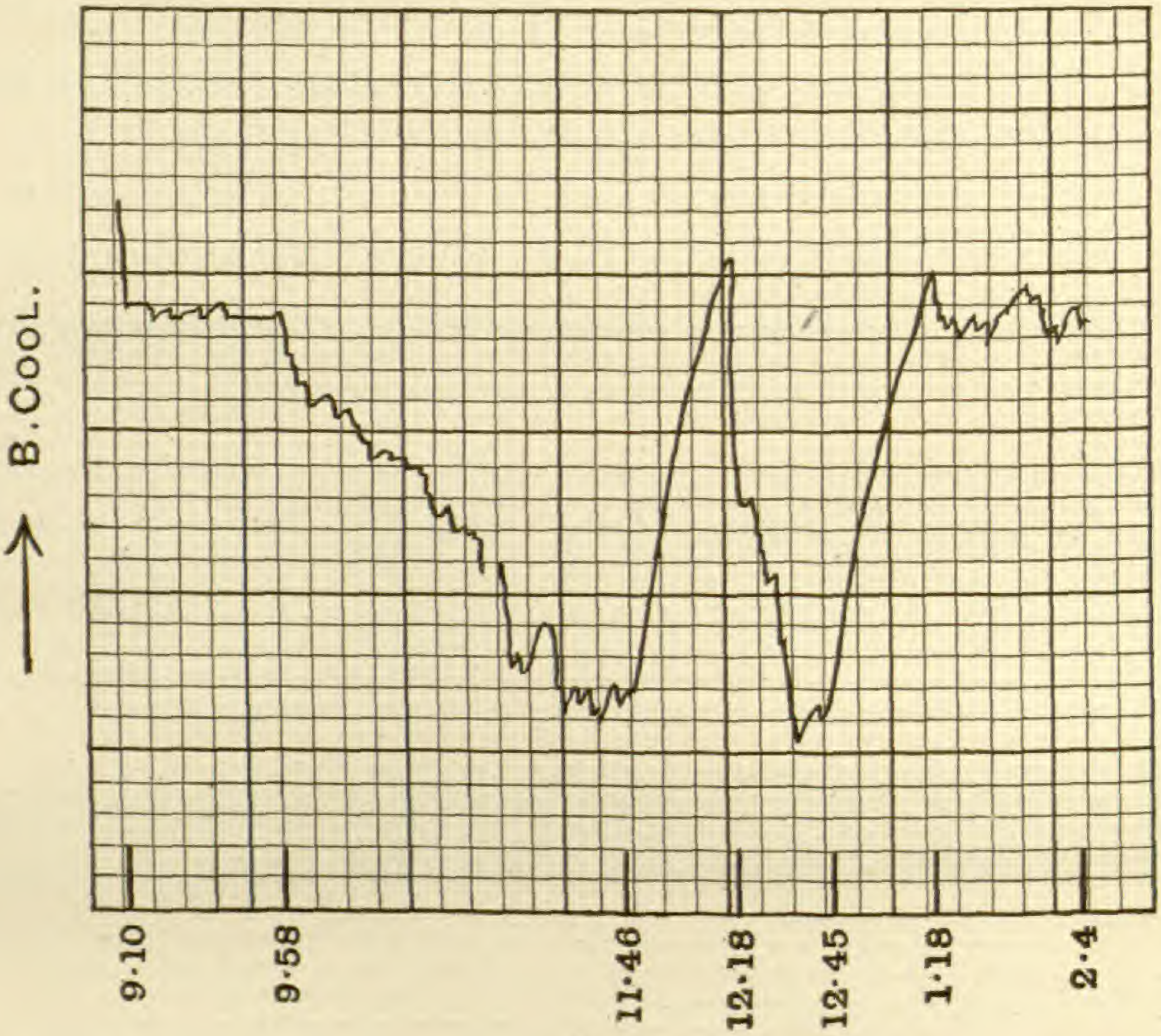

FIG. 7.

EXPERIMENT 23, *fig. 7*. *March 10, 1899*. CAMPANULA.

A. M.	
9 : 10	Zero line drawn.
9 : 58	Attached leaf on bulb R. Cut leaf (stomata shut) on bulb B.
9 : 58–11 : 46	Temperature of attached leaf on R sinks as stomata open more widely.
11 : 47	Plant moved from damp greenhouse (T. 19°, Psy. 78%) to dry greenhouse (T. 21.2°, Psy. 52.8%).
P. M. 11 : 47–12 : 18	Temperature of R rises (closure of stomata).
12 : 18	Plant moved to damp house (T. 19.6°, Psy. 81%).
12 : 18–12 : 38	Temperature of R sinks as stomata open.
12 : 45	Plant moved to dry house (T. 22.9°, Psy. 51.5%).
1 : 18	The temperature reading practically the same as the zero line at 9 : 58 (*i.e.*, before the leaves were placed on the bulbs). This is also true at 12 : 18; the inference being that in the dry air the stomata closed so completely that the temperature of the attached leaf (R) was the same as that of the cut and withered leaf (B).

The temperature difference recorded is about 36^mm or 1.5° C. It must be noted that at 11:46 A. M. or 12:38 P. M. when the plant was placed in dry air the effect of such change, if the stomata were immovable openings, would be to cool the attached leaf R still more. The stomata, therefore, must have closed at once.

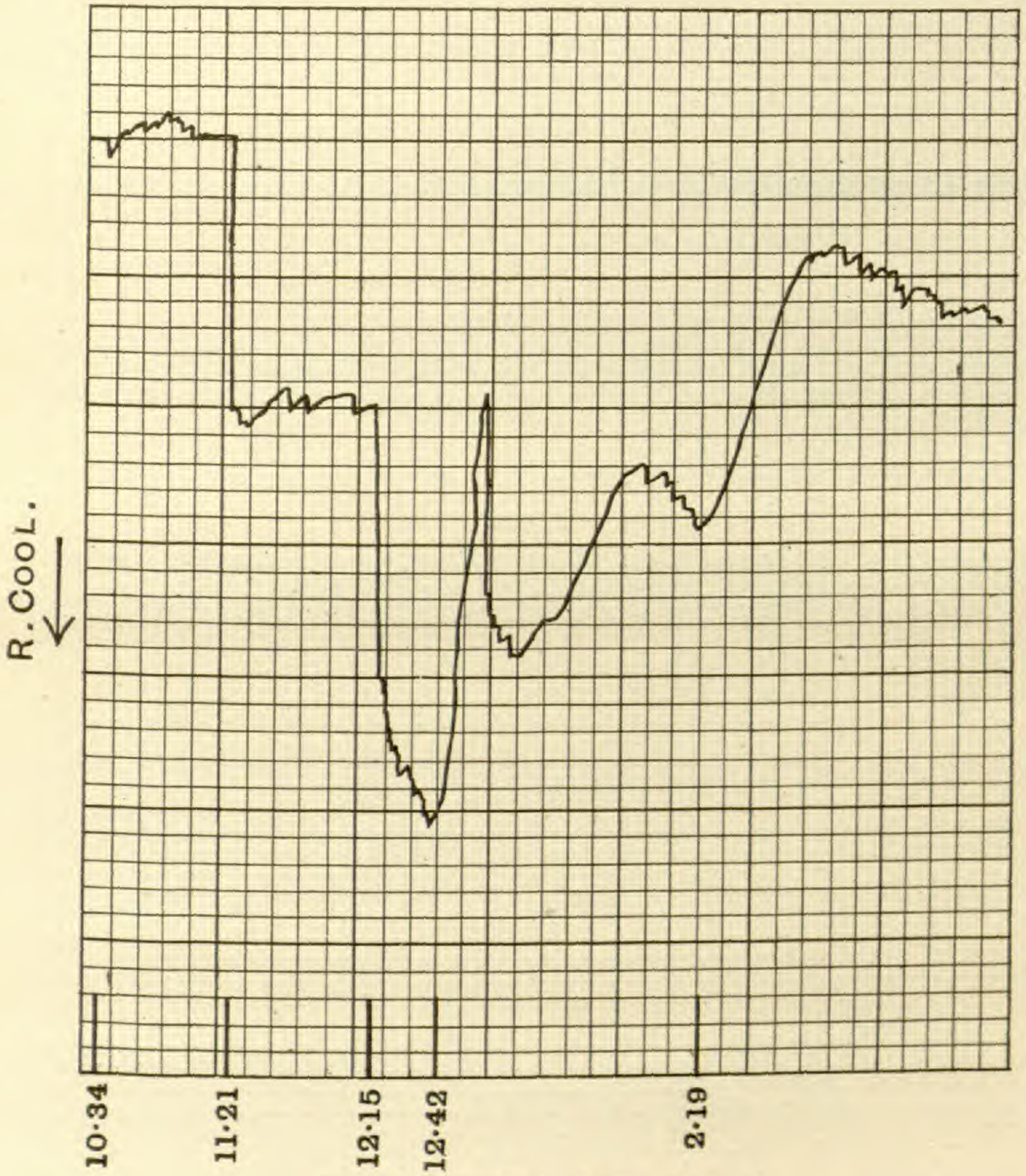

FIG. 8.—See Experiment 26, p. 96.

It may be suspected that, the damp house being some 3° cooler than the dry one, the rises of temperature at 12:18 and 12:38 were due to leaf R assuming the temperature of the air in the dry house more quickly than B. But if this were the case, the temperature curve between 1:18 P. M and 2:4 P. M. when both leaves were left on the recorder bulbs would have fallen to what it was at 12:38, as the leaves became equal in temperature. Inequality in assuming a given temperature is a genuine source of error, as appears at p. 85, but in the present case it cannot be admitted.

EXPERIMENT 26, *fig. 8. March 21, 1899.* CAMPANULA.

A. M.	
10:34–11:21	T. at 10:34 13.7°, Psy. 88%. Zero line drawn; nothing on either bulb.
11:21	T. 15.0°, Psy. 75%. Attached leaf on bulb R. Withered leaf on bulb B.
P. M.	
12:16	T. 21.2°, Psy. 47%. Plant removed to dry greenhouse. The first effect of the dry air is a considerable fall in temperature (R-cool).
12:42–2:25	T. 24.5–21°, Psy. 43–48%. An irregular rise indicating a partial closure of stomata.
2:19	(T. at 2.40 21°, Psy. at 2.40 58%.) A further closure of stomata, owing probably to the darkening effect of a snow-storm.

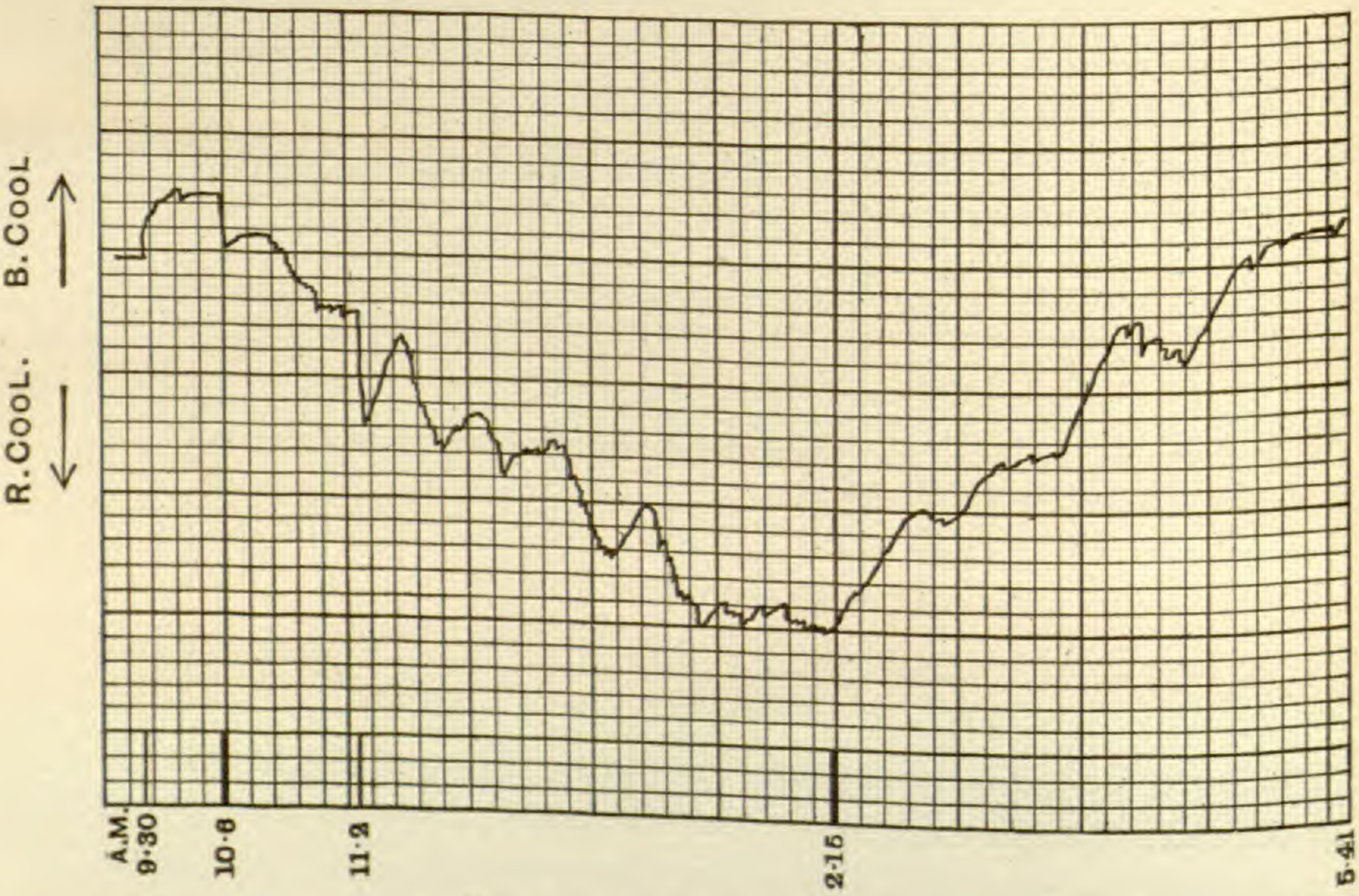

FIG. 9.—See Experiment 15, p. 97.

EXPERIMENT 15, *fig. 9*. *February 21, 1899*. TROPAEOLUM.

A. M.

9:30–10:6 Zero line drawn, nothing on either bulb.

10:6 Attached leaf on bulb R, withered leaf on B.

10:6 T. 12–13°, Psy. 77–78%. A gradual opening of stomata till 11:2.

11:2 Plant moved to dry greenhouse (T. at noon 25°, Psy. 40%). A sudden R-cool move, owing to increased evaporation but there was no sign of a permanent R-warm move (which would have indicated a closure of the stomata) until 2:15, although the air remained very dry, *e. g.*, at 3 P. M. Psy. 35%, T. 24.1°, and at 5:2 P. M. the psychrometer still gave 40% and the temperature was 23.5°. The rise of the curve (R-warm move) was probably due to a genuine withering of the attached leaf, though the horn hygroscope did not indicate any closure even at 3 P. M.; at 5:40 the temperature curve shows complete closure, and this is confirmed by a horn reading at 5:50.

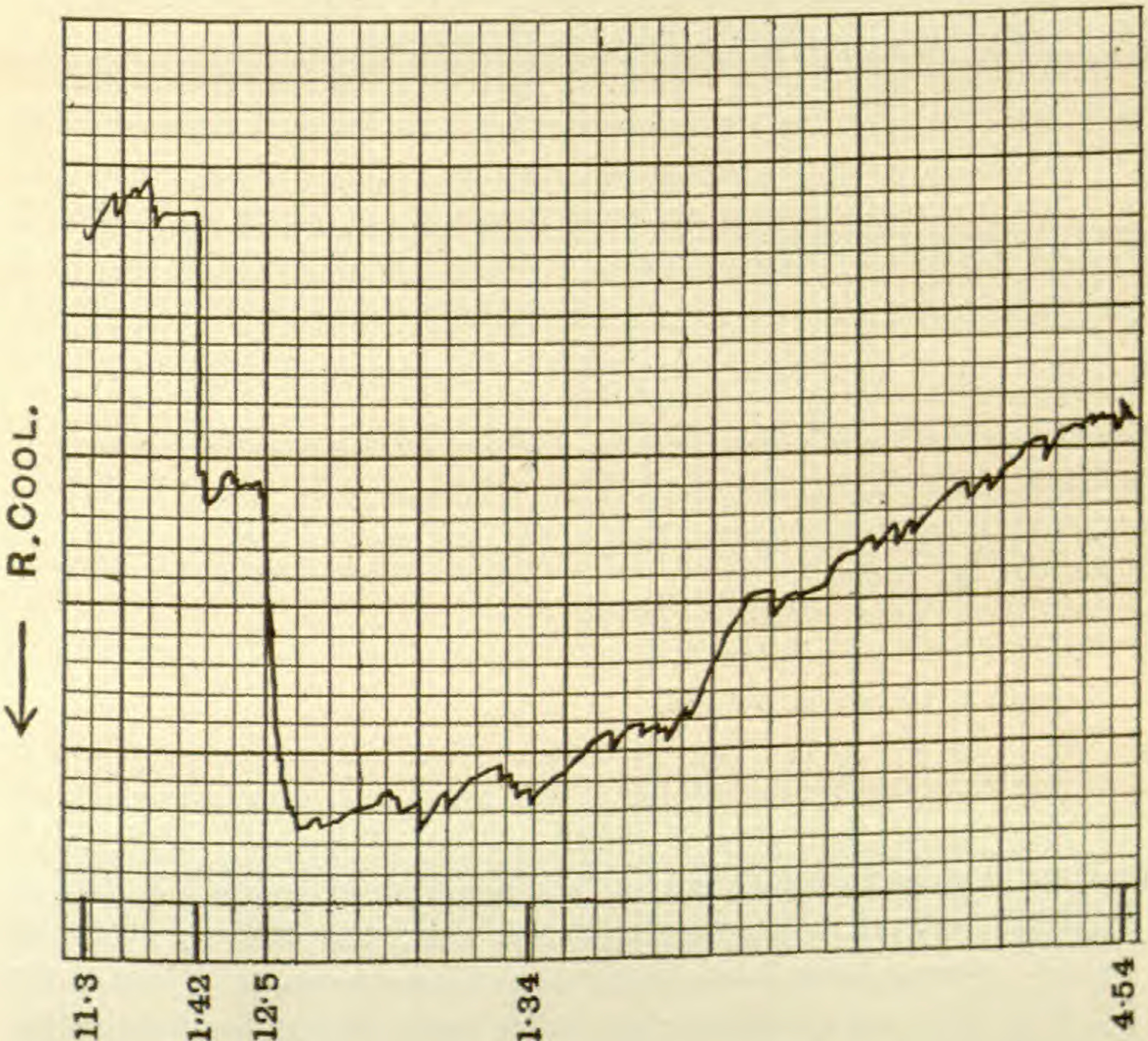

FIG. 10.—See Experiment 17 B, p. 98.

EXPERIMENT 17 B, *fig. 10. February 23, 1899.* NICOTIANA AFFINIS.

A. M.

11:3–11:42 Zero line (nothing on either bulb). T. at 11:8 19°, Psy. 74%

11:42 Attached leaf on bulb R, withered on B.

P. M.

12:5 Plant placed in dry greenhouse. T. 27°, Psy. 41%. Rapid R-cool move owing to the physical effect of the dryness of the air.

1:34–4:54 Gradual R-warm move, indicating gradual closure of stomata. The occurrence of closure was confirmed by horn hygroscope readings.

4:49 T. 23.6°, Psy. 37%.

EXPERIMENT 16, *fig. 11. February 24, 1899.* EUPATORIUM WEINMANNIANUM.

No zero line drawn, but the beginning of the curve is roughly zero.

A. M.

11:39 Attached leaf on bulb R; withered leaf on bulb B. T. at 11:35 20.6°, Psy. 71%.

P. M.

12:40 Moved plant to dry greenhouse. T. 30.8°, Psy. 40%. A rapid R-cool move, owing to physical effect of the dry air.

1:2 A rapid R-warm move, indicating partial closure of the stomata.

2:52 T. 33°, Psy. 42%. A young leaf on the plant showed signs of being withered, but the experimental leaf not visibly flagging; nevertheless it must have been suffering from want of water, as it showed no sign of opening its stomata on being placed in damp air.

Here follow two experiments on the different behavior of dry air on plants well and badly supplied with water in the soil.

EXPERIMENT 87, *fig. 12. July 25, 1900.* TROPAEOLUM MAJUS.

Two pots of Tropaeolum, viz., R and B; of these, plant R had been kept well watered; B had been kept without water, but was not so dry as to produce closure of the stomata.

A. M.

9:39 An attached leaf of plant R placed on bulb R. An attached leaf of plant B placed on bulb B.

10:28 The horizontal line ending here shows that the well-watered leaf R was considerably the cooler. The leaves were now removed from the recorder, and plant B placed in damp air under a bell-jar.

11:18 Plant B removed from damp air, and again placed on bulb B; leaf B, badly watered, is now cooler than it was; this can only be due to the stomata being more open; the difference cannot be due to the physical effect of the bell-jar, where, owing to the check to transpiration, it would have been warmer than leaf R, still exposed to the air of the greenhouse. T. 23–28°, Psy. 67–58%.

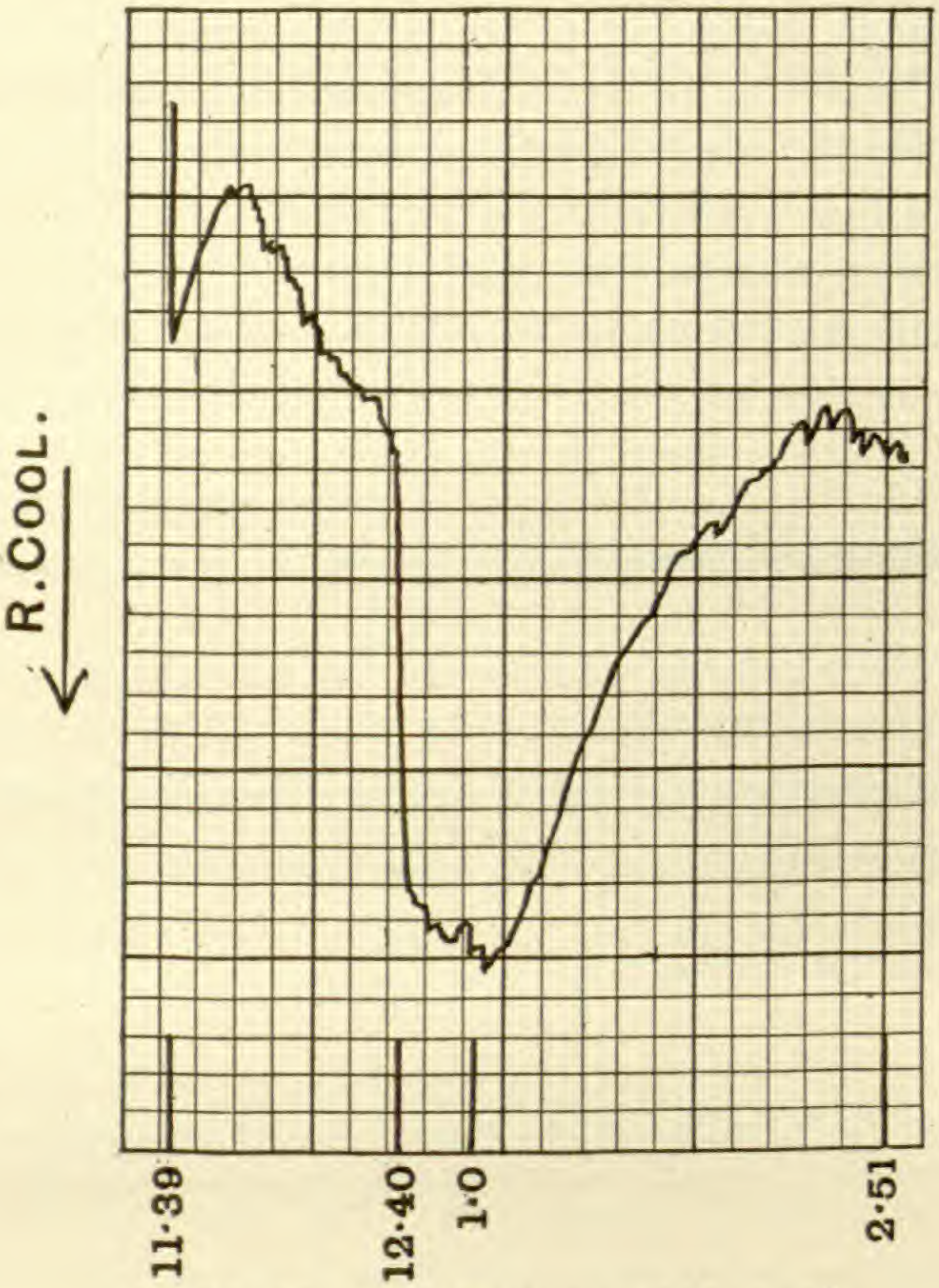

FIG. 11.—See Experiment 16, p. 98.

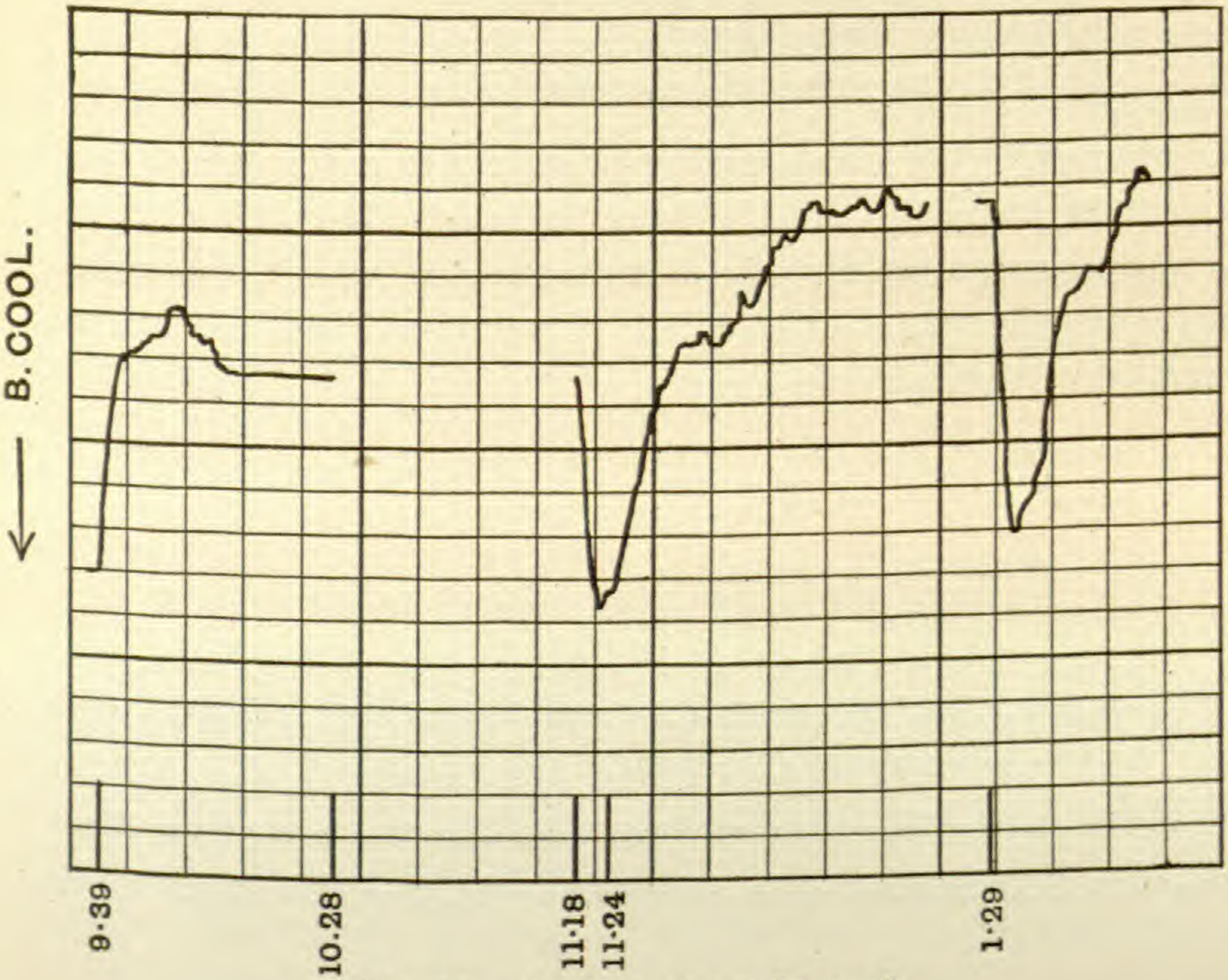

FIG. 12.—See Experiment 87, p. 98.

11:24 Sudden change, indicating a rise of temperature in B or fall in R, and as there is no reason to suppose that any change in R had taken place, the rise in the curve must be due to the closure of the B stomata in the drier air of the greenhouse.

P. M.

12:31 Plant B again placed in damp air.

1:29 Leaf B again placed on pyrometer B. Again the curve indicates that the stomata were more open and rapidly close in dry air. The opening of the stomata in the damp, and the closure in the dry air, was observed in this experiment by means of the horn hygroscope, and these approximately follow the temperature curve.

The above results were confirmed by two more observations on the same Tropaeolum plants. In both cases the stomata of a leaf on the unwatered pot B were opened by damp air. Judging by the temperature curve only, in one case the dry air produced rapid and striking closure, in the other, slow and less obvious closure.

These experiments are not thoroughly satisfactory, since both the well watered and unwatered plants should have been exposed to alternations of dry and damp air; but they show at any rate a degree of sensitiveness to such changes in the unwatered plant which I have not observed in normal plants.

COMPRESSION OF THE STEM.

It is known[11] that compressing the stem in a vise checks the transpiration current. And I have shown[12] that the checked water supply produces closure of the stomata, which apparently reopen when the vise is unscrewed. The following is a temperature record of the same experiment:

EXPERIMENT 97, *fig. 13*. *August 23, 1900*. CLEMATIS MONTANA. A branch placed with the cut end in water.

A.M.

10:23 A leaf on bulb B, an artificial leaf on R.

10:49 Vise screwed tightly to branch below the leaf.

The first effect is a B-cool move, indicating the preliminary opening observed (*loc. cit.*) with the horn hygroscope; followed by a closure of the stomata (B-warm).

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[11] DARWIN, FRANCIS, and PHILLIPS. Proc. Cambridge Phil. Soc. 5:364. 1886.

[12] DARWIN, FRANCIS, Observations on Stomata. Phil. Trans. Roy. Soc. London B 190:555. 1898.

11:55 Vise unscrewed.

The final result is B-cool, *i. e.*, opening of the stomata; the preliminary increased closure, lasting about five minutes, I have not observed elsewhere, and is no doubt the expression of the fact that release from compression does not at once take effect.

P.M.

1:22 Vise again applied.

Preliminary opening followed by closure.

2:19 Vise removed. No effect. This no doubt is due to the vessels being so much crushed that their lumens remain closed even when relieved from compression. In a second experiment on Aug. 24, 1900 with another branch of *Clematis montana* the preliminary opening, 12 minutes, and closure, 24 minutes, were clear, but the effect of removing the vise was very slight. When, however, the branch was cut under water between the vise and the leaf, an immediate cool-move occurred.

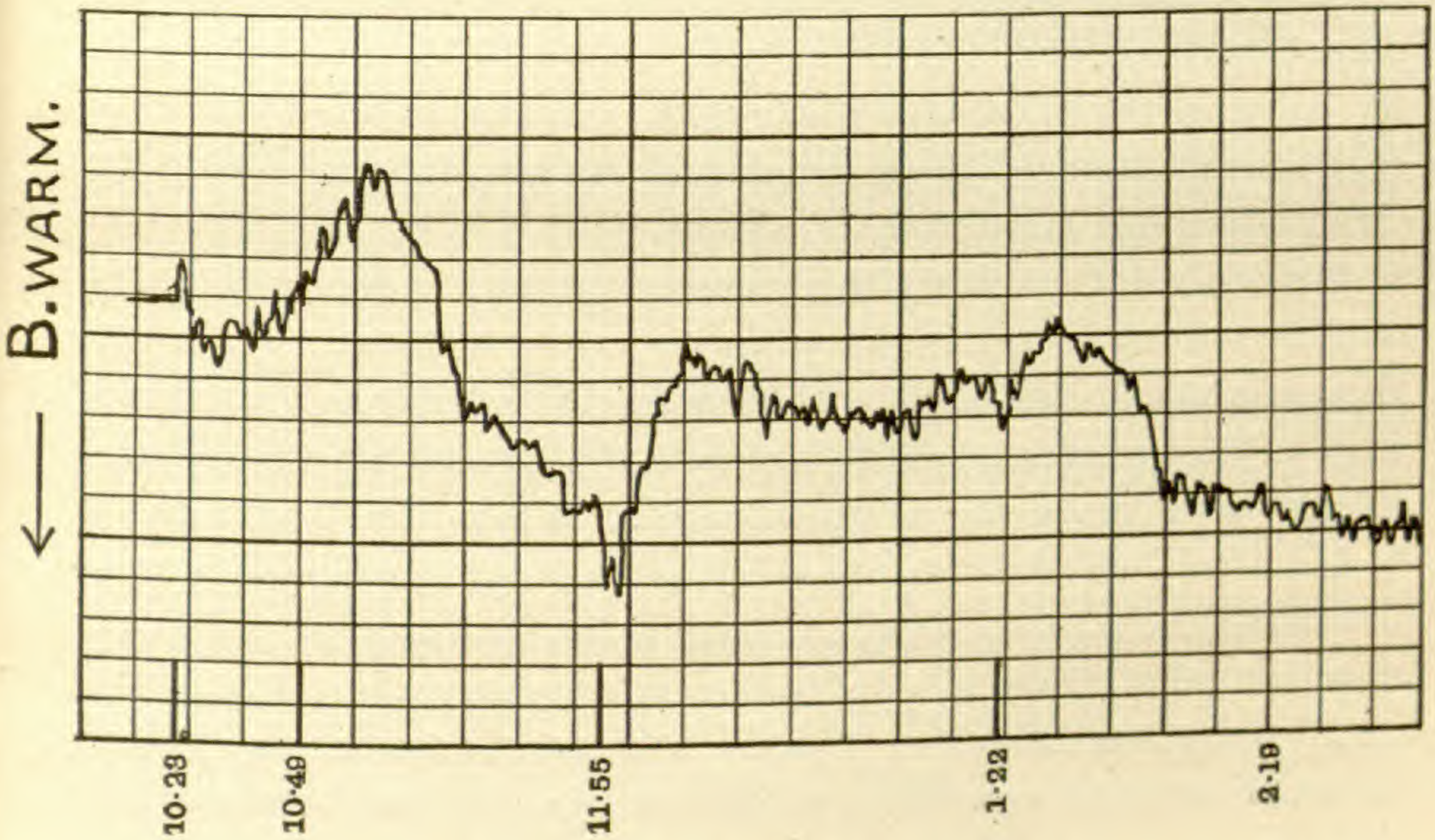

FIG. 13.—See Experiment 97, p. 100.

I have discussed (*loc. cit.*, p. 556) the question whether the increased transpiration which generally follows the relief from compression is really due to the opening of the stomata, or whether the sudden rush of water into the leaf could produce the effect, even though the stomata remained half closed. I see no way of deciding the question.

LIGHT AND DARKNESS.

I made a considerable number of experiments on the diurnal opening and closing of the stomata, using as a control either a leaf whose stomata remain open at night, or an artificial leaf made of damp linen, or a withered leaf. The curves obtained show clearly enough a lowering of the temperature at sunrise, and a rise at sunset, but I have gradually come to think the results not sufficiently trustworthy to be published, and for the present I withhold them.

ARTIFICIAL CHANGES IN ILLUMINATION.

The most interesting results were obtained by artificial darkness. In my early experiments the plan followed was to fix a large horizontal sheet of glass close above the bulbs of the recorder which were placed as near as possible to each other. By covering the glass with black cloth, a considerable diminution in illumination could be produced without any danger of altering the hygroscopic conditions of the air.

Afterwards I managed to produce a greater degree of darkness by adding a curtain, hanging down like a flounce, all round the glass plate. As long as the horizontal glass was uncovered the leaf on the recorder bulb was well-illuminated, as the experiments were made in a greenhouse. When the black cloth was drawn over the horizontal glass the light was sufficiently diminished to produce rapid closure of the stomata; at the same time the other physical conditions are not altered in such a way as to produce a difference in temperature between the two bulbs. In order to make sure that the increase in the leaf temperature (which occurs in darkness) is actually due to stomatal closure and not to purely physical effects, several experiments were made with "artificial leaves." The two bulbs, wet and dry, were placed close together under the flounced glass plate, one bulb being covered with damp linen, the other being left naked, or covered with dry paper on platinum. The effect of alternating periods of light and darkness on the relative temperature was uncertain and variable, and in this respect very different from the results obtained with living leaves. The results with artificial leaves were as follows:

Exp. 79.—There was either no effect on the temperature, or when an effect was produced it was the reverse of the leaf-effect, *i. e.*, the artificial leaf became relatively cooler in darkness, warmer in light.

Exp. 86.—No definite effect on the temperature-curve.

Exp. 89.—The effect of alternate light and darkness was perceptible, and was of the same character as in the case of leaves, *i. e.*, darkness produced a relative rise of the temperature of the artificial leaf. But the curve as a whole is strikingly different from a leaf-curve, both in the slight amplitude and the slow occurrence of temperature change.

Exp. 96.—Four alternate observations of light and darkness produced no visible effect on the relative temperature.

From these experiments I conclude that alternations of light and darkness do not produce alternations in the temperature of a layer of wet linen. This being so, we may, I think, accept the obvious explanation that the temperature changes produced in a living leaf are simply due to opening and closing of the stomata.

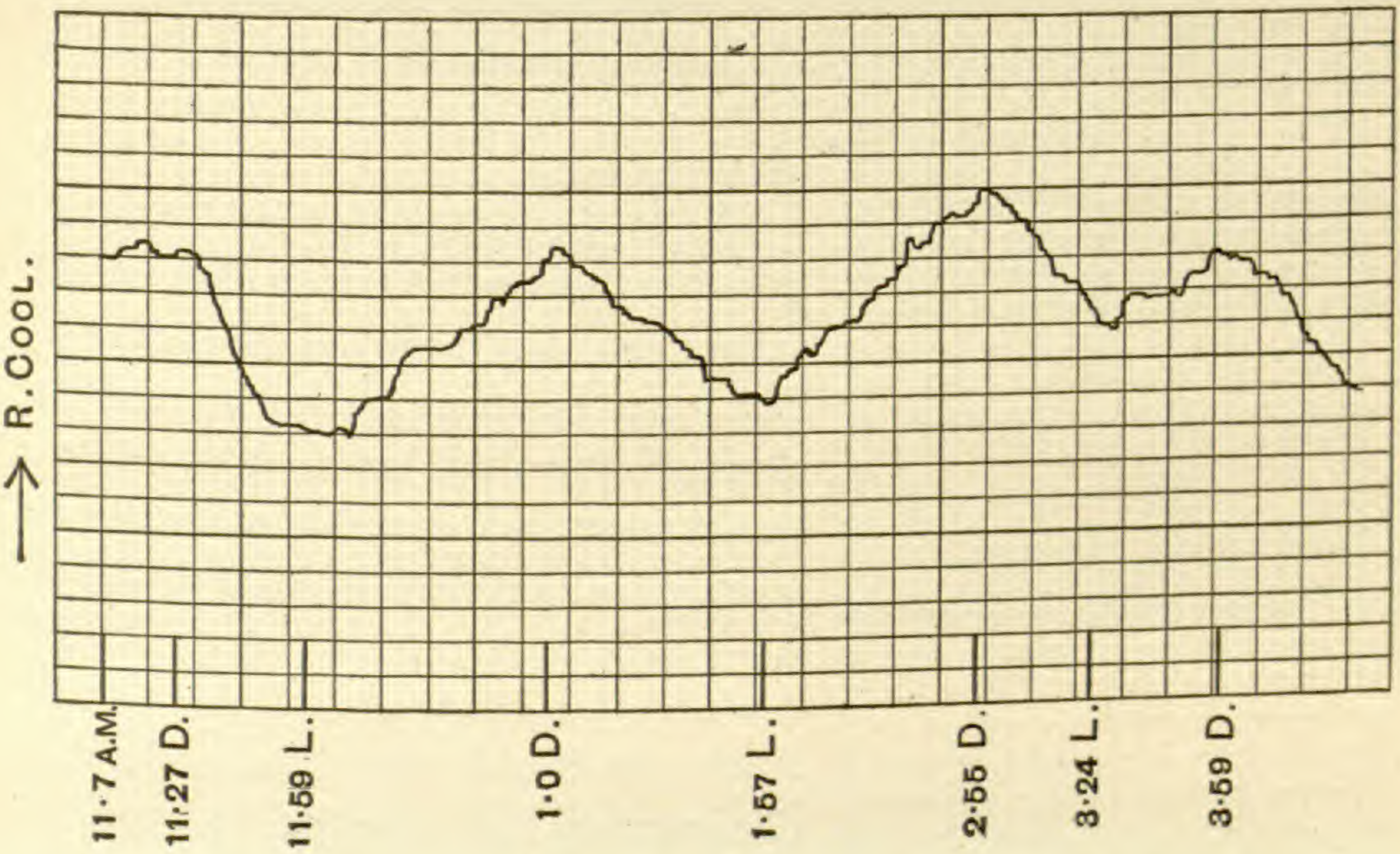

FIG. 14.

EXPERIMENT 62, *fig. 14. March 27, 1900.* NARCISSUS.

The leaf on bulb R, an artificial leaf on B; therefore, an R-cool rise in the curve means an opening of the stomata.

The diagram shows the times at which the illumination was changed, D meaning that the black velvet was drawn over the glass, L that it was removed.

The first two changes at 11:27 and 11:59 A. M. take place somewhat slowly, *i. e.*, from 6 to 10 minutes after the change in illumination, but the later variations in the curve coincide very closely with the letters D and B. The R-cool change at 3:24 is smaller than the others. This is probably an instance of what is usually quite obvious, that late in the afternoon the stomata do not open when illuminated.

EXPERIMENT 77, *fig. 15*. *May 23, 1900.*
CAMPANULA PYRAMIDALIS.

Campanula on bulb B, withered leaf on R; a B-cool fall in the curve means opening stomata.

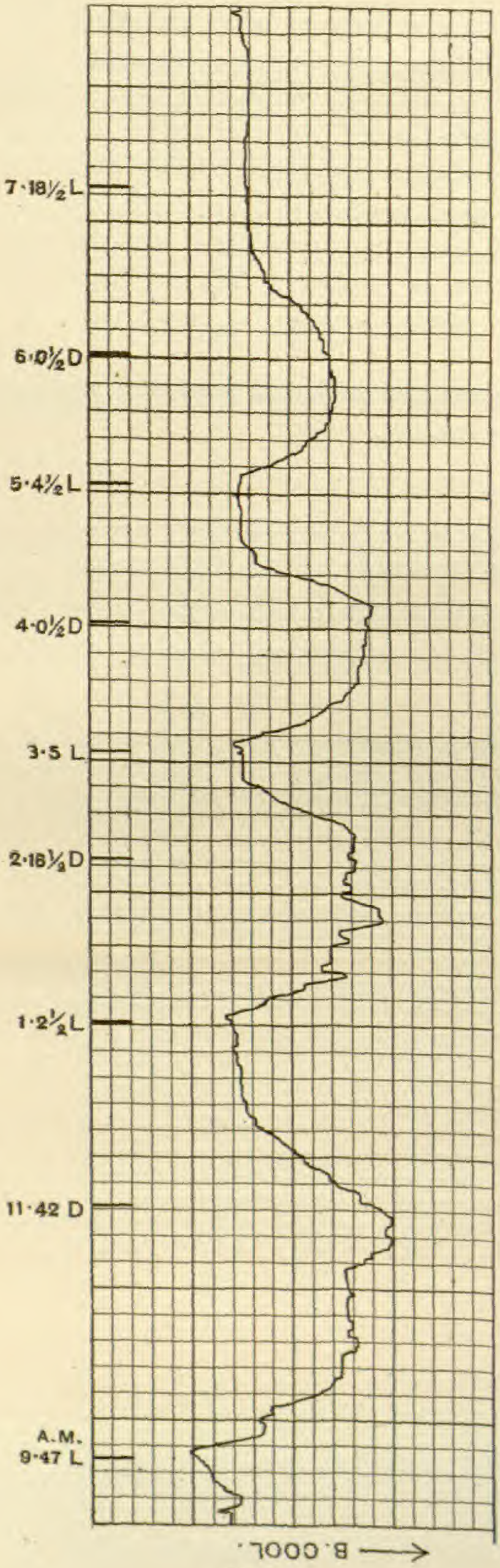

FIG. 15.

As in *fig. 14*, the letters D and L give the times at which the black velvet was replaced or withdrawn. The reaction time varies somewhat through the day, but in many cases the change in the curve follows very closely the change in illumination. At 7:19, *i. e.*, 40 minutes before sunset, the removal of the black cloth produced no effect. In my *Observations on stomata*, p. 596, I called attention to this fact, so that in this respect *fig. 15* and other similar results confirm my former work. But this refusal of the stomata to open at a time approximating to their natural hour for closing is the only evidence of periodicity which I have obtained. It corresponds exactly to some of Pfeffer's experiments on the "sleep" of flowers.[13] On the other hand, my curves do not confirm the more detailed differences between the behavior of the stomata in the morning and afternoon, as given in my *Observations* at the foot of p. 596. This is a difficulty which I hope to clear up.

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Cambridge, England.

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[13] Physiol. Untersuchungen. 1873.

THE ARCHEGONIUM OF MNIUM CUSPIDATUM.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LIII.

G. M. HOLFERTY.

(WITH PLATES V AND VI)

ALTHOUGH the archegonium of mosses has been much studied, the origin of the axial row and the relationships of the various members comprising it have been left in uncertainty. These points can be established best by mitotic figures, but mitosis in mosses must go on very rapidly, for figures are rare; and it is no doubt due to the infrequent observation of mitotic figures that these questions have been left so long in uncertainty and that observers have been led to different views.

For the present work material was collected at the Dalles of the Wisconsin River in Wisconsin, along the Missisisippi River in upper Iowa, near Oberlin in Ohio, at Starved Rock and in the vicinity of Chicago in Illinois. The methods used were those that have been generally approved. Since the terminology used in the various papers dealing with this subject is confusing, it may be stated that that used in this paper is largely that of Janczewski (9).

I am under obligation to Professor John M. Coulter, Professor Charles R. Barnes, and Dr. Charles J. Chamberlain for valuable suggestions during the progress of the work; and also to other members of the Department of Botany who have kindly contributed valuable material.

HISTORICAL.

In 1851 Hofmeister (1) outlined the development of archegonia and antheridia in bryophytes, showing that the earliest stages of both are identical, a fact fully confirmed in the present paper; but his view as to the origin of the axial row in the archegonium and of a similar row in the antheridium receives no confirmation.

Schimper (2), in studying Sphagnum, confirmed Hofmeister's account of the early stages of the archegonium, but did not commit himself in reference to the origin of the axial row.

Leitgeb (5), in examining a few plants of Sphagnum, found a single archegonium in each, directly arising in each case from the apical cell, the first division being transverse.

Kühn (8) investigated Andreaea, and discovered similarity in the very earliest stages of archegonia and antheridia, but outlined the further development of the two organs very much as they are ordinarily understood today.

In 1872 Janczewski's paper (9) appeared, and his conclusions that concern this paper are as follows: The first divisions of the archegonium initial are exactly the same as those of the antheridium, and at this stage the two organs are not distinguishable. The cover cell does not remain inactive, but produces adventitious segments (not exceeding six) and canal initials. The inner cell (the first cell cut from the lower end of the terminal cell) divides to form the central cell and the primary canal initial, and the central cell produces the egg and ventral canal cell. The canal cells have different origins; the lower arising through transverse divisions of the primary canal initials, the remainder through the divisions of the adventitious cells.

Hy (12) in an extensive review of researches on the archegonium supports the views of Janczewski.

In 1895 Campbell (13) gives a detailed account of the development of the archegonium in *Funaria hygrometrica,* agreeing very nearly with that of Kühn for Andreaea. The cover cell acts as an apical cell, cutting off four rows of segments, three from the lateral faces to form neck cells and one from the base to form the axial canal row. The lateral segments divide by vertical walls, making six peripheral cells which later divide by transverse walls; but the canal cells, so far as could be determined, do not divide after they are first formed.

In 1897 Gayet (15) published observations on the development of archegonia in twenty-two genera of mosses and liverworts. His conclusions differ at two critical points from those of other observers, namely the origin of the axial row and the similarity of archegonial development in liverworts and mosses.

He finds that the archegonium in liverworts exhibits both intercalary and terminal growth; that in mosses this terminal growth contributes notably to the length of the organ, five or six adventitious segments being formed at the expense of the apical cell; that the terminal cell does not contribute at all to the canal cells, either in mosses or liverworts; that the neck canal cells all arise from an initial cut from the mother cell of the egg; that two ventral canal cells are occasionally found in Sphaerocarpus, and one such case was noted in Marchantia; and that the ventral canal cell in Marchantia is capable in rare cases of being fertilized in place of the egg.

Goebel (18), having examined the development of archegonia in *Mnium undulatum*, is unable to sustain Gayet's views, but corroborates those of Kühn, Janczewski, and Campbell, namely that the moss archegonium develops in part by segments (some of which are axial) cut from an apical cell; and in this regard is to be distinguished from the liverwort archegonium with its inactive cover cell.

EARLY STAGES OF THE ARCHEGONIUM.

In early stages archegonia and antheridia cannot be distinguished. Enlarged papilliform cells arise from the surface of the receptacle, and segments are cut off right and left from a two-sided apical cell (*figs. 1–10*). This method, just as characteristic for archegonia as for antheridia, agrees with Hofmeister's account (1), but differs from the accounts of Leitgeb (4), Kühn (8), Janczewski (9), Campbell (13), Gayet (15), and Goebel (18) in the absence of a wall that cuts off a basal cell from the archegonium initial or the archegonium mother-cell. When six to eight segments have been cut off, the two-sided apical cell is transformed into a three-sided one, a process that introduces a history distinctly characteristic of the archegonium.

The first indication of this change that marks the organ as an archegonium is seen in a division of the apical cell which results in the introduction of a curved wall more nearly vertical than that which cuts off any preceding segment. The approximately vertical position of this wall causes it to fall upon the same wall below as that which the wall immediately preceding joins (*figs.*

11, 12). This ends the work of the two-sided apical cell and introduces that of the three-sided one, so characteristic of growing organs in the archegoniates. Leitgeb (**4**, p. 6) sought some instances of divergence by which this shift from a one-half to a one-third divergence could be explained, but without success. The transition is abrupt and not by gradual stages. The next division of the apical cell is longitudinal and cuts off a tangential segment from a middle cell. It is evident that the introduction of the last three walls constitutes the beginning of the archegonium proper, and the middle cell the beginning of the canal. All that lies below this constitutes the pedicel, which in mosses comes to be very massive (*figs. 14, 19, 25, 28*) and often very long (*figs. 16, 20, 45, 47*).

While the divisions of the apical cell have been in progress, transverse and longitudinal divisions have been taking place in the segments below (*fig. 12*), only two or three of the lowest segments not being thus divided (*fig. 12*), and the transverse divisions generally appearing first (*fig. 7*). Longitudinal divisions occur in the three peripheral cells, producing a neck of seven cells, a middle cell surrounded by six peripheral cells (*fig. 48, c, d*). The middle cell next divides transversely, producing a terminal cell (*t*) and an inner cell (*i*) (*figs. 13, 14, 18*). There is no dissent from the view that this inner cell in both mosses and liverworts is the first of the axial row and a progenitor of the egg. It divides transversely, giving rise to the central cell (*c*) (*figs. 15, 16, 19, 22*) and the primary canal initial (*p*) (*figs. 19, 22*). The central cell does not divide again until the division which gives rise to the egg and ventral canal cell, gradually increasing in size until its volume is six or eight times that of the neck cell lying next to it (*figs. 24, 33*). The primary canal initial, on the other hand, soon divides, and with the subsequent divisions of its daughter cells helps to form the canal series. It will be seen that the development thus far is practically that of the archegonium in liverworts.[1]

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[1] Compare Leitgeb (**10**), Kny (**3**), Janczewski (**9**, p. 402), Strasburger (**6** and **7**), and other observers who deal with liverworts.

THE TERMINAL CELL AND THE CANAL CELLS.

The most difficult part of the research is to determine the behavior of the terminal cell and that of the canal cells from this period. That the origin of the axial row, including the points just mentioned, is a difficult problem is evident from the conflicting accounts of those who have attempted to solve it. There is quite general agreement, however, that the terminal cell in the mosses does not cease activity after cutting off the primary peripheral cells and the inner cell, as does the cover cell in the liverworts, but continues to increase the length of the archegonium neck by cutting successive peripheral segments from its three lateral faces.

The status of the problem of the origin of the canal series may be summarized as follows: Hofmeister's (**1**) idea that the canal series arises from one of the four original pedicel rows as triangular tangential segments of its cells is mentioned only as a matter of history, the erroneous conception soon being abandoned; Kühn (**8**, p. 31) claims that all the cells of the axial row are cut from the base of the apical cell (*cf.* his diagram, *pl. 10, fig. 71*); Janczewski (**9**, pp. 412, 413) says that the numerous canal cells are of diverse origins, the lower arising through transverse divisions of segments cut from the base of the apical cell; Campbell (**13**, p. 19) says that the segments cut from the base of the apical cell constitute the axial row of neck canal cells, which, so far as could be determined, do not divide after they are first formed; according to Gayet (**15**, p. 241), all the neck canal cells have the same origin, all arising from an initial cut from the mother-cell of the oosphere, and no segments being cut from the base of the terminal cell; and finally Goebel (**18**, p. 244) holds that the moss archegonium is distinguished from that of the liverwort by its characteristic growth from an apical cell, which also contributes canal cells, figuring such a cell in a row of twenty canal cells.

Three sources are thus alleged for the canal cells: (1) the apical cell with intercalary additions; (2) the apical cell alone; (3) not the apical cell at all, but one at the opposite end of the row. Gayet alone holds the process to be like that in the liverworts; the others declare it to be peculiar to mosses. In the full accounts some authors state that this process of basal segment cutting ceases very early; one that it continues late in the growth of the archegonium; and a third implies this, though it is not stated. The disagreement as to time is thus as evident as the disagreement as to method.

It may be argued that the disagreement in these conclusions is to be accounted for by the fact that they are drawn from observations on different forms; yet it would seem that such a process in closely related forms would not be radically different. There seems to be no alternative but to examine the development of the archegonium in a sufficient number of forms to discover whether there is any such thing as general agreement, and as a contribution to this the record of events in *Mnium cuspidatum* is here presented.

In this species the terminal cell continues to cut off successive peripheral segments laterally (*figs. 13–20, 24, 30, 34, 37*), and these increase the length of the archegonium neck. Transverse divisions in the peripheral cells and in the canal cells go on simultaneously (*fig. 15*). The presence of mitotic figures in the same phase side by side in the two rows leaves no room for doubt on this point, and establishes the fact that part of the growth in length of both neck and canal is intercalary. The terminal cell now cuts off a second cell from the lower face. This statement rests on the presence of the mitotic figure shown in *fig. 20*. The search for a figure in this particular cell was a long one, and its value should not be underestimated, for it proves that the terminal cell contributes to the growth of the axial row. The process would seem to be unique, differentiating the mosses from all other archegoniates in this particular.

In this connection it may be stated that careful search was made in the literature bearing upon this and related points for confirmatory evidence of the relationships of the members of the axial row based on the presence of mitotic figures, but no such evidence was found. Hundreds of figures illustrating all stages of archegonial development in both mosses and liverworts were examined, but in none of them are spindles shown. Conclusions in all cases seem to have been reached without the sure evidence of the mitotic figure.

Having shown thus that some cells are added to the axial row by segments cut from the lower face of the terminal cell, it must next be determined whether all or only part of the remainder are thus formed, intercalary divisions being the alternative. Here too the evidence of the mitotic figures will be appreciated, for if found in the row intercalary growth can hardly be questioned. Fortunately these were found, and four such cases are shown (*figs. 24, 31–33*), proving that there are additions to the row by intercalary divisions.

How long the terminal cell continues to act as an apical cell, and whether the cutting off of canal cells ceases before the cutting off of peripheral cells are questions to be asked at this point. The number of cells constituting the row is variable. That the cutting off of cells from the lower face of the terminal cell ceases early, in some cases at least, is evident from *figs. 24, 32, 33*. Here a longitudinal wall through the center of each terminal cell clearly prevents any further additions to the axial row from this source. The presence of such a wall in the terminal cell when the number of cells composing the row was only eight or ten is very common; that in *fig. 24* is exceptionally early. There is no evidence to show that addition to the row from the terminal cell continues in any archegonium later than the age indicated in *figs. 32–34*, and much to show that it does not. Goebel (**18**, p. 244, *fig. 138*, IV) reports one case where such a division has occurred in a row of eighteen or more cells, but the absence of a mitotic figure leaves some room for question.

On the other hand, the production of neck cells by the terminal cell continues till late in the development of the archegonium, but the last divisions for this purpose are always intercalary (*fig. 30*). In many cases the number of cells in the axial row is noticeably less than those in the peripheral rows which inclose the canal row. There does not appear to be any relation between neck rows and canal row in this regard, for in other cases the numbers are nearly equal, and in a few cases those of the neck rows were less than those of the axial row.

THE DIVISION OF THE CENTRAL CELL.

The division of the central cell results in many cases in two cells of nearly equal size. This is well illustrated in *figs. 26–29*, in which the ventral canal cell is nearly as large as the egg. This character strengthens the view that the difference in size and function of the egg and ventral canal cell may not always have existed. In fact, an equality in size and probably in function may reasonably be regarded as a primitive condition; and the existing inequality may be regarded as a specialization, which among pteridophytes and gymnosperms has led to a gradual reduction in the relative size of the ventral canal cell, then to the disappearance of the wall separating its nucleus from that of the egg, and finally to the entire disappearance of any vestige of the cell. Goebel (**18**, p. 242) refers to this approximate equality in size of egg and ventral canal cell in the bryophytes, saying that they are nearly equal in many cases, but that in most cases the egg is larger. He admits that the meaning of this division is not known, but since the ventral canal cell is always present, he is inclined to believe that it has some physiological rôle, and suggests the separation of the chemotactic substance for the attraction of the sperms as a probable function.

The division of the central cell is comparatively late. No case was found where division occurred before a row of seven cells had been formed (*fig. 34*), and very often eight or ten (*figs. 32, 33*). No mitotic figures for this division were found, but the position of the nuclei and the septum, and other features, are such as to leave no doubt whatever concerning the relations of these two cells. A wall separating egg and ventral canal is always present for some time after the division takes place, but not infrequently it disappeared while the remaining septa of the row were still intact.

TRANSVERSE SECTIONS OF THE ARCHEGONIUM.

All the evidence for the development of the archegonium thus far presented has been drawn from longitudinal sections. Several series of cross-sections were made, two of which are presented herewith, and from them the following conclusions are drawn: (1) The terminal cell is triangular in cross-section, inclosed by three peripheral cells which have been cut from it successively (*figs. 48, b, 49, a*). No mitotic figures were found, but the position of the walls and nuclei indicate their origin, (2) The three peripheral cells divide longitudinally and produce a neck of seven rows—six peripheral and one central (*fig. 48, c, d*). These divisions are not simultaneous (*fig. 49, a*) and appear early, for the neck has six peripheral cells at the level of the second nucleus, less than 0.5^{mm} from the apex (*fig. 48, c*). (3) The neck has two peripheral layers near the venter (*fig. 48, j*). (4) The canal is hexagonal in outline and maintains this character till the egg is formed (*fig. 48, i*), and the venter wall breaks up into many cells (*fig. 49, g*). (5) Certain large cells, lying just below the egg and having the appearance in longitudinal sections of being members of the row (*figs. 26, 27*), are found here also, but are clearly no part of the row (*fig. 48, k, l*). (6) The pedicel bears throughout its length the quadrant character given to it by the early longitudinal divisions of the pedicel segments. Beginning at the base, the development upward is through quadrant, octant, and intermediate stages to the base of the archegonium proper, where the pedicel is twelve-celled in cross-section. At this point each quadrant consists of a center cell and two peripheral cells (*fig. 49, g–k*).

THE PERIPHERAL CELLS.

From the mode of origin of the neck of an archegonium of six rows, as already described (*fig. 48, c, d*), it is evident that the cells forming any row do not stand directly over one another, but alternate spirally around it, since they are cut off successively around the apex (*cf.* Janczewski, 9, p. 409). The longitudinal divisions which produce the six neck cells are usually followed by two or more transverse divisions in each cell, giving rise to vertical groups of four (*fig. 23*). In the early pedicel segments only one division occurs, and in some of the later segments division occurs in only one of the two cells arising from the first division, giving rise in such cases to groups of only two or three cells. The axes of these groups come later to stand in an oblique direction (*fig. 23*).

It is well known that as the archegonium approaches maturity there is usually more or less torsion of the neck. I am disposed to attribute this torsion to the alternating arrangement of the peripheral cells as a disposing cause, if not the efficient cause. Janczewski (**9**) noticed both the alternation (p. 408) and the torsion (p. 410), but did not relate them. Campbell (**13**, p. 194) calls attention to the fact that the rows are not vertical, but says that the neck cells do not stand in vertical rows, but are somewhat obliquely placed owing to the torsion of the neck during its elongation. This explanation would account for the cells not being in vertical rows, but leaves out the fact that the cells never were in vertical rows, but in oblique rows from the first, owing to the way in which they were cut from the terminal cell. A study of *fig. 19* will show that as the cells composing each group lengthen in their growth torsion must be inevitable.

THE HOMOLOGY OF ARCHEGONIA AND ANTHERIDIA.

The question of homology of archegonia and antheridia is not new. Homologies in the development of male and female sex organs and of the gametes themselves among the lower forms are well established, as mentioned by Goebel (**18**, p. 243). This has been a more difficult problem for organs as stable as archegonia and antheridia. The archegonium is highly differentiated, but maintains its form and other characters so constantly that it serves as the important structure in establishing the natural relationships of several great groups of plants. It is so different in form and function from the antheridium that attempts to homologize the two organs on general features have not been successful. Goebel (*l. c.*) admits that in the mosses very great differences in structure of the sex organs exist from the very beginning of their development, and thus implies the difficulties that lie in the way of homologizing these organs. I shall attempt to establish the homology of archegonia and antheridia by showing the homology (1) of the early stages, (2) of the cells of the axial row, and (3) of the axial row series and sperm mother-cells.

1. *Homology of early stages.*—Both organs start from papilliform superficial initials, increase in length through the alternate

divisions of a two-sided apical cell, and from these early segments a pedicel is formed. From the cells supported by the pedicels arise the sterile external wall of the gametangium, and the fertile gamete mother-cell tissue inclosed by the wall. Both organs are closed while developing, but organize special regions in which apertures appear at maturity.

2. *The homology of the axial row series.*—That the cells composing the axial row constitute a homologous series is indicated by development of the row. In the first place, egg, ventral canal cell, and neck canal cells are all closely related in origin. They are all the progeny of either a single cell cut from the truncate apex of the terminal cell (Riccia), or of such a cell and subsequent cells cut from the same region in identically the same way as the first (Musci). Again, egg and ventral canal cell are sister cells, and at the time of formation are not widely different in size or appearance (*figs. 26, 28, 29*). It appears possible even that the ventral canal cell or the lowest canal cell may function as the egg.

The theory that the ventral canal cell is an abortive egg is strongly supported by Chamberlain's account of Pinus (**17**), in which the ventral canal cell is occasionally organized as an egg and in rare cases may function as such. Ikeno (**19**) from a study of Ginkgo, and Land (**21**) from his study of Thuja have arrived at similar conclusions. Gayet (**15**) reports an instance in Marchantia where the ventral canal cell was fertilized instead of the egg, but unfortunately the specimen was not saved, nor was a figure made. My own observations on Mnium yielded a case in which the ventral canal cell had outstripped the egg in growth (*fig. 42*), and doubtless would have been fertilized in place of the egg. It is possible in cases of this nature (*fig. 42*) that the larger of the two cells may be the lowest cell of the canal row and would later have given rise to a ventral canal cell and an egg.

Another unusual case which supports this homology is seen in *fig. 43*. Here there are two eggs each with its own ventral canal cell. There can hardly be any doubt that either or both of these eggs could have functioned and produced embryos, had fertilization taken place. There are two ways in which this phenomenon can be accounted for: first, the central cell may have divided very early, giving rise to two central cells, each of which later divided and gave rise to an egg and ventral canal cell; second, the lowest canal initial may have acted as a central cell, producing by its division an egg and ventral canal cell. Coker (**22**, p. 137) has reported and figured a similar case in Mnium, and regards the supernumerary egg as derived from the lower neck canal cell. The absence of septa is to be noted in each instance, a condition not infrequent in gymnosperms.

Campbell (**14**) figures an archegonium of Geothallus which apparently had cut off successively two ventral canal cells, and there is no wall separating the second cell from the egg. There is here the possibility that the two ventral canal cells may be the result of a division of the original ventral canal cell instead of successive divisions of the egg. This view is suggested by the position of the nuclei of the ventral canal cells, both of which are in contact with the septum.

We are disposed to attribute the vigor and consequent supremacy and potency of the egg in bryophytes, just as we do that of the lowest megaspore in angiosperms, to the advantages of nutrition, that is, it is the cell nearest the source of supply. It would be an interesting problem to determine whether by nourishing the canal cells and starving the egg the former could be made to assume the function of the latter. *Figs. 42* and *43*, as also the case in Marchantia noted, seem to suggest that they could do so. At least it is clear from the illustrations here given that there is more or less fluctuation in the origin and work of the cells of the row, and that under certain conditions other closely related cells may do the work of the egg. The cases enumerated seem to furnish sufficient evidence to support the view that the cells of the row are homologous.

3. *Homology of the axial series and sperm mother-cells.*—Another line of evidence indicating the homology of archegonia and antheridia is offered by a number of abnormal forms that constitute a series lying between normal archegonia and antheridia. Bisexual organs are by no means rare. That egg and sperms can

develop in the same gametangium (*fig. 40*), which combines the form, structure, and mode of development of the two sex organs, certainly shows a close relationship between the organs which ordinarily produce egg and sperms separately. We have seen how close is the relationship between the members of the axial row. The central cell and the primary canal initial are sister cells; the division of the former produces two sister cells—egg and ventral canal cell—and the division of the latter also produces two sister cells—canal cells. We find, further, that the second pair may with other canal cells divide longitudinally and produce two canal rows (*figs. 35–37*). An organ of this nature, with its egg and ventral canal cell, with its double-walled venter and single walled neck, must still be looked upon as an archegonium, even if it has deviated slightly from the type. But when the canal members break up by successive divisions until we have an organ such as that shown in *fig. 40*, where the canal row is lost in sperm mother-cells; or that in *fig. 45*, where the egg is lost, but other members of the canal series are retained as a row, we can no longer regard the organ as an archegonium, but must look upon the first (*fig. 40*) as a bisexual organ and the second (*fig. 45*) as a modified antheridium. It will be seen that these three forms—modified archegonium (*fig. 37*), bisexual organ (*fig. 40*), and modified antheridium (*fig. 45*)—constitute a progressive series leading from the normal archegonium to the normal antheridium.

In addition to the abnormal forms already mentioned, two important cases of the apparent conversion of archegonia into antheridia have been reported from different parts of Europe by Lindberg (**11**) and de Bergevin (**20**). In these cases, which are quite similar, a radical change in the life-history of the organs appear. Each organ begins its development with the characters of an archegonium, but closes it bearing the evident characters of an antheridium. De Bergevin gives no sections of the organs, but only a series of external views representing a normal antheridium, an archegonium, and various club-shaped organs leading up to a second antheridium more than twice the length of the first. He speaks of the process as an interconversion of the sex organs. It is doubtful if we should look upon this as a conversion of an archegonium into an antheridium, but rather as the development of a bisexual organ, or a modified antheridium.

These cases seem sufficient to establish the homology of antheridia and archegonia, and point to their derivation from a structure in which eggs and sperms had not yet been differentiated. As an illustration, attention may be called to the fact that in Selaginella the microsporangia and megasporangia are differentiated from primordia which are doubtless indifferent and capable under suitable conditions of producing either kind of sporangium. In this case the microsporangium has deviated less from the structure of the hypothetical sporangium of the homosporous ancestor. Mnium furnishes an illustration of an analogous process, the probably indifferent primordia differentiating into antheridia and archegonia, the antheridia deviating less from the structure of the hypothetical ancestral gametangium. Here, as in Selaginella, the organ which has become most profoundly modified contains vestigial structures which indicate its ancestry and the method by which it has become modified.

THE ORIGIN OF THE ARCHEGONIUM.

The origin of the archegonium and its development into the distinct female organ has never been satisfactorily worked out. There has been some attempt to relate it to the oogonia of Chara or Coleochaete, but no serious claim could now be made for this. To derive the bryophyte antheridium from that of some member of the Chlorophyceae would seem to be a less difficult task.

Barnes (**16**, pp. 277–290) has distinguished between simple and compound spermaries and ovaries, using these terms to designate sperm-producing and egg-producing organs, the simple organs being confined to algae and fungi. The compound spermary could be derived from the simple one by the formation of walls at the time the sperm cells are organized, and by the sterilization of an outer layer of sperm mother-cells for protection. The latter process would be a most natural one in case the plant was forced to change from an aquatic to a terrestrial habitat. In lectures on the bryophytes at the University of Chicago, Barnes has suggested the derivation of the archegonium from some form of primitive compound gametangium. In such a case, by sterilization, a protective wall was secured and the number of gametes greatly reduced, perhaps to a single row as the form took on terrestrial habits. Barnes (**16**, p. 289) regards each member of such a central row as the homologue of a simple ovary. These undergo sterilization from the apex downward, a natural consequence of conditions of nutrition when the eggs are retained in the ovary. Such a process of progressive sterilization would not occur in the antheridium since the formation of a large number of simple sperms is the function, and with this effected the work is done. The egg, on the other hand, must provide for the development of the young sporophyte and requires an abundant store of food for this purpose.

Recently Davis (**23**) has proposed a theory for the origin of the archegonium that has very much in its favor. Because there seems to be no organ among the heterogamous algae from which the archegonium could have arisen, Davis goes to the lower Phaeophyceae for a type to illustrate his views. He takes the asexual plurilocular sporangium of certain Ectocarpaceae as a starting-point. From the asexual zoospores of such an organ sexual gametes arise through differentiation. With sexuality established, the gametangia differentiate until organs are reached from which archegonia and antheridia can be produced by processes already indicated. The aperture at the apex of each organ is significant, and the sterilization of all the gamete mother-cells but one a great advantage to the egg. Davis goes a step further and records that under certain conditions, *Schizomeris Leibleinii* and Draparnaldia have developed zoospores in organs that strikingly resemble plurilocular sporangia; and he is disposed to look upon these structures as forerunners of well-differentiated plurilocular sporangia in the Chlorophyceae.

These views of Barnes and Davis seem to be in the right direction; though it is understood that in any case it is necessary to assume the existence of heterogamous Chlorophyceae of which we have no knowledge at present. Since these views have been advanced considerable evidence in their support has been accumulating, and several cases in Mnium, described in the preceding pages, would seem to support them. The modified organs just discussed (*figs. 36, 37, 45, 46*), and the archegonia taking on antheridial characters in their development reported by Lindberg (**11**) and de Bergevin (**20**), I interpret as indicating that the archegonium is the more specialized of the two organs, and that its atavistic tendency is toward the sporangium-like form and structure of its ancestor. It is natural, since the antheridium is less differentiated, that this atavistic tendency of the archegonium should express itself by first taking on antheridial characters. This it does by its reduced row breaking up again into gamete mother-cells (*fig. 40*); by the neck enlarging (*fig. 40*, also de Bergevin **20**); by its wall tissue becoming chlorophyll-bearing; by the loss of egg and ventral canal cell (*figs. 45, 46*); and by its assuming a general antheridial aspect. A vestige of these processes is also seen in very many archegonia where the expanded apical regions inclose masses of indefinite cells. The explanation offered for the appearance of these expanded apical regions has been that they arose on account of the stretching in a tangential direction of the peripheral cells (Janczewski **9**); but I interpret this as nothing more than an expression in every archegonium of this atavistic tendency. This view of the occasional partial atavism of archegonia expressing itself in antheridial characters bases itself upon the common origin of the two organs from a primitive organ of a sporangial nature, and upon the demonstrated homology of archegonia and antheridia.

SUMMARY.

1. The receptacle is flat-topped with many papilliform cells on its surface, which give rise to archegonia, antheridia, and paraphyses.

2. Archegonia arise from single superficial cells not distinguishable at first from those which give rise to antheridia.

3. The first two divisions of the archegonium initial are oblique and give rise to a two-sided apical cell.

4. The succeeding divisions up to as many as six are from the faces of this two-sided apical cell, archegonia and antheridia agreeing in this regard.

5. Longitudinal radial divisions follow in these segments and form a pedicel of four rows.

6. In the young archegonium the two-sided apical cell gives place to a three-sided one which is truncate.

7. This terminal cell divides transversely soon after its formation, giving rise to the first cell of the axial row.

8. The terminal cell adds to the growth of the neck by segments cut from its three lateral faces, and to the growth of the axial row by segments cut from its truncate face.

9. Growth in length of the archegonium neck is intercalary as well as apical in both the neck and canal rows.

10. The canal series is not always a single straight row, but sometimes double for a greater or less distance.

11. The peripheral cells are not in vertical rows, but alternate with preceding cells; and torsion is a consequence of this feature.

12. The egg and ventral canal cells are often of nearly equal size.

13. The cells of the axial row are homologous with each other and with sperm mother-cells.

14. Archegonia and antheridia are homologous structures throughout.

15. The breaking up of the axial row into sperm mother-cells is an expression of partial atavism on the part of the archegonium.

16. The mass of indefinite cells in the apex of the archegonium neck is the vestige of this atavistic tendency on the part of the archegonium.

17. Archegonia and antheridia probably had a common origin. Hypothetically, the structure from which they have been derived was an asexual multilocular terminal zoosporangium of some primitive extinct member of the Chlorophyceae; the course for the archegonium being through a gametangium possessing more than one functioning gamete.

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EXPLANATION OF PLATES V AND VI.

The figures were all made with an Abbé camera. The lenses used were Bausch and Lomb 1 and 2-inch oculars and $\frac{1}{6}$ objective, and Leitz $\frac{1}{12}$ oil immersion. The plates have been reduced one-half in reproduction, the magnification before reduction being 930, except for *figs. 45–47*.

FIGS. 1–10. Archegonium initial and pedicel segments.

FIG. 1. Papilliform archegonium initial rising above the surface of the receptacle.

FIG. 2. After first division, showing first wall oblique.

FIG. 3. Second wall laid down, forming the two-sided apical cell (*X*).

FIGS. 4–7. Successive stages in ditomic segmentation up to the introduction of the eighth wall; segment cells (*s*) dividing.

FIGS. 8–9. Lateral views of the archegonium initials represented in *figs. 2* and *4*.

FIG. 10. Lateral view of a young archegonium after vertical radial division of the pedicel segments, *cf. fig. 49*, *p*.

FIGS. 11–22. Showing origin of archegonium mother-cell and other members of the axial row.

FIG. 11. Young archegonium showing first peripheral cell (*r*) cut from archegonium mother-cell (*m*); this division is the first character clearly distinguishing the young archegonium from the young antheridium.

FIG. 12. Young archegonium farther advanced; the archegonium mother-cell (*m*) has divided, giving rise to the terminal cell (*t*) and the inner cell (*i*).

FIG. 13. Young archegonium, lateral view; inner cell (*i*) and second peripheral cell (*r*) cut off.

FIG. 14. Young archegonium; prophase of mitosis in inner cell (*i*).

FIG. 15. Young archegonium; metaphase of mitosis in both the peripheral (*r*) and inner cells (*i*).

FIG. 16. Young archegonium; metaphase of mitosis in inner cell (*i*).

FIG. 17. Young archegonium showing primary canal cell (*p*) and central cell (*c*) resulting from division of the inner cell.

FIG. 18. Young archegonium; same stage as that shown in *fig. 13*.

FIG. 19. Young archegonium; same stage as that shown in *fig 17*, but with pedicel farther developed.

FIG. 20. Young archegonium showing mitosis in terminal cell preparatory to cutting off the second canal cell; this feature distinguishes the moss archegonium from all others.

FIG. 21. Young archegonium showing transverse division in a peripheral cell; the section in this region is tangential, not diametral.

FIG. 22. Young archegonium showing increase in size of central cell and progressive work of terminal cell.

FIG. 23. Tangential segment from young archegonium; each peripheral cell has divided once; a second division has occurred in most of resulting cells; torsion of neck probably due to this arrangement of groups.

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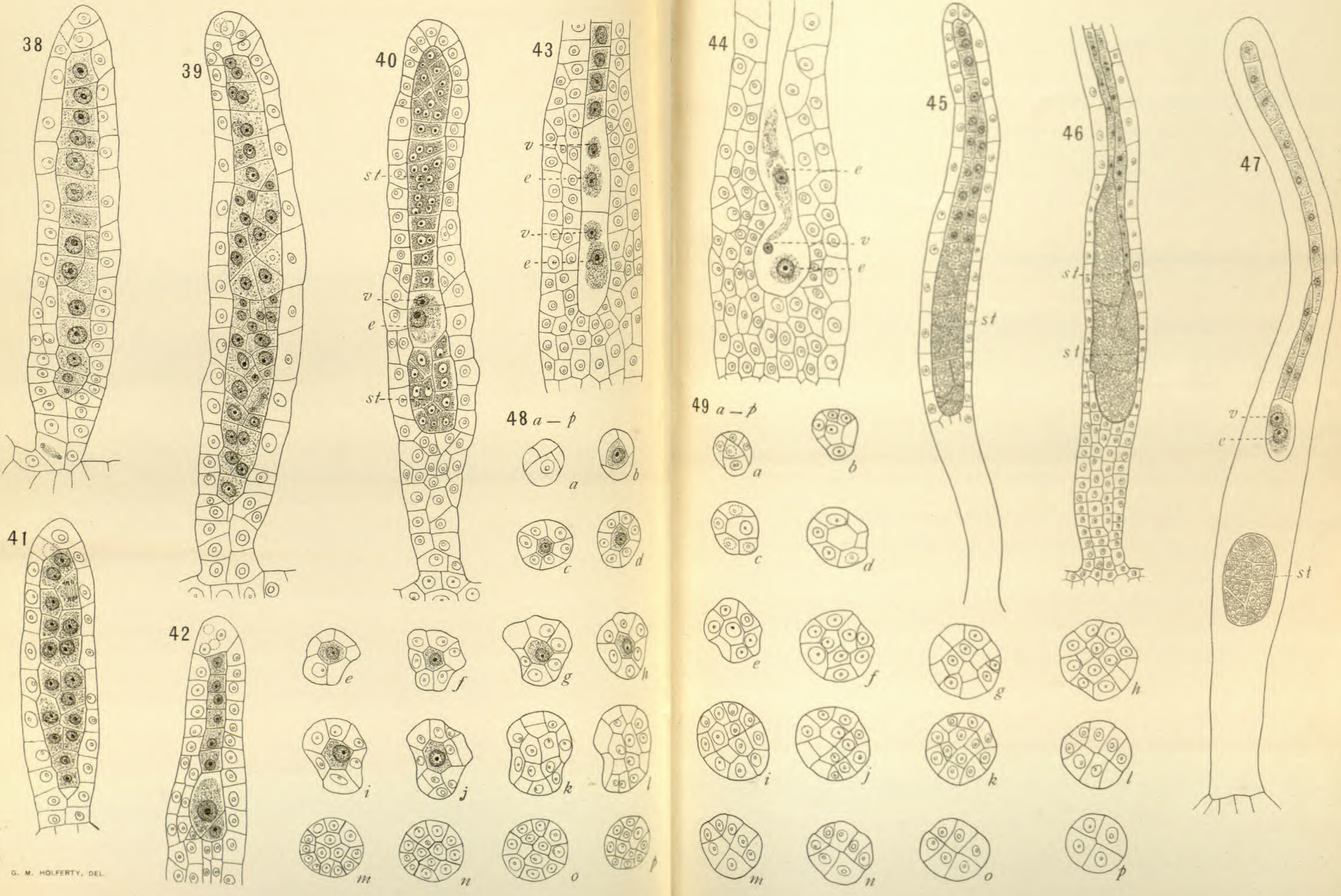
HOLFERTY on MNIUM.



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HOLFERTY on MNIUM.

FIG. 24. Archegonium showing division of third canal initial and rapid increase in size of the central cell; basal work of terminal cell apparently closed.

FIG. 25. Archegonium showing axial row affected by method of peripheral segment cutting (see *fig. 23*); work of terminal cell not finished; venter double walled, pedicel very massive.

FIGS. 26–29. Venters after recent division of the central cells; eggs and ventral canal cells of nearly equal size; egg cells showing masses of chromatin thrown off into the cytoplasm — an occurrence quite common for eggs, less so for ventral canal cells; evidences of a row below the egg in *figs. 26–28*.

FIG. 30. Tip of a mature archegonium, showing that last divisions in both neck and axial row have been intercalary.

FIG. 31. Venter with egg and ventral canal cell; lowest canal cell dividing showing that intercalary growth takes place after the cutting off of the ventral canal cell.

FIGS. 32–33. Young archegonia with remarkably large canal cells; central cells not yet divided; intercalary divisions taking place in last cells of the axial rows; both mitotic figures show bodies resembling centrospheres; basal segment cutting of apical cells completed.

FIG. 34. Egg and ventral canal cell, and seven canal cells; no division of central cell found earlier; upper canal cell appears to be produced by the terminal cell; longitudinal division of terminal cell prevents further basal segment cutting; intercalary growth of neck in progress as shown by mitotic figures; venter double-walled to an unusual distance above the egg.

FIG. 35. Young archegonium slightly abnormal, showing beginning of two axial rows near apex.

FIG. 36. Part of neck of an old archegonium, showing two axial rows for a short distance.

FIG. 37. Tip of an abnormal archegonium having two axial rows, each with its own apex and apical cell.

FIG. 38. Young antheridium modified by the possession of archegonium characters; the members of an evident axial row are separated by transverse walls; these cells dividing to form two rows; the double wall in the lower part and the two undivided large cells opposite to it are indications that this specimen might have produced a bisexual organ of the nature of that shown in *fig. 40*.

FIG. 39. Young antheridium further advanced; the double axial row with transverse walls are archegonium characters.

FIG. 40. A bisexual organ with evident archegonial and antheridial characters; the egg, ventral canal cell, and adjacent canal cells; the divisions to form a double-walled venter; the elongated pedicel and the terminal cell are undoubted archegonial characters; the oblique and irregular primary

walls and the spermatogenous tissue are antheridial characters; several similar organs were found.

FIG. 41. A young normal antheridium; in mature antheridia distinct regions of spermatogenous tissue can be detected representing each of these primary cells.

FIG. 42. A young archegonium with a cell cut from the lower part of central cell; whether the larger cell represents the ventral canal cell and the smaller one the egg could not be definitely determined.

FIG. 43. A venter containing two eggs and two ventral canal cells; whether the upper cell is the lowest canal cell divided or the original ventral canal cell divided could not be determined.

FIG. 44. A double venter with two eggs; all cross walls have disappeared.

FIGS. 45–46. Abnormal antheridia; in each case the mass of spermatogenous tissue is separated by the primary walls into distinct regions characteristic of antheridia; each organ has an outlet of two axial rows which before reaching the apex becomes one row; in *fig. 46* there are two masses of sperm tissue, each with its own axial outlet; the pedicels and necks are distinctly archegonial characters.

FIG. 47. A modified archegonium with traces of two 'axial rows, and a mass of sperm mother-cells developing in the elongated pedicel.

FIG. 48, *a–p*. Cross-sections of an archegonium from the terminal cell to the lower part of the pedicel; the middle cell and the three peripheral cells cut from it shown in *b;* the central cell and double wall of venter are shown in *j;* and the quadrate character of the pedicel in *n* and *o*.

FIG. 49, *a–p*. Cross-sections of an archegonium from terminal cell to base of pedicel; the massive character of pedicel shown in *f–i;* the four basal cells not divided (*p*).

STUDIES ON SOME ANOMALOUS DICOTYLEDONOUS PLANTS.

CHARLES E. LEWIS.

(WITH PLATES VII AND VIII)

HISTORICAL.

SEVERAL genera commonly referred to the dicotyledons differ from the typical ones both in the structure of the flower and in the form and arrangement of the vascular bundles. Among these anomalous dicotyledons are certain Nymphaeaceae, Ranunculaceae, and Berberidaceae, which have been referred to dicotyledons chiefly on account of the structure of the mature embryo.

The striking resemblance of the Nymphaeceae to the Alismales, which are typical monocotyledons, has led to the study of the development of the embryo in certain genera of the former in order to determine the origin of the structures found in the mature embryo. The first work of this kind was done by Lyon (1901), who investigated the development of the embryo of Nelumbo. He found that the two large fleshy bodies of the mature seed seemed to be lobes of a single cotyledon which has its origin as a crescentic ridge of tissue, partly surrounding the plumule and later bifurcating to form what appears as two cotyledons.

Cook (1902) published the results of a study of the embryo sac and embryo of *Nymphaea advena* and *Castalia odorata.* He describes the embryo as monocotyledonous and agrees with Lyon that the Nymphaeaceae should be regarded as monocotyledonous.

In a paper which appeared a short time after that of Lyon, Campbell (1902) calls attention to the affinities of certain anomalous dicotyledons. It is pointed out that the embryo of the mature seed and the seedlings of certain Ranunculaceae and Berberidaceae, as observed by Lubbock and Holm, show the petioles of the cotyledons grown together where the edges are in contact, thus forming a tube which extends down to the plumule and in some cases is quite long. In the light of Lyon's work on Nelumbo, the tube surrounding the plumule suggested to Campbell the possibility of a like origin of the cotyledons in these forms and a lateral origin for the plumule as in monocotyledons.

In the light of these facts, and because of our limited knowledge of the embryology of the so-called anomalous dicotyledons, it seemed desirable to study the embryology of several of these forms.

As the Berberidaceae include peculiar and varied plants, many of which differ widely from the typical Berberis, it was decided to begin work on certain representatives of that family, in which it seems that little of importance has been done on the development of the embryo. Holm (1899) has traced the development of *Podophyllum peltatum* from the seedling to the flowering plant, and both Dickson and Lubbock have observed the seedlings of *Podophyllum Emodi*, the Asiatic form. All agree in the description of a long cotyledonar tube with a very small plumule at the bottom, and that the cotyledons are peltate in form, the two together resembling the single leaf of the second year. Holm makes the statement that the cotyledons really represent a single leaf of this plant.

COLLECTION AND METHODS.

Material for all stages in the development of the embryo of *Podophyllum peltatum* and *Jeffersonia diphylla*, together with ripe seeds for germination, were collected during the spring and summer of 1902. The stages of *Caulophyllum thalictroides* important for this study were also secured. The material was fixed in 1 per cent. chrom-acetic acid, washed and brought into 70 per cent. alcohol, where it remained until ready for use. In the older seeds the outer seed coats were cut away in order to allow the fixing fluid to penetrate the tissue of the embryo. The sections were stained with safranin, Bismarck brown, gentian, and orange G. In this manner all morphological and cytological details are clearly brought out.

PODOPHYLLUM PELTATUM.

The mature embryo sac does not differ in any important particulars from that of typical angiosperms. The fecundated egg cell increases appreciably in size, becoming slightly elongated. The first division wall is transverse, and the two cells thus formed elongate rapidly, especially the one which is to form the suspensor. At this stage (*fig. 1*) one synergid is still to be seen near the embryo, but it does not persist for any length of time, as it was not observed in older stages. At this time several endosperm nuclei are seen scattered about within the embryo sac. The antipodal cells are distinct, but they soon begin to disintegrate and are not found in the stage represented by *fig. 5*.

The eight-celled embryo (*fig. 2*) is club-shaped, and the suspensor is rather long, consisting of two or three cells. The body of the embryo soon becomes broadened (*fig. 3*), and at the stage shown in *fig. 4* it is almost spherical. Growth now takes place most rapidly in the longitudinal direction, and at the same time the suspensor becomes somewhat thickened, its cells dividing longitudinally (*figs. 5, 6*). The embryo may now be well described as pear-shaped, although there is some variation in form at this stage. In some cases one side seems to grow more rapidly than the other, and an unsymmetrical form results (*fig. 6*). From the study of a large number of preparations, both longitudinal and cross-sections, it is highly probable that *fig. 5* represents the typical shape of the embryo shortly before the beginning of the development of the cotyledonar primordium. At this time the endosperm fills the entire embryo sac, except a small cavity around the embryo, which is partly filled by material from broken-down endosperm cells.

The origin and development of the cotyledons is peculiar. In typical dicotyledons the cotyledons are supposed to have their origin as two entirely separate and opposite ridges of tissue, standing at the same level, at the broadened distal end of the embryo, so that if cross-sections be made through the base of the cotyledons they would be separate at both sides in the first section in which they appear. Although this mode of origin has been assumed by certain writers, it seems that comparatively little has been done in the investigation of the origin of the cotyledons in the typical dicotyledons, especially by the use of series of cross-sections which are often indispensable in getting the correct orientation of parts. It may be that in many so-called typical dicotyledons there is much variation from what has been described as the accepted origin of the cotyledons. This can be determined only by a thorough and detailed study of a large number of forms.

In Podophyllum the primordium of the cotyledons appears first as a rather broad outgrowth from the margin of the truncated distal end of the embryo, forming an almost complete ring. This is made clear by a series of cross-sections such as *fig. 6*. In this figure *a* and *b* are sections through the broad part of the embryo just beneath the primordium of the cotyledons; *c*, through the plumule and the base of the ridge; *d–l* include the remainder of the cotyledonar primordium. From this figure it is apparent that the cotyledons arise as a single primordium which consists of a circular ridge broken at one side by a notch or indentation. As soon as the ridge has attained a little height, a notch is formed on the opposite side, and we have now two divisions or lobes which will develop into what are considered as two cotyledons. The figure shows that one lobe is slightly longer than the other; but this is not of importance, because in other preparations the two were found frequently to be of equal size.

A later stage is shown in *fig. 7*. The bottom of the first notch together with the cotyledonar primordium has undergone intercalary growth, so that a very short tube has been formed. This series shows that both the ridge and the lobes have increased in height, but the lobes have grown the more rapidly, because their height is now about equal to that of the ridge (compare *fig. 6*), and are of equal size. The open ridge is more prominent at this time than in younger or older stages, the notch first formed being about twice as deep as the other. The edges of the ridge are in contact below, but above they are separated. The growth of the tissue at the bottom of the first notch goes on more rapidly than that at the bottom of the second notch, so that the two tend to become equalized. This greatly increases the length of the cotyledonar tube. *Fig. 8* represents a series of sections from an embryo a little older than the one represented by *fig. 7*. Only alternate sections were drawn. This series makes apparent the great increase in the length of the tube and the almost equal depth of the bifurcations. It seems that the bifurcations do not become of exactly the same depth at any time, as an examination of a number of series from mature embryos did not show them more nearly equal than they are in the stage represented by this figure.

It is very necessary to use series of cross-sections in tracing this development. Median longitudinal sections at right angles to the plane of bifurcation of the cotyledonar ridge present the appearance shown in *figs. 10, 11, 12*, and cannot be distinguished from similar sections of a typical dicotyledon. The ring of tissue and its two divisions increase greatly in length. There does not seem to be a localization of growth in the lobes here, as described for Nelumbo, but the ring itself grows at about the same rate as its two lobes. A narrow opening extends down to the growing point of the stem. The opening is conical just above the plumule, but for most of its length the walls of the tube are in contact.

The hypocotyl is short, and the plumule is but little developed in the mature embryo. The growing point of the stem shows simply a slight protuberance into the conical opening at the base of the cotyledonar tube. The cells of this mound of tissue are slightly different in size and staining properties from those around them (*fig. 13*).

The conducting tissue begins to develop as a central strand of narrow elongated cells, which extends almost to the plumule, where it divides, one division going to each of the cotyledons. The form of the mature embryo is shown by *fig. 14*, which is a diagram to represent a median longitudinal section of a mature embryo. The figure was constructed from micrometer measurements of a series of cross-sections of known thickness. This was found more satisfactory than making a drawing from a longitudinal section, because in the latter it is impossible to distinguish the place where the cotyledonar tube leaves off and the opening between the two lobes begins.

JEFFERSONIA DIPHYLLA.

The development of the embryo sac of Jeffersonia has been described by Andrews (1895). The mature embryo sac differs from the typical form only in the large size of the antipodal cells. The fecundated egg cell elongates and is divided into two cells by a transverse wall (*fig. 15*). The embryo soon elongates, the distal end becomes somewhat broadened, and a definite suspensor consisting of two or three cells is formed. The cells at the distal end are divided by longitudinal walls, but the suspensor remains as a single row of cells (*figs. 16, 17, 18*). In *fig. 18* a synergid is shown which has increased greatly in size. This is an unusual occurrence, as the synergids usually disappear early. By the time the embryo has reached the eight-celled stage a large number of endosperm nuclei can be seen scattered about in the cytoplasm of the embryo sac. The antipodal cells disappear very early.

The suspensor increases in length by the growth and division of the cells composing it. The cells divide by transverse walls until a row of four or five cells is formed. At first the body of the embryo seems to increase in size by the division of its cells in three planes, so that it becomes rounded (*fig. 19*). A little later the body elongates, and the symmetrical form shown in *fig. 20* is produced. Growth now takes place most rapidly in a lateral direction, the distal end becoming broad and truncate. *Fig. 21* represents a stage just before the beginning of the development of the cotyledons. The development of the embryo to this point corresponds very closely with that described for Podophyllum. The cavity surrounding the embryo is small, and the endosperm cells near it do not become so nearly disorganized as in Podophyllum or Caulophyllum.

Examination of longitudinal sections, or of series of cross-sections of embryos in which the cotyledons are somewhat developed, would lead one to the conclusion that Jeffersonia is a typical dicotyledon (*figs. 22, 23*). There is a slight peculiarity in the origin of the cotyledons, however, which is shown by a series of cross-sections at the stage when the cotyledonar primordium first appears. *Fig. 24* shows that the cotyledons really have their origin as a very broad crescentic ridge of tissue. After the ridge has attained a little height it bifurcates, so that two lobes are formed.

In older stages the two lobes are of equal size and the notches are of almost equal depth. *Fig. 23* represents the condition in the mature embryo. Section *a* passes through the body of the embryo just below the growing point; *b* passes through the plumule; the remaining sections pass through the cotyledons. It will be observed that no cotyledonar tube is formed and that the edges of the cotyledons are not close together.

The mature embryo is small, both hypocotyl and cotyledons being short. The plumule has about the same development here as in the mature embryo of Podophyllum, being simply a small mound of tissue between the two cotyledons. The conducting tissue is beginning to develop as a central strand of narrow elongated cells, which divides into two branches, one going to each of the two cotyledons. *Fig. 25* shows the shape of the mature embryo in longitudinal section.

CAULOPHYLLUM THALICTROIDES.

Material for the study of the younger stages in the development of the embryo of Caulophyllum was not secured, but it is hoped that the investigation of the development of the embryosac and young embryo may soon be carried out.

The youngest stages examined show the embryo at about the time when the cotyledons begin to develop. The embryo at this time shows a long, slender suspensor and a rather broad, short body (*fig. 26*). From this longitudinal section the cotyledons seem to arise as two opposite ridges of about equal size, but it is impossible to say that this is the case, as cross-section series of this stage were not secured and series from embryos a little older do not support this view. A cross-section series from an embryo corresponding in size to the one represented by *fig. 27* is shown in *fig. 28*. From this figure it is apparent that the cotyledons have a common base consisting of a low ridge of tissue which bifurcates to form two very symmetrical cotyledons. Older stages show that the bifurcations soon become of almost equal depth (*fig. 29*). The edges of the cotyledons are very close together, so that the plumule is almost inclosed in a tube. The opening just above the plumule is conical as in Podophyllum. The plumule is slightly more developed here than in Podophyllum or Jeffersonia, but consists simply of a mound of tissue. The hypocotyl is longer in relation to the size of the entire embryo than in either of these forms.

SUMMARY.

1. In each of the three plants studied the embryo is small, surrounded by a large amount of endosperm richly stored with starch.

2. In each case the cotyledonar primordium is a broad, ridge-like structure open at one side. This ridge later bifurcates opposite the opening to form two lobes, the cotyledons. The two notches soon become of almost equal depth, so that older stages do not give a correct impression of the origin of the cotyledons.

3. In Podophyllum a long cotyledonar tube is formed, and in Caulophyllum the edges of the cotyledons are close together. The plumule of Jeffersonia is not inclosed in either way.

4. The plumule is not well developed in any of these embryos, but has a central origin in each.

THEORETICAL CONSIDERATIONS.

There are among the angiosperms certain plants which show peculiarities either in their vegetative structure, their embryology, or in both. Some of these plants have flowers of very simple form, and certain botanists believe that in them we have primitive characters, and that the comparative study of a large number of these forms may reveal much concerning the origin of the structures found in more highly developed plants. Others hold that the simple forms represent merely a derived condition, and that their peculiarities are not of the highest value in determining relations, but have been acquired as an adaptation to the conditions under which the plant has developed. All agree that it is important to investigate the development of these plants, because it is only by the accumulation of a large number of facts that we have a basis for definite and reliable conclusions.

There are two points of great interest in the study of these low plant forms, when they are considered as representing primitive characters: first, the possibility of determining something concerning the origin of the angiosperms; and, second, the origin and order of derivation of the monocotyledons and dicotyledons.

The gap existing between the seed-bearing plants and the pteridophytes of the present time is wide, the nearest approach to the seed habit being found in the few heterosporous forms. It seems probable that the seed-bearing plants had their origin from heterosporous pteridophytes of past ages, and that the Gymnosperms and Angiosperms arose independently from different stocks. On the other hand, from certain similarities it seems probable that the monocotyledons and dicotyledons are derived from a common stock. If these two divisions had a common origin, the question arises as to which is the more primitive and how the other has been derived from it. There are two theories concerning this which are diametrically opposed.

The theory advanced by Lyon (1901) is that the single cotyledon is homologous with the foot of the pteridophytes, and that the dicotyledons are derived from the monocotyledons by the bifurcation of the single cotyledon as in Nelumbo. However true this theory may prove to be, it seems necessary that it should be substantiated by a larger collection of facts before it can be of great value. If the study of a large number of anomalous forms should show the ridge of tissue at the base of the cotyledons of varying height, so that a connected series could be built, it would in some measure support this theory, although even then the conditions under which the plants develop would have to be considered, as the peculiarities might represent simply derived conditions.

Opposed to this theory is that of Miss Sargant (1903) set forth in her paper on the origin of the monocotyledons. This observer argues that the monocotyledons are derived from the dicotyledons, the single cotyledon of the former having arisen by the union of the two cotyledons of the latter, and that therefore the dicotyledonous plants are the more primitive. This theory is based on the study of the seedlings of a large number of plants, many of which show the cotyledons grown together at one or both sides.

To determine which of these theories is the more probable will require the study of the embryology and development of the seedlings of many plants in the families which show these peculiarities. Something of value may be learned by growing the seedlings under different conditions and observing results.

The interpretation of such a structure as that found in Podophyllum, or that of Nelumbo as one cotyledon or as two, must be unsatisfactory until a greater number of anomalous forms has been investigated. If the cotyledons of some of the plants which have the other characters of the dicotyledons are found to have their origin as a single ridge, it will support the view that here also we have two cotyledons and not lobes of one. The early division of the ridge in Podophyllum, as well as in Jeffersonia and Caulophyllum, leads to the conclusion that here we have two cotyledons. The fact that a cotyledonar tube is formed in Podophyllum is probably best explained as a derived condition brought about by the geophilous habit of the plant. The hypocotyl is short in comparison with the length of the entire embryo. The plumule is small and develops but little during the first year. The cotyledonar structure is long, so that, while the plumule remains underground in a protected position, the cotyledons are pushed up into the air and sunlight and carry on the work of assimilation. The great length of the cotyledons makes necessary some means of strengthening the part which must support the weight, and this is done by the formation of the tube. The fact that cotyledonar tubes have been found in families far removed from each other, and usually in embryos having a short hypocotyl, supports this view.

In Caulophyllum the ridge does not attain much height, and the later stages show that the notches are of almost equal depth and that the cotyledons are very symmetrical. The hypocotyl is long and the cotyledons short in comparison with Podophyllum. Possibly this explains why no tube is formed.

It is highly desirable to trace the development of the seedlings of Jeffersonia and Caulophyllum for comparison with the conditions found in Podophyllum. Up to this time (March 20) seeds of Podophyllum and Jeffersonia collected last year have refused to germinate. It seems that they require a long resting period and will not germinate until the spring following their maturity. It is hoped that this year the germination of the seeds and the development of the seedlings may be observed.

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EXPLANATION OF PLATES VII AND VIII.

PLATE VII.

FIGS. 1–14. *Podophyllum peltatum.*

FIG. 1. Section of two-celled embryo with large synergid. × 180.

FIG. 2. Eight-celled embryo. × 180.

FIGS. 3–4. Embryos with broad or rounded body and long suspensor × 180.

FIG. 5. Embryo shortly before the beginning of the development of the cotyledonar primordium. × 180.

FIG. 6. A series of cross-sections from an embryo showing the cotyledonar primordium; the sections of all the series shown in the figures are 15μ thick. × 25.

FIG. 7. A series of sections from an older embryo, showing the beginning of the cotyledonar tube, and the bifurcation of the ridge to form two cotyledons. × 25.

FIG. 8. A series of sections from an embryo in which the cotyledonar tube is somewhat developed; the bifurcations are of almost equal depth; alternate sections were drawn. × 25.

FIG. 9. Embryo of irregular shape. × 180.

FIG. 10. Longitudinal median section of an embryo at right angles to the plane of bifurcation of the cotyledonar ridge. × 100.

FIGS. 11–12. Similar to *fig. 10*, but later stages. × 100.

FIG. 13. Longitudinal section through the plumule of a mature embryo. × 180.

FIG. 14. Longitudinal section of a mature embryo of Podophyllum. × 25.

PLATE VIII.

FIGS. 15–25. *Jeffersonia diphylla.*

FIG. 15. Two-celled embryo. × 180.

FIG. 16. A later stage to show that the suspensor becomes long, before longitudinal walls are formed in the cells at the distal end. × 180.

FIG. 17. Eight-celled embryo with large synergid near it. × 180.

FIG. 18. Similar embryo with endosperm nuclei in cytoplasm of embryo sac. × 100.

FIG. 19. Older embryo in which the body is somewhat rounded. × 180.

FIG. 20. Embryo in which the body is more elongated than in *fig. 15.* × 180.

FIG. 21. Form of embryo just before the beginning of the development of the cotyledons. × 180.

FIG. 22. An embryo in which cotyledons are almost developed. × 100.

FIG. 23. A series of sections from a mature embryo.

FIG. 24. A series of cross-sections of an embryo, showing that the cotyledons begin their development as a single broad ridge. × 25.

FIG. 25. Longitudinal section of a mature embryo. × 25.

FIGS. 26–30. *Caulophyllum thalictroides.*

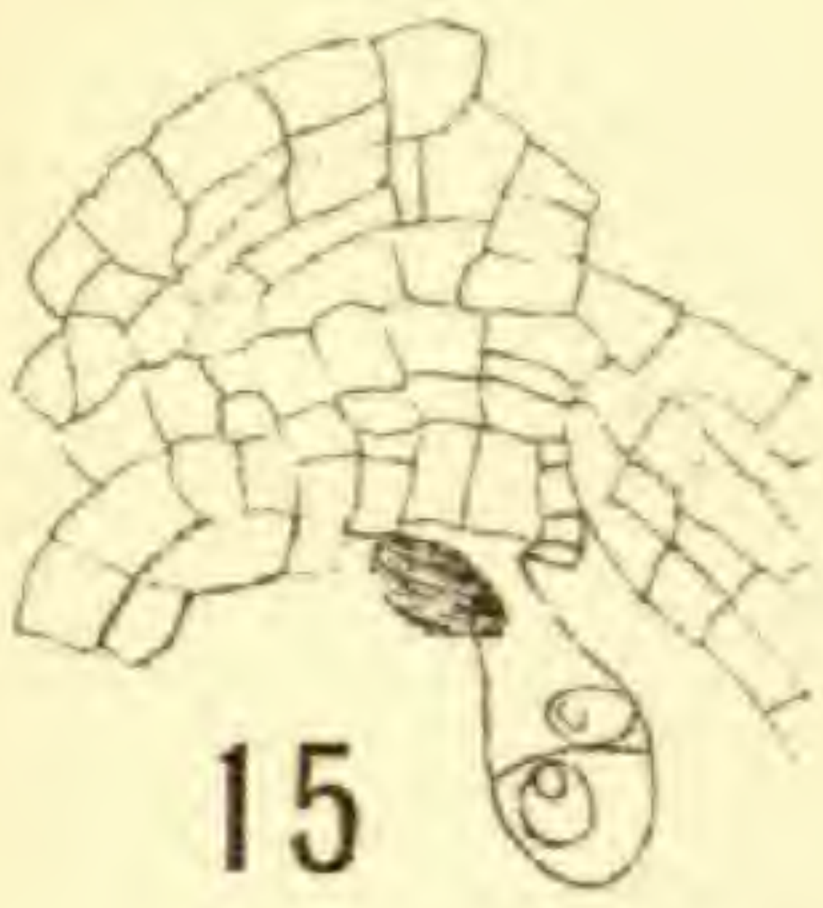
FIG. 26. Embryo at beginning of development of cotyledons. × 180.

FIG. 27. Older embryo. × 100.

FIG. 28. A series of sections through the plumule and base of the cotyledons. × 25.

FIG. 29. A series of sections from an older embryo; the first eight sections are consecutive, the others are alternate. × 25.

FIG. 30. Longitudinal section of a mature embryo. × 25.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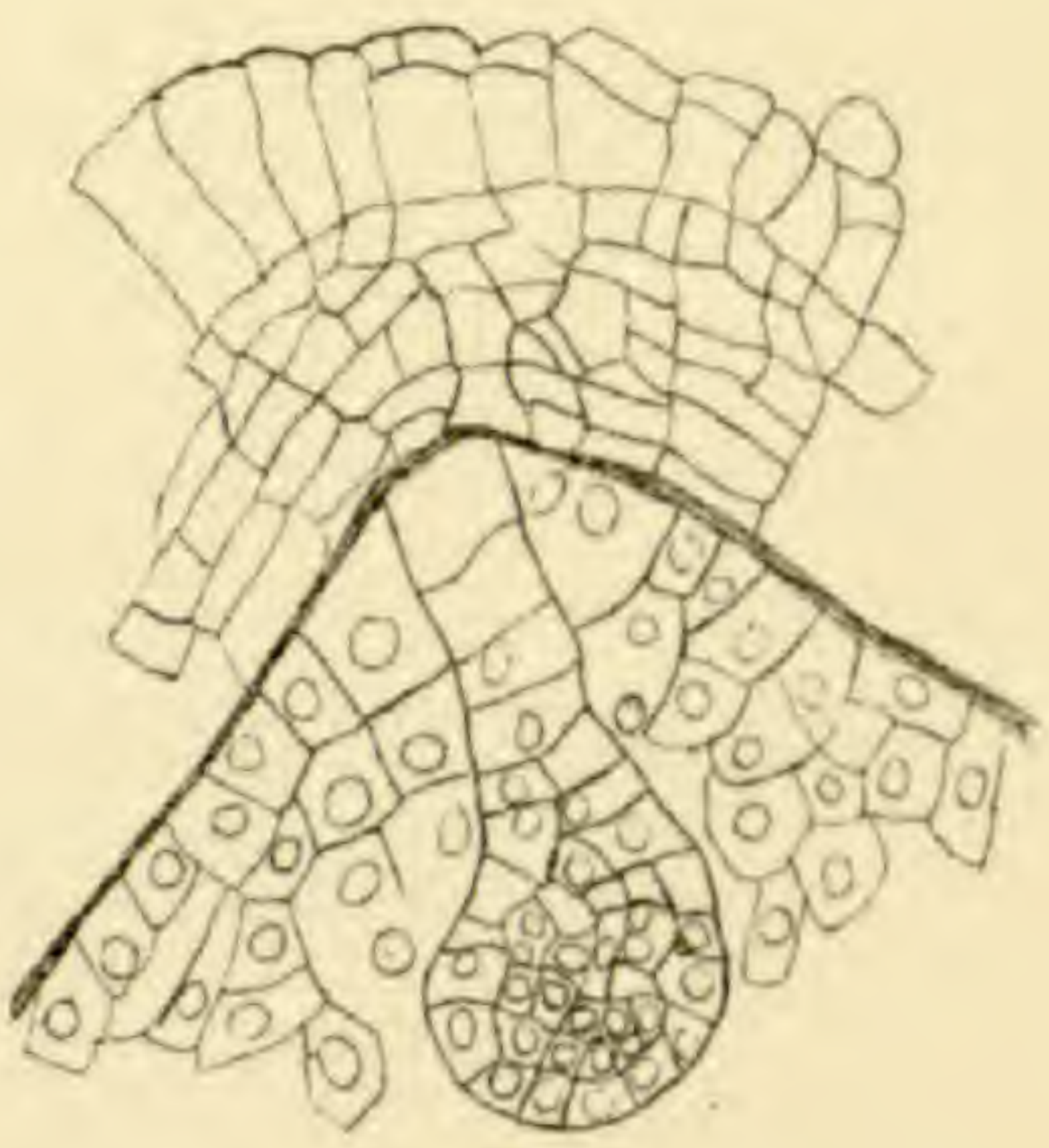
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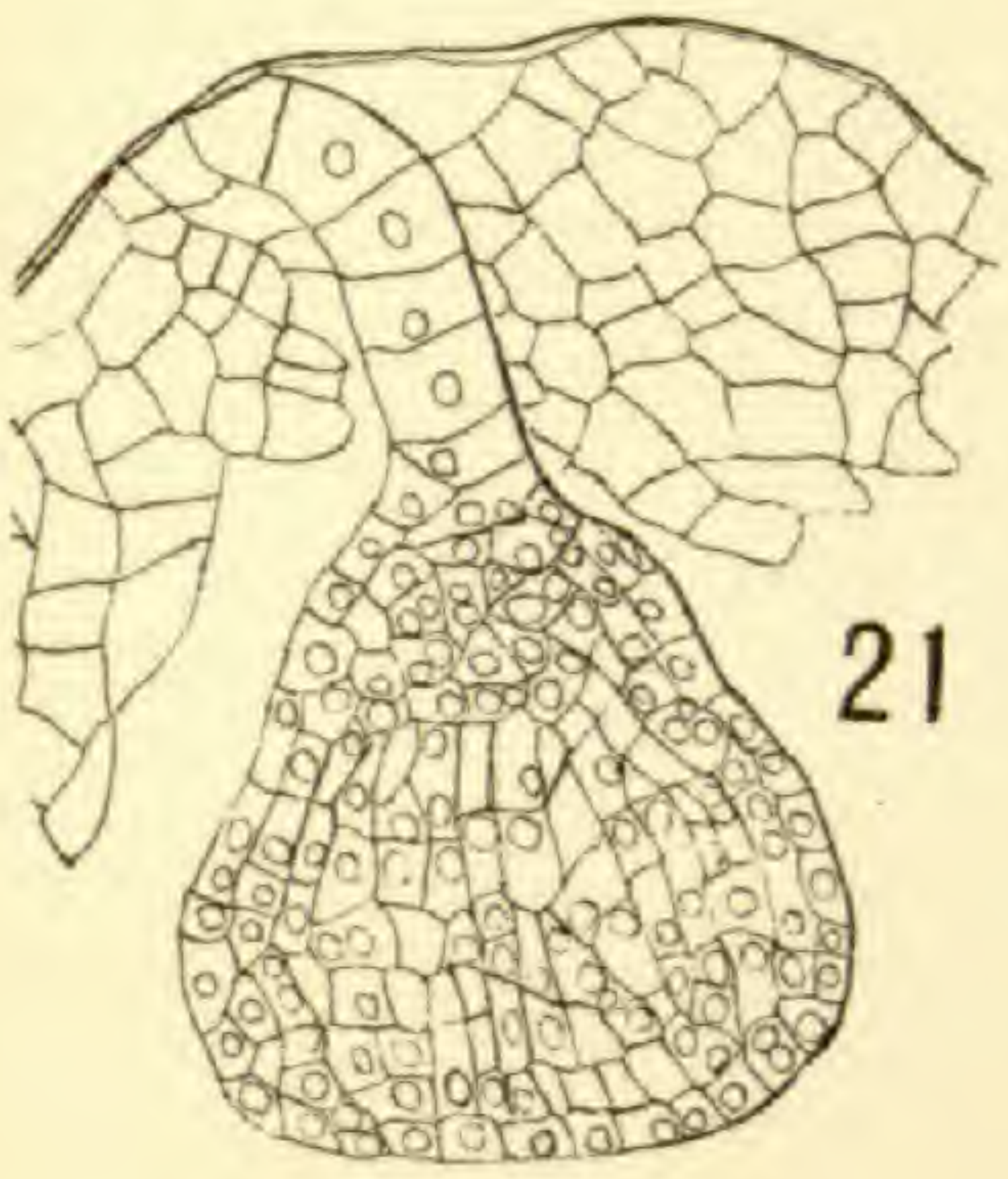
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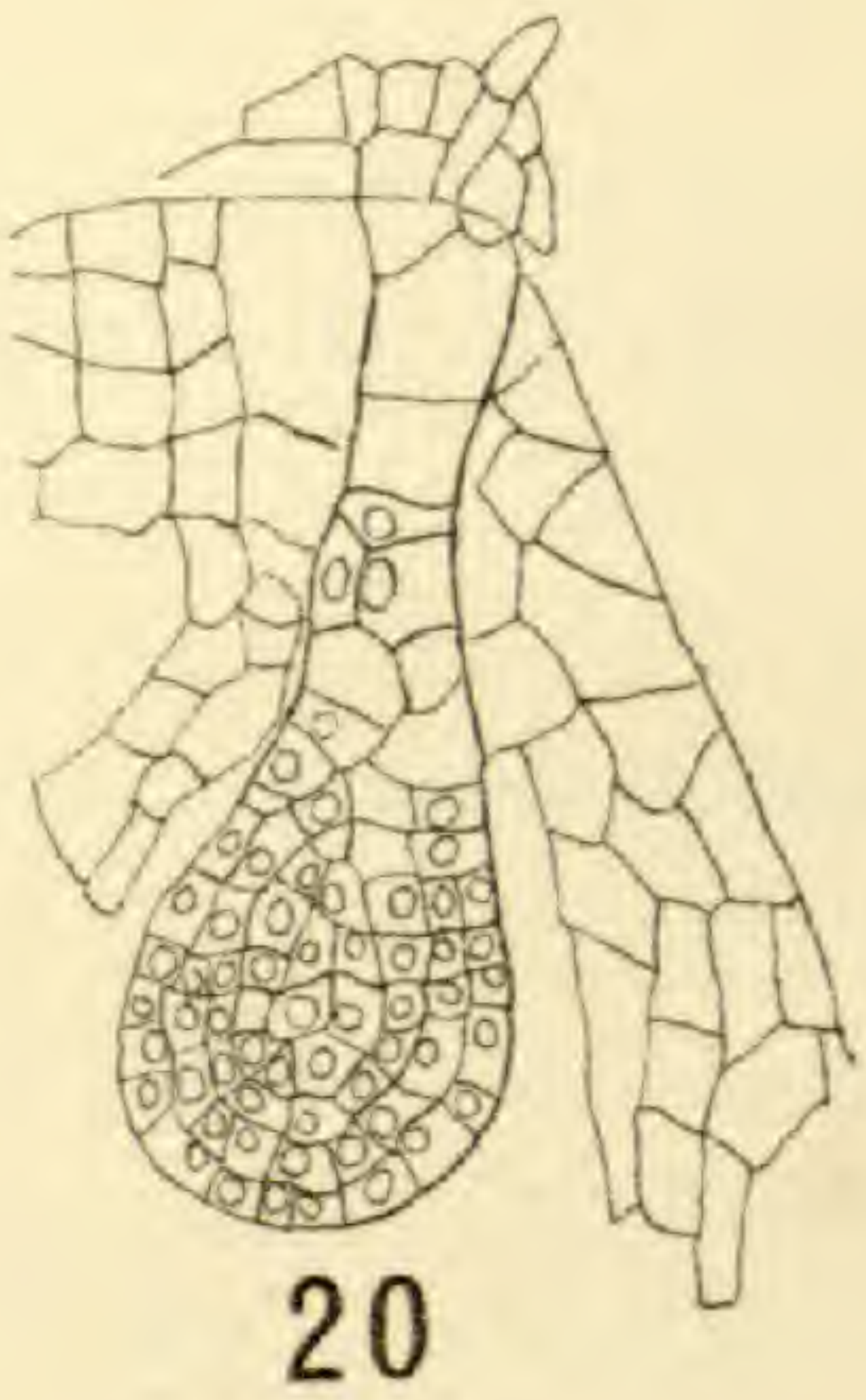
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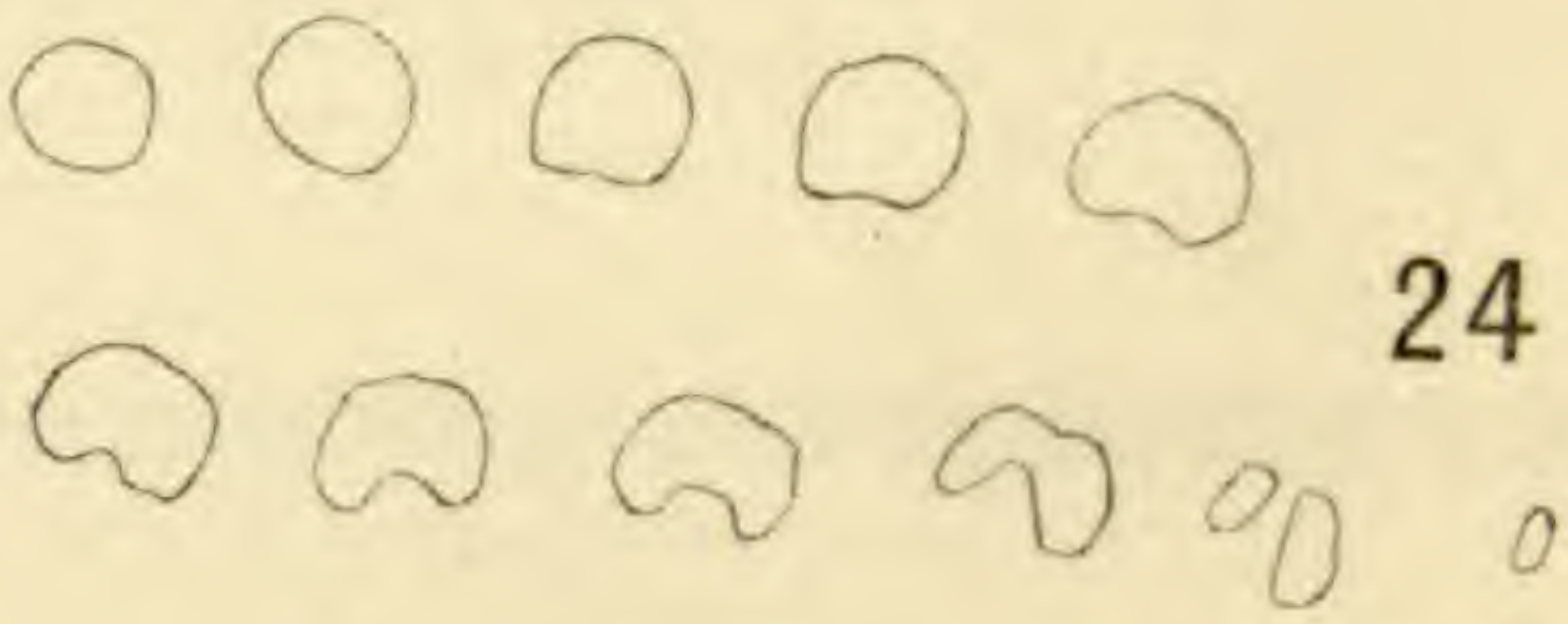
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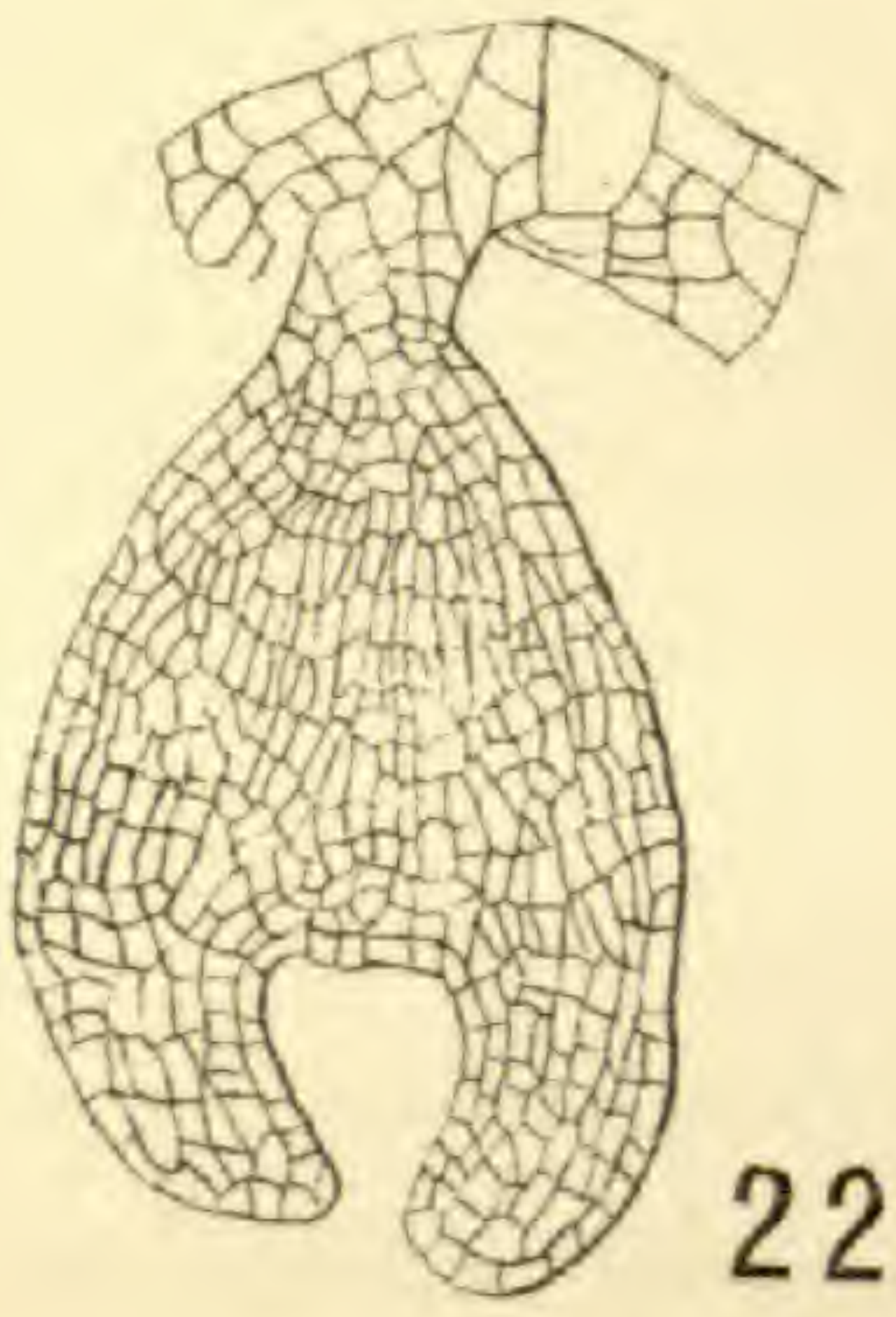
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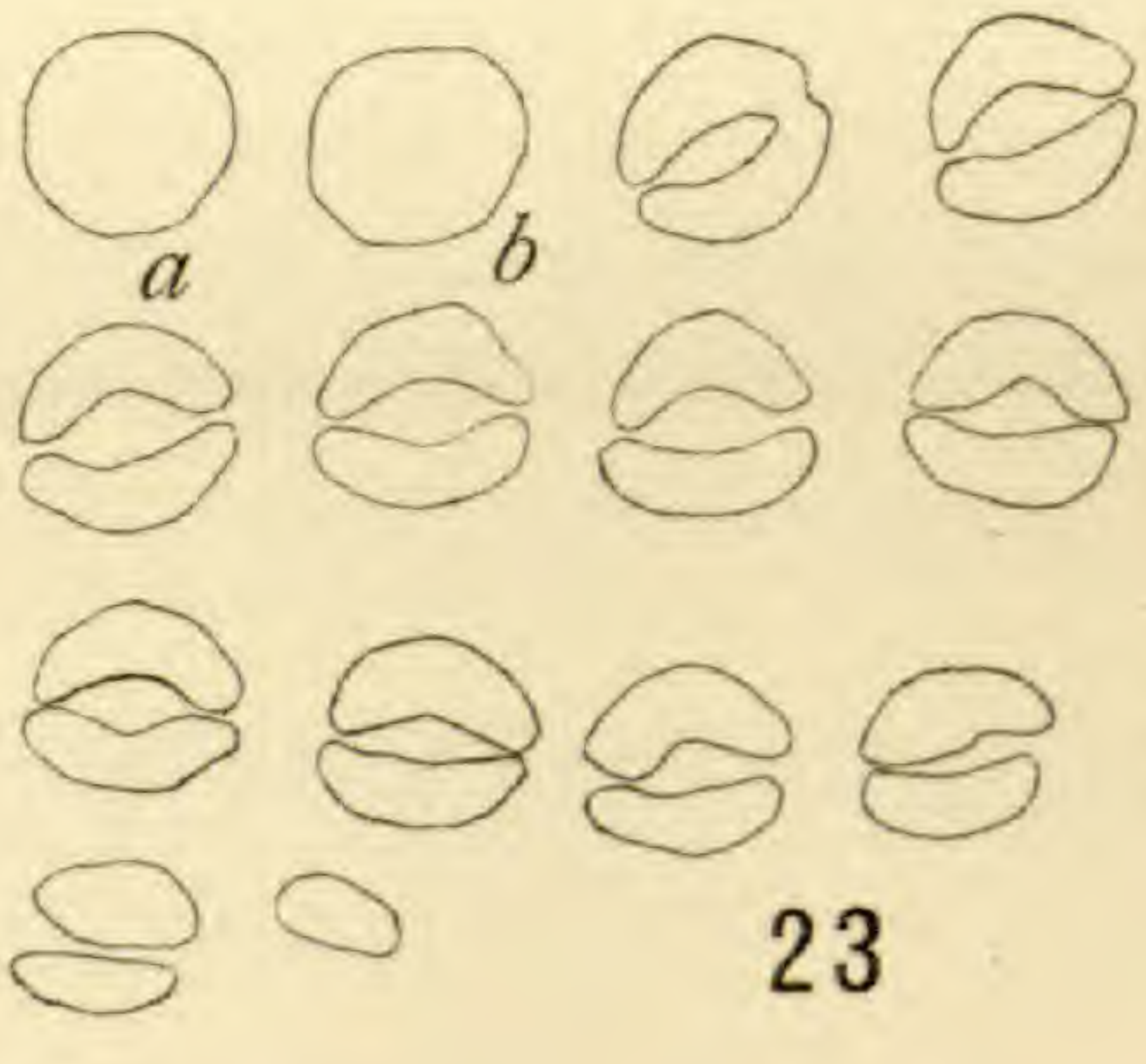

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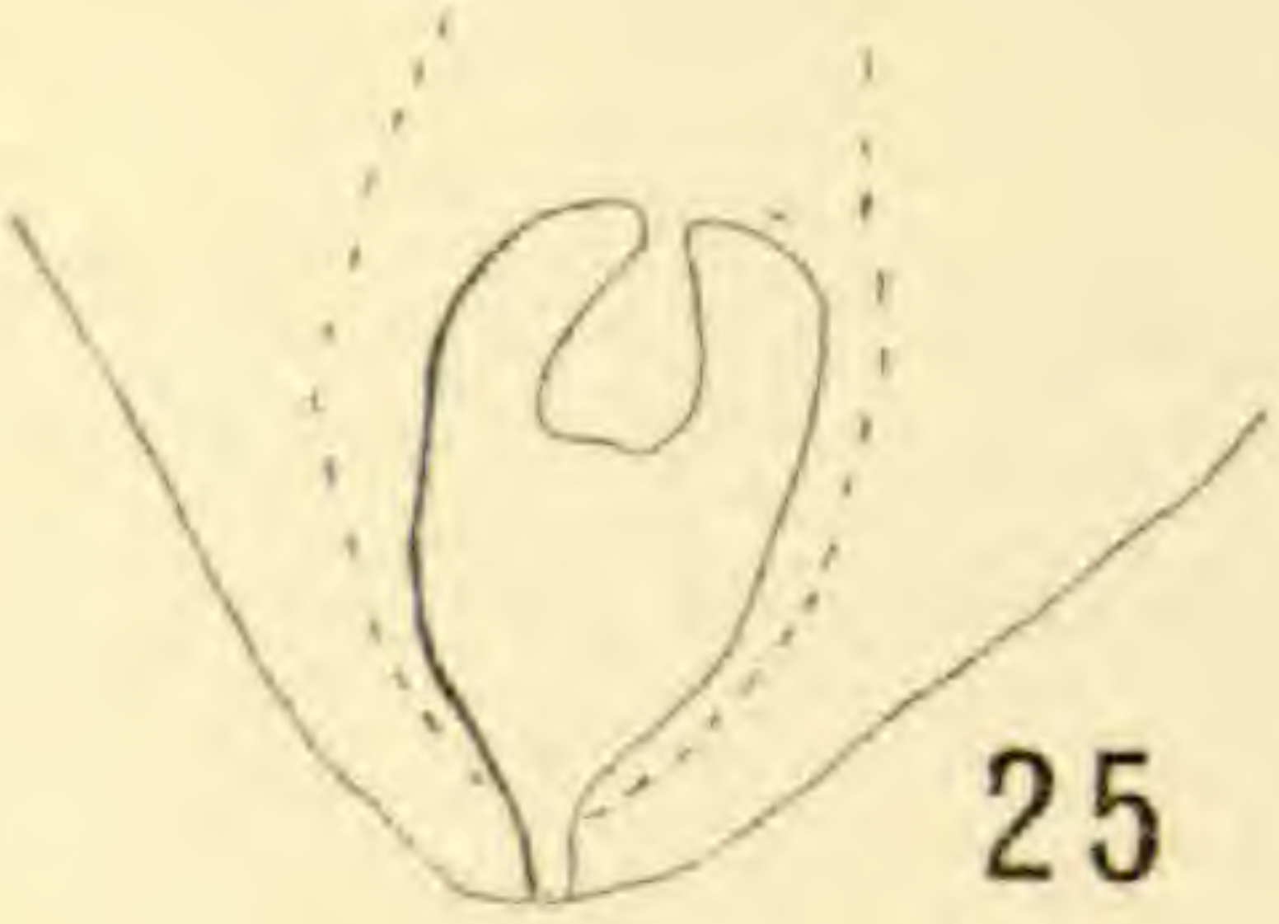
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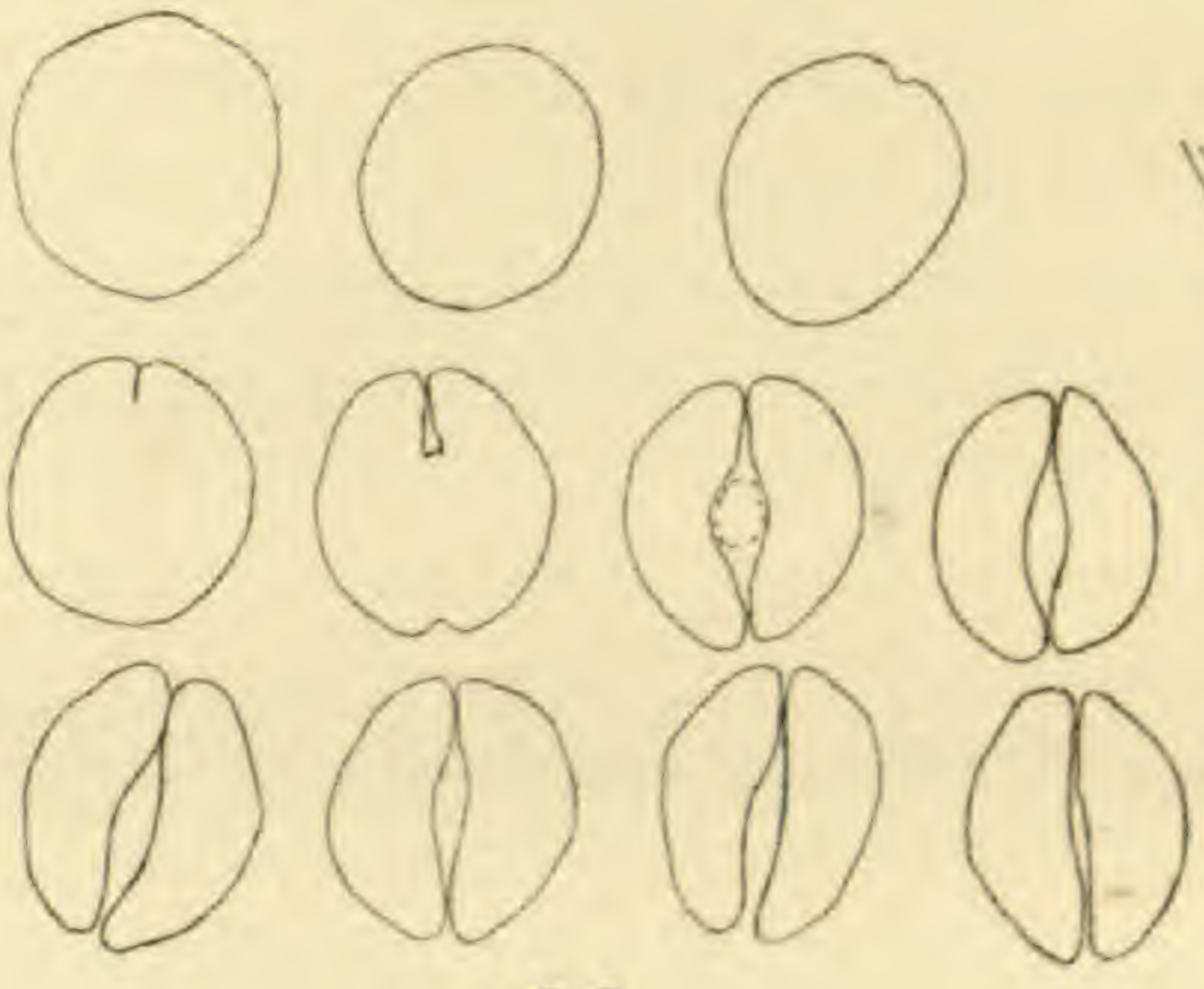
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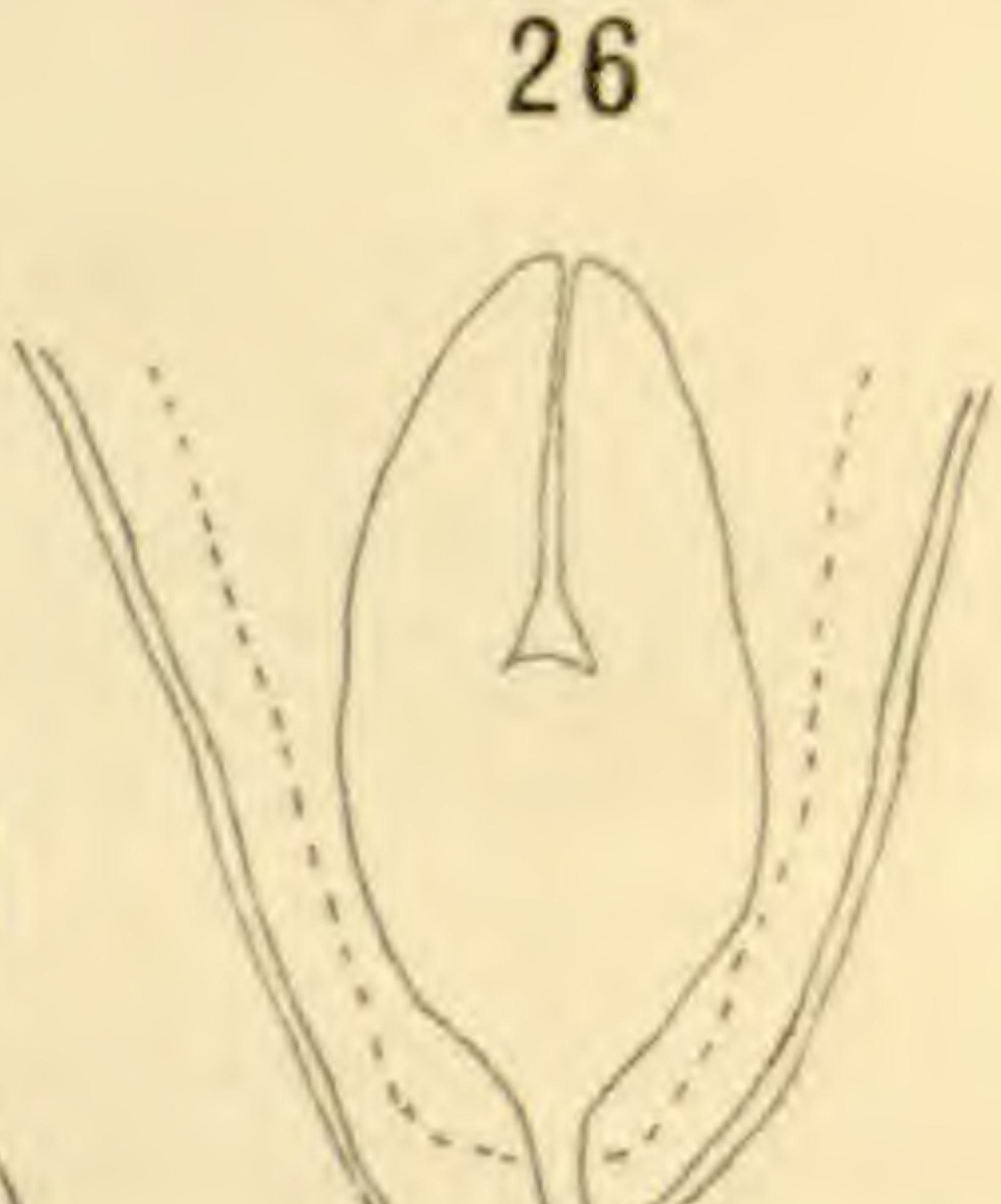
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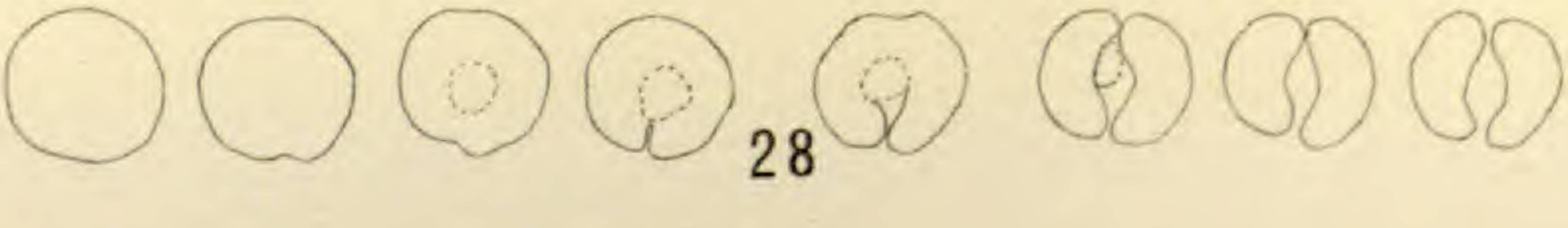
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LEWIS, DEL.

LEWIS on EMBRYOS.

BRIEFER ARTICLES.

DEFORESTATION AND CREEK FLOW ABOUT MONROE, WISCONSIN.[1]

(WITH A MAP)

On a large scale and in a rather hazy way the drying up of lands whose forests are removed is a matter of history and is popularly accepted as a fact. In detail and near at hand, however, there is still some scarcity of available evidence. This note and the accompanying map show, as far as a map can, the changes in the surface flow of water which have accompanied the gradual removal of the native forest from four townships of Green county, Wisconsin.

The tract is typical of the surrounding region. To the south there is more native prairie and the forest has been more completely removed, while to the north and west a rather larger trace of the primeval forest survives. Including the neighboring towns on the east and north would not have altered the complexion of the map at all.

The land in these towns is almost wholly tillable. Underlying most of it is limestone (Galena), with a coat of clay under the fertile surface of soil; the Pecatonica River and some of the larger creeks cut through into the St. Peter sandstone. The limestone shows on the brow of a few hills and low sandstone cliffs border the valleys of the creeks in a very few places. Practically all the land can be plowed, and all of it makes valuable pasture.

The settlement of these towns began about the time of the Black Hawk War, and a number of the earliest settlers are still living. They located along the edge of the timber, and the prairie towns preceded those forested in settlement. The population increased rapidly after 1840, and by 1860 was practically what it is now. The first great use of the land was grain-growing, which has declined since the Civil War. What lumbering industry there was has disappeared with the material for it. The dairying interest has steadily grown, very rapidly during

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[1] The most of the work embodied in this paper was done by Mr. Shriner and myself during the summer of 1902. After I left Monroe Mr. Shriner filled in the areas on the map where reliable information had not been obtained at the first attempt, and also prepared the map.—E. B. C.

the last twenty years, until Green is the greatest cheese-producing county in the country.

The expansion of the cheese interest made it possible for a limited rural population to get large returns from a much greater area of hilly country than it could till, and has certainly been a large cause of the final clearing of the land. At the same time the demands of the neighboring cities have advanced the price of fuel, and three lines of railroad in these four towns built during the eighties gave all parts of them a short haul to market.

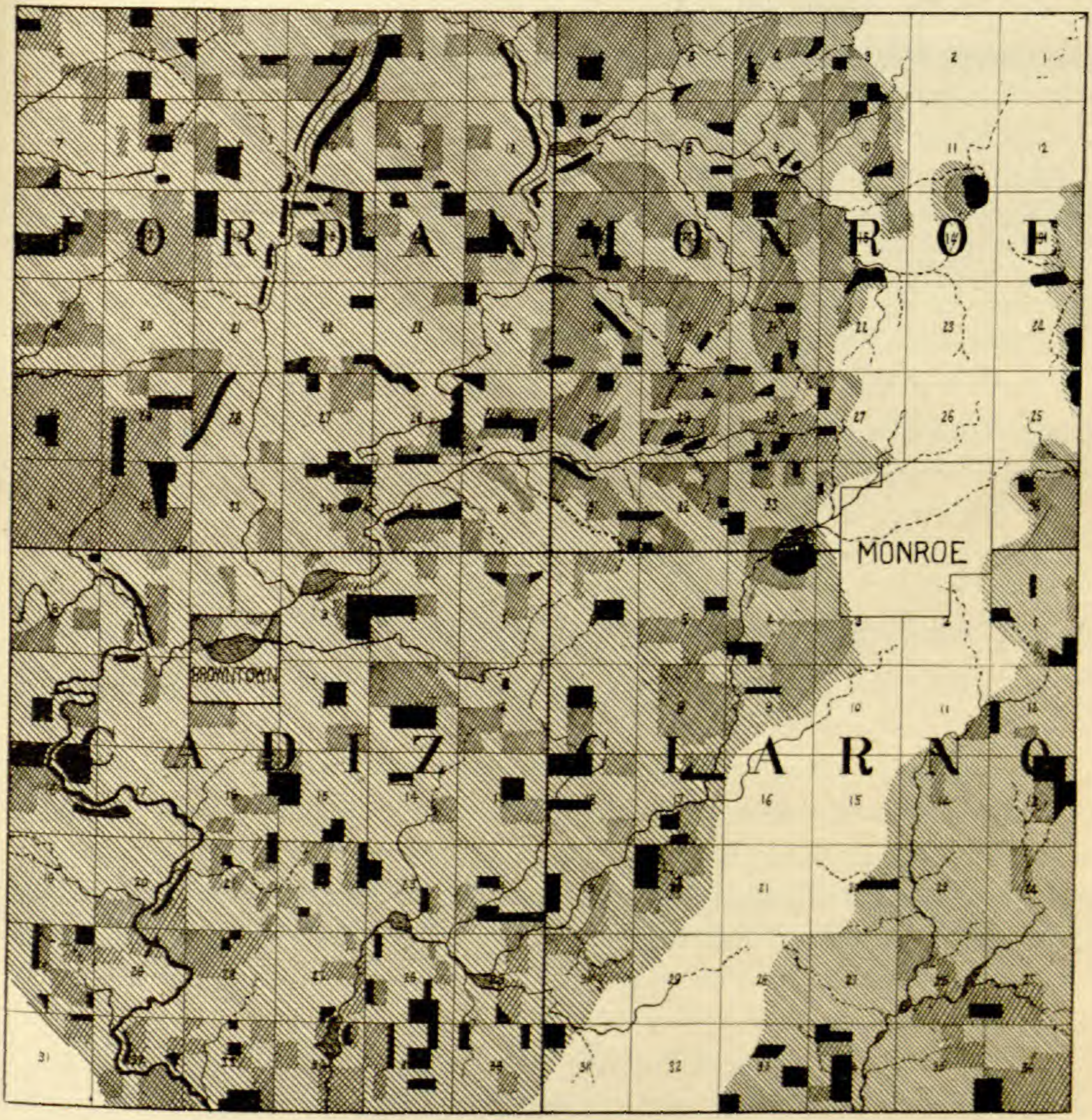
The accompanying map shows the native prairie and forest, the timber removed during the last fifteen or twenty years and that standing now, the water courses and former water courses now dry a large part of the year, and most of the former millponds. I have determined, by weighing them, the relative areas differentiated on the map, the result being: prairie 16.8 per cent., original forest 83.2 per cent., cleared fifteen to twenty years ago 55.9 per cent., cleared within fifteen to twenty years 27.3 per cent., timbered now (September 1902) 5.8 per cent.

"Fifteen to twenty years ago" is inexact, but it is usually impossible to tell exactly when a given tract was cleared, and any sharp line is therefore impracticable. The time indicated is that at which we became personally familiar with the country. It is also difficult, when the trees are gradually cut from an area, saw-logs first, cordwood a decade later, the young trees later still, or when some more or less abundant kinds are spared in the cutting, to decide when it ceases to be fitly mapped as timber. We have called any land timbered as long as the heavy shade is more continuous than the sod—a loose test, but as good as we knew.

The map and the figures based on it cannot show the change in the character of what timber remains. The forest was never homogeneous, but in general it was as dense as temperate deciduous forests often are. In general there was a considerable mesophytic undergrowth of thin leaved shrubs and herbs; more rarely the forest was dense enough to keep its floor relatively clear. In either case the ground was kept open and loose and the air over it cool and moist. In these four towns not a ten-acre grove of such forest is left. The surviving timber is pastured and the ground is tramped. The shade-loving, shade-making mesophytes disappear and grass gradually comes in. The trees become less vigorous and the grass more so. No axe is now needed. The grass-covered ground with scant shade is harder and smoother than the old forest soil, and dries very much more rapidly.

The vanishing percentum of surviving forest is thus practically even less than it appears.

From the settlement of the country until at least 1887 practically no creeks went dry, though there was a noticeable lowering. Since that time, according to the map, the water courses that are dry during the entire summers or longer amount to 29½ miles in Monroe, 10¾ miles in Jordon, 7½ miles in Cadiz, and 17¾ miles in Clarno, a total



MAP OF PART OF GREEN COUNTY, WIS.

LEGEND:
- ▨ Original forest.
- ▦ Timber twenty years ago.
- ■ Timber in September 1902.
- ─ Flowing creeks.
- ┄ Creeks which have gone dry.

of 65½ miles. This falls short of the real fact, because in Jordon and Cadiz, in the absence of certainty about some former creeks, we have omitted them; and because in exceedingly dry times the water has disappeared further than we represent, and these are the crucila times.

With the drying up of their head waters, the flow of the creeks has of course diminished everywhere. There are no measurements of flow at any time in the past, and, having nothing to compare with, we have made none. The millponds show the state of affairs most graphically. Rich, Honey, and Skinner Creeks each ran several mills; altogether there were twelve of these. All have been discontinued or equipped with steam power. On each creek there were running by water power twenty years ago at least two mills. The occasion for saw and grist mills is largely gone—reason enough why some of them are absent; but several now use steam. One mill near the mouth of Skinner Creek uses both water and steam. Where most of these mills stood less water runs now than used to be wasted.

A change in the forest covering of a region might indirectly affect the stream flow, through an effect on the total rainfall or its seasonal distribution; we have no evidence that this occurs. And the more direct effect in changing the structure and exposure of the ground might be years in making itself fully seen. Still, because of the length of the time involved, and because the deforestation had been relatively slow for some time preceding twenty years ago, we conclude that the creek flow there was adjusted to the forest area and condition; likewise, there having been no considerable change within five years, the timber and creeks seem to be in equilibrium now. If this be so, and assuming still that these four towns fairly represent the general region near about them, we can conclude that 27 per cent. of forest will nearly enough conserve the surface flow of water in country originally 83 per cent. forest so that the difference does not appear in any considerable loss of springs or drying up of creeks; but that if this forest be further reduced to 6 per cent., many creeks dry up and the flow of water in those remaining is reduced to probably about one-third.

About the rainfall in Monroe nothing exact is known, and if we had data, their relation to the deforestation would be very doubtful. While the loss of flowing water is a very local function of deforestation, the rainfall, if it be a clear function, is not localized at all. And the variation in different seasons and localities is so great that very extensive data in space and in years, as to both rainfall and the timbered area, would be needed to make conclusions of any value. From the Weather Bureau reports at our disposal from stations from Milwaukee to Dubuque, some of them going back to 1871, it does not appear that there has been any significant change. The last decade includes dry years and wet years, dry and wet summers.

The influence of deforestation on the character of the flora is another interesting subject. While the relative representation of different components of the flora has of course changed profoundly, remarkably few plants have as yet become extinct. No tree has certainly disappeared except the juniper, which had a single locality and has not been seen within thirty years. We have the only local herbaria of any size, that of Herbert E. Copeland dating from the early seventies, and our own, mostly about seventeen years later. The only plants whose disappearance in that interval is highly probable are *Camassia Fraseri* and *Pogonia pendula*. In the last fifteen years *Cypripedium spectabile*, *Gaultheria procumbens*, *Phegopteris Dryopteris*, and possibly as many more plants all strictly local, seem to have been killed out. On rare rough hillsides and in gulches where the timber is relatively native, and in fence corners, in brush, or around stumps, the old flora persists. It is a most instructive lesson in the survival of what exists that above thirteen-fourteenths of the native habitat has been altogether changed in character, and the other one fourteenth decidedly modified, without the extinction of a single common forest herb, shrub, or tree.—F. A. SHRINER and E. B. COPELAND, *Monroe, Wis.*

THE EFFECTS OF EXTERNAL AGENTS ON THE PRODUCTION OF ROOT HAIRS.

PRELIMINARY NOTICE.

DURING an endeavor to find the causes for the production of root hairs, results were obtained, which, though incomplete, may be of sufficient interest to warrant publication.

Seedlings of *Zea mais*, *Helianthus annuus*, *Lupinus albus*, *Avena sativa*, *Triticum vulgare*, *Vicia sativa*, *Cucurbita Pepo*, *Raphanus sativus*, *Brassica alba*, and *Cannabis sativa*, grown in water, showed a tendency not to develop typical water roots at once, but produced a longer or shorter zone of hairs, passing, in some forms, into the smooth surface usually characteristic of water roots. Apparently this zone of hairs in sunflower, radish, and white mustard was not directly influenced by light or darkness.

In solutions seedlings showed a general tendency for the hair development to vary with root development, though the results are rather discordant, and more work is required before any conclusion can be reached. The roots seem to be able to bear higher percentages of saccharose than of lactose, glucose, glycerin, mannite, or modified Knop's solution, a result in accordance with that of Livingston. The discordance of results above mentioned may be due, in part at least, to the absorption of different chemicals from the different kinds of glass in the vessels used, since Benecke found such absorption to influence the development of rhizoids in Lunularia.

The effect of the quantity of food is of importance, apparently, because of its influence upon the growth of the root. Seedlings of Helianthus, whose cotyledons had been cut off at various distances from their insertion, produced different root lengths corresponding to the lengths of cotyledons remaining, and the hair development varied accordingly.

The oxygen pressure in water was varied by boiling, with no very marked difference in the hair production of corn seedlings. Further experiments in variation of oxygen pressure are in progress.

From the cases mentioned there appears to be a tendency for seedlings under most conditions to produce a longer or shorter zone of hairs, probably on account of the surplus energy provided by the stored food.

The growth of roots is more rapid in water than in air of the same temperature (as has frequently been noted), with hair production in inverse relation; the water condition appears to be produced, however, in saturated air. The average length of epidermal cells in water roots exceeds that of the same cells in air roots, though the average number of cells produced each day appears to be approximately the same under the same conditions. Therefore the increased length, in this case at least, seems to be due to greater elongation of the cells of the water roots. In the same section there appears in general to be a relation between the length of the cells and the production of hairs, the average length of hairless cells being greater than that of cells with hairs.

A retardation of growth when the root tip meets with resistance causes the root to kink and produce hairs. If wounded, the growth is also retarded, and the region immediately behind the tip usually becomes abnormally enlarged, and at the same time shows a marked tendency to form hairs.

In accordance with the statements of Haberlandt and Schwartz, Elodea roots, though hairless in water, produce hairs when growing in the substratum of the aquarium, even if the material be ground quartz. Microscopic examination has shown thus far that the average length of epidermal cells of roots in the substratum is less than that of epidermal cells of roots in the water. The presence of hairs seems to be related, therefore, to the length of the cells rather than to superficial contact. In support of the idea that contact of the epidermal cells with solid bodies does not appear to be a stimulus for hair production, may be cited certain instances where roots of seedlings grew against the sides of a glass vessel; in this condition there was a marked tendency for the suppression of hairs along the region of contact. Also seedlings grown in saturated sand or garden soil show a diminution or even absence of hairs, as previously indicated by Persecke.

That temperature has an effect, though possibly an indirect one, upon hair production is evidenced by roots of corn and wheat seedlings showing a tendency to omit the hair zone when growing rapidly in warm water.

From the foregoing statements there appears to be a relation between the production of root hairs and the elongation of the cell; whatever has a tendency to increase the elongation also tends to suppress the development of hairs, "water etiolation" being especially important in this connection in soil roots. In two cases of decapitated sunflower seedlings the water etiolation of the periblem and epidermis was apparently so great that the poorly nourished, deeper lying plerome was not able to keep pace with it and hence split transversely in several places. The frequently noted decrease of hairs in etiolated conditions of the aerial parts of plants, whether from darkness or moisture, supports this view.

The production of hairs coincident with slow growth above mentioned is not thought to be due to excess of nourishment, as supposed, but merely to the tendency of the cells to grow transversely rather than to elongate longitudinally. This is supported by the condition of affairs in Lycopodium and Isoetes, and by Leavitt's association of root hairs of Azolla with cells which do not elongate. The root hair problem therefore, appears, to resolve itself in large part into the search for the causes of arrested growth or the elongation of cells.

Other references, illustrations, and conclusions will be reserved until the work is more complete. — LAETITIA M. SNOW, *Hull Botanical Laboratory, The University of Chicago.*

PRESERVATION OF SEEDS BURIED IN THE SOIL.

DURING the latter part of the winter of 1901–2, while the new medical building was being erected on the campus at the University of of Michigan, an excavation was made adjacent for the purpose of securing gravel and sand to be used in the masonry work. At this particular time I happened to be reviewing the literature pertaining to the vitality of buried seeds, and was thus prompted to see what this pit would yield. An investigation revealed a layer of black soil, approximately one inch in thickness, at a depth varying from fourteen to sixteen inches below the surface.

On March 7, 1902, while the ground was frozen very hard, samples of this black soil were taken from three different places, representing in all approximately two square feet of surface. This soil was then distributed in four eight-inch clay pans, which were placed in the greenhouse under favorable conditions for the germination of any seeds that were lying dormant in the soil. The pans were covered with glass plates so that no foreign seed could enter during the course of the experiment.

On March 14 pan no. 1 showed four clovers; pan no. 2 six clovers and four plantains; pan no. 3 twelve clovers and two plantains, and pan no. 4 thirteen clovers and two plantains; a total of thirty-five clovers and eight plantains in seven days. New seedlings continued to appear from day to day. The experiment was terminated on May 6, after a period of sixty days, when the entire number of seedlings had reached 128, representing seven genera and nine species, as follows: *Trifolium pratense* L., 70; *Polygonum aviculare* L., 19; *Plantago Rugelii* Dec., 10; *Euphorbia maculata* L., 8; *Panicum pubescens* Lam., 6; *Plantago major* L., 5; *Bursa bursa-pastoris* (L.) Britton, 5; *Trifolium repens* L., 3; *Anthemis Cotula* L., 2.

On inquiry it was found that the grading in that part of the campus was done in the autumn of 1898, consequently the seeds giving rise to these plants must have been lying dormant in the soil at least three and a half years.

In addition to the species named above, an examination of the soil showed the presence of many old fruits of *Ambrosia artemisiaefolia* L., but the vitality of these had been destroyed.

The conditions in this particular place were very favorable for the preservation of vitality of buried seeds. The first six or seven inches below the new surface consisted of a firm clay, below which was a mixture of clay and gravel. Directly underneath the stratum of the original surface soil which contained the seeds was a very thin layer of clay, below which was the bed of gravel and sand.

These seeds were not buried sufficiently deep to prevent them from being frozen, but the layer of clay above served quite well to protect them from the air, thus diminishing the respiratory activity, and the gravel and sand beneath furnished the best possible conditions of drainage. Under such favorable conditions the vitality of many seeds might be preserved, when buried in the soil, for a score of years or more.—J. W. T. DUVEL, *U. S. Department of Agriculture, Washington, D. C.*

CUMAPHYTISM IN ALARIA.

(WITH TWO FIGURES)

AMONG the species of Alaria displayed upon the kelp beds of the Minnesota Seaside Station, the one named *Alaria nana* by Mr. H. F. Schrader[2] has been found to show a somewhat remarkable adaptation to the surf habitat which it shares with *Postelsia palmaeformis* Rupr. along the Straits of Fuca. Plants of *Alaria nana* are found intermingled with Postelsia and form for the most part an undergrowth between the trunks of the larger kelp. Upon few rocks have there been found unmixed growths of Alaria. Last summer, however, I was enabled to examine two or three beds of *Alaria nana* which had not come under the observation of Mr. Schrader. A series of plants was collected for the laboratory work in the University of Minnesota, and two of them have been photographed to accompany these notes. Their consideration will make it apparent how strongly the Alaria type may become adapted to existence in the surf.

When growing intermixed with Postelsia the common form of *Alaria nana* is as shown in *fig. 1*. The plants will not average more than 20$^{\text{cm}}$ in length. In these plants the mid-lamina is well developed, and the gonidiophylls are comparatively slender and their entire surface, with the exception of a narrow marginal region, is soral. Toward the base of a Postelsia formation the plants of *Alaria nana* average somewhat larger, and the stipes are not erect, but decline upon the rocks. Higher in the formation the size of the plants diminishes and the stipes become more erect, until well toward the top the erect habit

[2] SCHRADER: Observations on *Alaria nana*, sp. nov. Minn. Bot. Studies 3 : 157. 1903.

is the rule. At the same time the stipes become more massive and the gonidiophylls become broader.

Along the top of the formation, at two or three localities, decidedly unusual plants of *Alaria nana* have been observed. Sometimes hundreds of these are found growing together. *Fig. 2* shows such a plant placed upon the right of and beside an individual of *Postelsia palmaeformis* which is introduced for comparison. The plant shown in *fig. 2* is but 10^{cm} in height, nor do plants of this form ordinarily measure much more than this. The general resemblance in habit to Postelsia is certainly very marked. The mid-lamina is in all such plants eroded to the base or but poorly developed. Under such conditions it is evident that the gonidiophylls must assume the photosynthetic function, and they have consequently taken a broader form. One of these obovate gonidiophylls is clearly shown in the figure. Upon many of these gonidiophylls soral areas are either not developed or limited to the basal portion. The number, too, of the gonidiophylls seems to be increased as compared with normal plants of the lower levels. The stipe is quite erect, very firm, and provided with a strong growth of hapteres at the base. In general, the plant which has come to live under the conditions to which Postelsia has adapted itself receives the imprint of environmental forces, as did the ancestral forms of the other kelp, and exhibits a striking homoplasy.

FIG. 1.—Plant of *Alaria nana* H. F. Schrader; natural size about 20^{cm} in length. After photograph by C. J. Hibbard.

In comparing the plants shown in *fig. 2*, it should be remembered that Postelsia, a member of the Lessonia group, is essentially unilaminate, and the laminae displayed at the summit of the stipe have arisen by repeated longitudinal splitting of the original single lamina. Alaria, on the other hand, maintains its original mid-lamina without splitting, and this would be found at the center of the tuft, while the conspicuous laminae are the modified and hypertrophic gonidiophylls. Yet, while developed in this different manner, the ultimate result is, in each case, a tuft of leaves at the end of a short, thick, and firmly attached stipe.

FIG. 2.—Plants of *Postelsia palmaeformis* Rupr. (on the left) and *Alaria nana* H. F. Schrader (on the right). Extreme cumaphytic form. After photograph by C. J. Hibbard.

The series of plants as displayed upon the rocks is certainly very instructive and to be fully appreciated must be studied in the field. In this note I have attempted merely to indicate the extreme form which an Alaria may assume in the cumaphytic habitat.—CONWAY MACMILLAN, *University of Minnesota.*

CURRENT LITERATURE.

BOOK REVIEWS.

European moss flora.

THE SECTION of the monumental *Kryptogamen-Flora von Deutschland, Oesterreich, und der Schweiz* which describes the mosses, *Die Laubmoose* by Limpricht, has not yet quite come to completion, and the lamentable death of its author will doubtless delay somewhat the issue of the last supplementary parts. It has been in course of publication since 1886. This for central Europe, with the recent descriptive works on the mosses of France and England, have been the only dependence of bryologists who wished anything more recent than the second edition of Schimper's *Synopsis Muscorum* (1876). But no general work later than the latter touches Spain, Italy, Russia, or the Scandinavian countries. It is high time, therefore, for such a gathering together of the data on the species of mosses and their European distribution as seems planned in *Die europäischen Laubmoose*[1] by the grand-ducal "Rechnungsrat" at Laubach (Hesse), Georg Roth. The publication begins without preface and with the briefest prospectus. Evidently, from the quickness with which part follows part, the manuscript is ready for the publisher and the work, in ten or twelve parts, making two volumes, is not to drag its weary length along, as some of its predecessors have done. The parts (not sold singly) consist of 128 pages each, with ten plates, and are issued at the remarkably low price of 4 marks. The plates are photolithographs, very crowded and of rather inferior quality, though whether this inferiority is due to the drawing, which is done by the author, or to the process of reproduction is uncertain. Nevertheless, plates are quite indispensable in such a work and these are certain to be helpful, especially in showing those differential characters which can be only imperfectly conveyed by words.

The systematic arrangement departs very little from that of Schimper's *Synopsis* and Limpricht's *Laubmoose*, so as to reduce to a minimum the difficulties of using the books together.

In an introductory section of 100 pages the general characteristics, anatomical structure, reproduction, geographic distribution, and ecology of the mosses are treated, followed by brief directions for collecting and naming, and illustrated by three plates. This section, necessarily quite elementary, is well done, especially the chapter on ecology.

The descriptions are in German, covering half a page to a page, with diagnostic characters indicated. The synonymy is brief, and the habitat and distributions are given rather fully. The Sphagnaceae will be excluded.

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[1] ROTH, GEORG, Die europäischen Laubmoose. Imp. 8vo. Parts 1–4. pp. 1–572. *pls. 1–36, 46–49.* Leipzig: Wilhelm Engelmann. 1903. *M* 4 per part.

The work bids fair to be a most satisfactory one. A similar work for North America is greatly to be desired, for Lesquereux and James's *Mosses of North America* is now twenty years old.—C. R. B.

The problems of life.

THIS BOOK[2] contains a theory of ontogenic development, or rather an exposition of the fundamental principle governing ontogenic phenomena. To use an illustration of the author: if one wished to study the flow of rivers, and to determine in advance the course of a river in all its details, it would be necessary to know the rapidity and density of the water, the inclination and geological structure of the bed and banks at all points of its course, resistance of materials composing these, etc., so that the solution becomes practically impossible in detail. But theoretically the fundamental principle involved is simply that of gravitation. It is the same with the problem of development. Knowledge of all the various secondary factors that complicate each case is not necessary; what is wanted is knowledge of the fundamental principle governing all ontogenic phenomena. The author believes he has found this in the principle of "dévelopement monodique."

The principle of monodic development is derived from the author's ideas of the nature of assimilation, growth, and of cell division, which are discussed in the first part of the work, and are outlined in a review of it in this journal.[3]

The biomolecules of the egg assimilate the deutoplasm and so reproduce by division; this causes division of the biomores, and this cleavage (cell division). Thus assimilation is the first and necessary cause of each cleavage, and the assimilation is accompanied by progressive chemical ontogenic changes. The author here introduces as the main prop of the monodic theory the principle of "heterogenetic" development, viz.: that, owing to the nature of "biomolecular development," two daughter-cells must be different in constitution both from one another and also from the mother-cell. This is established as a universal principle in development by the consideration that there are only two other possible modes of cell division, viz.: *autogenetic*, in which the daughter-cells are like each other and also like the mother-cell, and *homogenetic*, in which the daughter-cells are like each other but different from the mother-cell, and that these are excluded as possible modes of development, for the assumption of either of them as a mode of development leads to an absurdity.

Thus it follows that the constitution of the cells alters with each cleavage which *ex hyp.* is preceded by a period of assimilation.

The next step in the hypothesis leads to the principle of monodic develop-

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[2] GIGLIO-TOS, ERMANO, Les problèmes de la vie. II^{e} partie; l'ontogénèse et ses problèmes. 8vo. pp. 368. Cagliari, chez l'Auteur, à l'Université, 1903.

[3] BOT. GAZ. 31:275. 1901.

ment. Supposing that the bioplasm of the egg passes through stages *a*, *b*, *c*, owing to the nature of the processes of assimilation of the biomolecules, biomores, etc., it is clear, the author states, that the first division of the egg cell *a* must result in two cells, one of which, on the principle of heterogenetic development, must be *b* and the other different from *b*; it may be *c* or it may be something different. "There are no other possible suppositions." The author examines the second alternative, "polyodic development," first, and arrives at the conclusion that this leads to an absurdity; hence the egg *a* must divide into *b* and *c*; *b* must divide into *c* and *d*; *c* into *d* and *e*, and so on to a particular limit fixed by the constitution of the egg. This is the principle of monodic development.

It would take us too long to follow the author's exposition of how this principle leads to a "rational" explanation of the development of all animals and plants, leaving no essential phenomena unexplained; and, moreover, it is not necessary to do so for already two things must be clear: (1) that the author has reared an inverted pyramid upon his conception of assimilation and growth; (2) that by the naïve method of proposing selected theoretical alternatives and demonstrating the absurdity of all but one, any principle may be "proved," the premises being granted.

Some of the main features of this system remind one of certain theories of Weismann, *e. g.*, the theory that protoplasm is a symbiotic aggregation of various orders of living units. But Weismann is far too good a biologist to endow the molecules themselves with life. The principle of "heterogenetic development" has some points of resemblance to the principle of "qualitative nuclear division" (Weismann). But the system of Giglio-Tos is more artificial than that of Weismann, and he tries to solve by force of *a priori* reasoning what Weismann is careful to consider on the evidence. In many respects the theory departs widely from Weismann's.

The book contains no new facts, though the author is evidently familiar with some of the current embryological literature; but he makes use of the knowledge only to show that his theory is capable of explaining all of the results of experimental embryology. With other results of recent embryological work he is apparently quite unfamiliar. Thus he declares positively in favor of the doctrine of isotropy of the egg, without the least consideration of all the many facts demonstrating that the organization of the egg is causally related to some of the most fundamental phenomena of development.

It is a Rip van Winkle experience to read this production; one wonders if all the results of exact and experimental embryology are only a pleasant dream, and if such attempts to explain inheritance by a single principle, characteristic of the biology of twenty or thirty years ago, are alone real. Fortunately even this book cannot bring one to such a conviction, and it is even probable that it will not be considered superfluous in the future to work for the discovery of new facts in ontogeny.—FRANK R. LILLIE.

The honeysuckles.

THE FOURTEENTH ANNUAL REPORT of the Missouri Botanical Garden, covering the year 1903, fully maintains the high standard of scientific excellence which has characterized this series of papers from the start. The report of the director contains much of interest in regard to the growth and usefulness of the various collections, their increase for some years past being graphically shown by a series of diagrams.

The body of the report is devoted to a systematic treatment of the genus Lonicera by Mr. Alfred Rehder, of the Arnold Arboretum of Harvard University. Although published under the modest title of a synopsis, this important paper is in reality a detailed monograph. It is true that specific descriptions, except in the case of newly characterized species, have been omitted in order to keep the paper within the limits of convenient publication, but the unusually full keys present so completely the differential features that the lack of further descriptions will scarcely be felt. Mr. Rehder began his work on the genus at the Botanic Garden of the University of Göttingen and completed it at the Arnold Arboretum. During its progress he has been able to visit a great number of the larger herbaria, both of Europe and America, and to see living in the wild and under cultivation more than a third of the species of Lonicera. Without tending to a minute division, he recognizes as valid 154 species and subdivides many of them into more or less clearly marked varieties and forms. The citation of bibliography, synonymy, icones, exsiccatae, and ranges is marvelously detailed. The genus is divided into two subgenera, CHAMAECERASUS (including 131 species) with 2-flowered mostly pedunculate cymes and distinct leaves, and PERICLYMENUM (including 23 species) with 3-flowered sessile cymes, the upper leaves being usually connate. The first subgenus is again divided into four sections, namely, *Isoxylosteum* Rehder with regular corollas; *Isika* DC. with labiate corollas, connate usually red fruit, and solid branches; *Coeloxylosteum* Rehder with labiate corollas, connate usually red fruit, and fistulose branches; and *Nintooa* DC. with labiate corollas and distinct usually black fruit. These sections are again subdivided into many subsections, mostly of the author's own delimitation. Of the twenty American species recognized, only seven belong to the first great subgenus Chamaecerasus, and these are all of the section Isika, the remaining thirteen North American and Mexican species being of the subgenus Periclymenum. The author makes some thirteen new species (and specific combinations) chiefly of Asiatic plants, and also recognizes some thirty-five new varieties and forms. So far as America is concerned, the novelties are chiefly Mexican. Little change is made in the naming and specific delimitation of our North American species. Due attention has been given to the numerous artificial hybrids, horticultural species, and forms of unknown habitat — the bane of the systematist. Mr. Rehder's paper is truly noteworthy, not only for its sound scholarship, but for the equal personal familiarity with the plants of the two continents; indeed, it is probably the most detailed treatment ever published in America of a large and difficult genus chiefly of Old World distribution. The paper is well illustrated both from drawings by the author and photographic reproductions.

The closing pages of the report are occupied with an extensive supplement to the Catalogue of the Sturtevant Prelinnaean Library, compiled by Mr. C. E. Hutchings, and including several hundred titles.—B. L. ROBINSON.

MINOR NOTICES.

THE CURRENT NUMBER of the *Minnesota Botanical Studies* (Ser. III, part II, pp. 209–273) contains the following papers: "The moss flora of the upper Minnesota River," by JOHN M. HOLZINGER, being a report of material collected under the auspices of the Minnesota Botanical Survey during the summer of 1901, and including 96 numbers, 6 of which are new species; "Two new species of Fontinalis," by J. CARDOT; "Outline of the history of leguminous root nodules and rhizobia with titles of literature concerning the fixation of free nitrogen by plants. III," by ALBERT SCHNEIDER; "Report on two collections of Hepaticae from northwestern Minnesota," by A. W. EVANS, including 32 numbers; "Observations on the tide pool vegetation of Port Renfrew," by S. A. SKINNER, in which, aside from the distribution of species, the conclusions reached were that the higher the elevation of the pool and the less exposed to wave action, the fewer the species found, though individuals may be abundant; the more gradual the slope and the rougher and more irregular the sides, the more abundant the plant life; and the presence of pebbles and loose rocks on the bottom of a pool prevent the distribution of plants over the bottom or far down the sides of the pool; "Observations on *Alaria nana*, sp. nov.," by H. F. SCHRADER; "Contributions to a knowledge of the lichens of Minnesota. VIII. Lichens of the northern boundary," by BRUCE FINK, being a study of lichen formations, together with a list of 310 species and varieties with their stations; "The Umbellales of Minnesota," by W. A. WHEELER, showing 5 Araliaceae, 33 Umbelliferae, and 9 Cornaceae; "The Pteridophytes of Minnesota," by HAROLD L. LYON, containing 74 numbers; "An addition to the knowledge of the flora of southeastern Minnesota," by C. O. ROSENDAHL, being an extension of the work of the Botanical Survey, resulting in the addition of nearly 100 species to the state list; "A new species of Razoumofskya," by C. O. ROSENDAHL.—J. M. C.

OTTO KUNTZE has revised Tom von Post's *Lexicon Generum Phanerogamarum*,[4] a work that has demanded a tremendous amount of drudgery, but which should be of corresponding service to taxonomists. Included in the volume is Dr. Kuntze's *Codex brevis maturus* of botanical nomenclature

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[4] POST, TOM VON, Lexicon generum phanerogamarum inde ab anno MDCCXXXVII cum nomenclatura legitima internationali et systemate inter recentia medio. Opus revisum et auctum ab OTTO KUNTZE. Stuttgart: Deutsche Verlags-Anstalt. 1904. *M* 10.

(40 pp.), printed in German, French, and English. Then follows the alphabetical list of approved genera (612 pp.) with their synonyms, fossil genera, and such cryptogamic generic names as needed change being included. A closing part (100 pp.) gives the list of valid genera under their families, which may serve also for herbarium arrangement. For twenty years Dr. Kuntze has been working at nomenclature, always confident of his ground, never discouraged by opposition or indifference, as ready now to force his views upon botanists as ever. His general attitude is indicated in the following quotation from the preface: "May our lexicon reestablish international order in nomenclature and reasonable harmony between botanists! There seems no other remedy." The present publication certainly contains a mass of information conveniently arranged.—J. M. C.

IN A PAPER on Tertiary plants, D. P. Penhallow[5] has recorded the results of his studies of a collection of fossil woods secured by Dr. G. M. Dawson during the British N. Am. Boundary Survey. The determinations are based upon stem structure, and include new species of Sequoia, Cupressoxylon, and Rhamnacinium. A section of the paper entitled "biological considerations" discusses spiral tracheids, uniseriate rays, resin cells and passages, ray tracheids, and fusiform rays. The interesting statements are made that the occurrence of resin passages in Abies has not been traced beyond existing species, and that in reference to certain characters Sequoia represents a transitional group and also the terminal member of a short side line which passes through Taxodium.—J. M. C.

THE EIGHTEENTH PART of Engler's *Das Pflanzenreich* includes a presentation of Taxaceae by R. Pilger.[6] The usual full and critical discussion of the group involves in this case many mooted points of great interest to the morphologist. In addition to the eight genera that ordinarily appear under Taxaceae the author recognizes two others: *Pherosphaera* Archer, a genus of 1850 that includes two species usually referred to Microcachrys and Dacrydium; and *Acmopyle* Pilger, nov. gen., a New Caledonian genus established to include a species variously referred to Podocarpus and Dacrydium. —J. M. C.

THE THIRD PART of Sargent's *Trees and shrubs*[7] contains plates and descriptive text of species of Magnolia, Liriodendron, Crataegus (8, 6 n.spp.), Tilia, Euonymus (4, 1 n.sp.), Acer (2). Virburnum (n.sp.), Lonicera (2), Ligus-

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[5] PENHALLOW, D. P., Notes on Tertiary plants. Trans. Roy. Soc. Canada II. 9:33–95. 1903.

[6] ENGLER, A., Das Pflanzenreich. Heft 18. Taxaceae von R. Pilger. pp. 124. Leipzig: Wilhelm Engelmann. 1903. *M* 6.20.

[7] SARGENT, CHARLES SPRAGUE, Trees and shrubs. Illustrations of new or little known ligneous plants prepared chiefly from material at the Arnold Arboretum of Harvard University. Part III. pp. 101–150. *pls. 51–75*. Boston and New York: Houghton, Mifflin & Company. 1903.

trum (2), Gryphocarpa (new genus of Compositae from Mexico), Vaccinium, and Pinus (n.sp. from W. Indies).—J. M. C.

CH.-ED. MARTIN[8] has described with great fulness the exceedingly variable fungus called *Boletus subtomentosus* as displayed in the region about Geneva. After a presentation of the bibliography and a discussion of the general characters, he describes eleven subspecies and illustrates them with 18 colored plates.—J. M. C.

WITTROCK[9] has published a very interesting set of photographs of botanists in the collection at the botanical garden at Stockholm, accompanying them with biographical notes. The plates contain the reproduction of 213 photographs, some of them representing well-known botanists at different ages.—J. M. C.

PART 217 of Engler and Prantl's *Die natürlichen Pflanzenfamilien* contains the Lichens (*Flechten*), by A. Zahlbruckner. Part 218 contains the Schistostegaceae, Drepanophyllaceae, Mitteniaceae, and Bryaceae, by V. F. Brotherus.—J. M. C.

THE SIXTH PART of John Donnell Smith's enumeration of Central American plants[10] has been distributed. It comprises a list occupying 87 pages, and three separates containing descriptions and plates of new species. —J. M. C.

THE CURRENT FASCICLE of Richter's *Plantae Europaeae*[11] concludes the Caryophyllaceae and continues the list to Clematis among the Ranunculaceae, the sequence being that of Engler.—J. M. C.

NOTES FOR STUDENTS.

ASO finds[12] that the best value of the ratio CaO : MgO for the mulberry lies between 2 and 3, an excess of magnesia over lime dwarfing plants very much.—C. R. B.

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[8] MARTIN, CH.-ED., Le "Boletus subtomentosus" de la région génevoise. Matériaux pour la flore cryptogamique suisse **2**: fasc. 1. 1903.

[9] WITTROCK, V. B., Catalogus illustratus iconothecae botanicae horti Bergiani Stockholmiensis anno 1903; notulis biographicis adjectis. Acta Hort. Berg. **3**: no. 2. pp. 198. *pls. 46*. 1903.

[10] SMITH, JOHN DONNELL, Enumeratio plantarum Guatemalensium necnon Salvadorensium Hondurensium Nicaraguensium Costaricensium. Pars VI. Baltimore, Md.: The author. 1903.

[11] GÜRKE, M., Plantae Europaeae. Enumeratio systematica et synonymica plantarum phanerogamicarum in Europa sponte crescentium vel mere inquilinarum. Operis a DR. K. RICHTER incepti. Tomus II, fasc. 3, pp. 321–480. Leipzig: Wilhelm Engelmann. 1903. *M* 5.

[12] ASO, K., On the influence of a certain ratio between lime and magnesia on the growth of the mulberry tree. Bull. Agric. Coll. Tokyo Imp. Univ. **5**: 495–499. *pl. 27*. 1903.

WITMER STONE[13] has published the results of his study of racial variation among the violets, and in connection with a general discussion of the subject has published a synopsis of the violets of Philadelphia and vicinity. —J. M. C.

L. M. UNDERWOOD[14] has published synopses of the genera of ferns known to exist in the Philippines, and states that the fern flora of these islands as known today embraces over 600 species, and that probably exploration will yield half as many more.—J. M. C.

TSCHIRCH with the assistance of Herr Gerdts, has examined the anthers of a number of Compositae and finds that their union (about which statements vary from coalescence to mere adhesion) is dependent wholly upon the cuticle of adjoining anthers, which is adherent, often freeing itself completely from the epidermis that produced it.[15]—C. R. B.

P. GUÉRIN[16] has called attention to the strong development of antipodal tissue in certain species of Gentiana. This expresses itself in the increased number and size of the cells; and in the extreme case, as in *G. campestris*, the antipodals form a layer of tissue almost completely lining the embryo sac. Such tissue is resorbed upon the formation of endosperm.—J. M. C.

ASO adduces[17] objections to the view of Kastle and Loevenhart[18] that oxidases are merely "peroxids formed when autoxidizable substances come in contact with air, and these peroxids give up a part of their oxygen to other less oxidizable substances present in the cell." He also has discovered in plants traces of nitrites, which seem to be formed by oxidation of ammonium salts.—C. R. B.

MR. and MRS. WEEVERS find that caffein, which has already been shown by Clautriau and by Suzuki to be probably a decomposition product of proteids, is not a waste product, but can be utilized in metabolism, as indicated by its gradual disappearance from young parts as they develop. From tea leaves caffein disappears only as the leaves become aged and yellowed before falling.[19]—C. R. B.

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[13] STONE, WITMER, Racial variation in plants and animals, with special reference to the violets of Philadelphia and vicinity. Proc. Phil. Acad. **1903**: 656–699.

[14] UNDERWOOD, L. M., A summary of our present knowledge of the ferns of the Philippines. Bull. Torr. Bot. Club **30**: 665–684. 1903.

[15] TSCHIRCH, A., Sind die Antheren der Kompositen verwachsen oder verklebt? Flora **93**: 51–55. *pl. 2.* 1904.

[16] GUÉRIN, P., Sur le sac embryonnaire et en particulier sur les antipodes des gentianes. Jour. Botanique **17**: 101–108. *fig. 9.* 1903.

[17] ASO, K., On the chemical nature of oxidases. Bull. Agric. Coll. Tokyo Imp. Univ. **5**: 481–489. 1903.

[18] Amer. Chem. Journal **26**: 539–566. 1901.

[19] WEEVERS, TH., and MRS. C. J. — DE GRAFF, Investigations of some xanthine derivatives in connection with the internal mutation [metabolism] of plants. Proc. Koninkl. Akad. Wetens. Amsterdam **1903**: 203–208 (meeting of Sept. 26).

VOSS FINDS that fusion and clamp-connections between hyphae, so well known in basidiomycetes and the higher ascomycetes, occur also in the Uredinales.[20] Sometimes the fusing hyphae are closed at the point of connection by a partition wall, sometimes there is an open fusion or plasma threads pass through the wall. From these structures he argues the correctness of Meyer's view that the Uredinales became early in development a distinct offshoot from the fungus stem. — C. R. B.

MOLISCH HAS HAD exceptional opportunities for studying the excretion of water from the leaves of a caladium (*Colocasia nymphaefolia* Kth).[21] He finds that drops are ejected under favorable conditions with some force (rising 1^{cm}), and so rapidly (up to 190 per minute) as to give the impression of a minute stream from a fountain, as Muntingh describes it in 1672, a statement which Pfeffer declares an exaggeration.[22] In a single night 97^{cc} were given off and in a week 1008^{cc}. Molisch's figures all far exceed those quoted by Pfeffer. —C. R. B.

IN THEIR STUDIES of the Scottish fresh-water plankton, W. and G. S. West,[23] have reached the conclusions that Scottish phytoplankton differs considerably from that of the western parts of continental Europe; that it is unique in the abundance of its desmids, the most conspicuous of which are of type confined almost exclusively to the extreme western and northwestern shore districts of Europe and to North America; that there is a remarkable scarcity of many of the free-swimming Protococcoideae; and that the plankton is much richer in species in the late summer and autumn than in the spring.— J. M. C.

IN A BRIEF NOTE, with five text figures, Emma Lampa describes[24] an exogenous occurrence of Anthoceros antheridia. Spores were sowed so thickly that the resulting plants grew upright or overrode one another. Upon some of these somewhat etiolated specimens antheridia developed from epidermal cells, along with others that arose in the normal fashion from underlying tissue. Aside from the method of origin and the fact that the exogenous antheridia ranged free above the dorsal surface of the thallus, they did not differ in appearance or mode of growth from the endogenous type. The author regards the exogenous antheridia as a reversion to the ancestral type, thus explaining the persistent wall of the sunken antheridium as vestigial.— FLORENCE M. LYON.

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[20] VOSS, W., Ueber Schnallen und Fusionen bei den Uredineen. Ber. Deutsch. Bot. Gesells. **21**: 366–371. *pl. 19.* 1903.

[21] MOLISCH, H., Das Hervorspringen von Wassertropfen aus der Blattspitze von *Colocasia nymphaefolia* Kth. Ber. Deutsch. Bot. Gesells. **21**: 881–389. *pl. 20.* 1903.

[22] PFEFFER, W., Pflanzenphysiologie **1**: 262. 1897.

[23] WEST, W. and G. S., Scottish fresh-water plankton. No. 1. Jour. Linn. Soc **35**: 519–556. *pls 14–18.* 1903.

[24] LAMPA, EMMA, Exogene Entstehung der Antheridien von Anthoceros. Öster. Bot. Zeits. **53**: 436–438. *figs. 5.* 1903.

NEWS.

PROFESSOR E. L. GREENE has begun a new publication bearing the title "Leaflets of botanical observation and criticism," in the style of *Pittonia.* The first fascicle (16 pp.) of the first volume was issued November 24, 1903, and the second January 5, 1904.

OTTO G. JENNINGS, formerly herbarium assistant in the botanical department of the Ohio State University, has been appointed custodian of botanical collections at the Carnegie Museum, Pittsburg, Pa., *vice* John Shafer, who goes to the New York Botanical Garden.

IN HIS SOUTHPORT address as president of the botanical section of the British Association, Mr. A. C. Seward spoke of the "Floras of the past; their composition and distribution." The address is an admirable presentation of our knowledge and lack of knowledge of the paleobotanical record.

AT THE St. Louis meeting of the American Association for the Advancement of Science Professor W. G. Farlow was elected president of the Association, and Professor B. L. Robinson vice-president of the Section of Botany. The Botanical Society of America elected Dr. Frederick V. Coville president.

THE *Forestry Quarterly* will contain hereafter both original papers and reviews of literature. It is to be hoped that complete and accurate citations will be given of articles so reviewed. This is not done in the first number. We commend to the *Quarterly* the style adopted ten years ago by the botanists and now widely used both here and abroad.

E. W. D. HOLWAY, of Decorah, Iowa, has presented to the botanical department of the University of Minnesota his library and collection of fungi. The library contains about 1000 volumes, and the herbarium, including duplicates, is estimated to contain from 85,000 to 100,000 specimens. Mr. Holway plans to devote himself hereafter to the study of fungi and will probably reside in Minneapolis when not in the field.

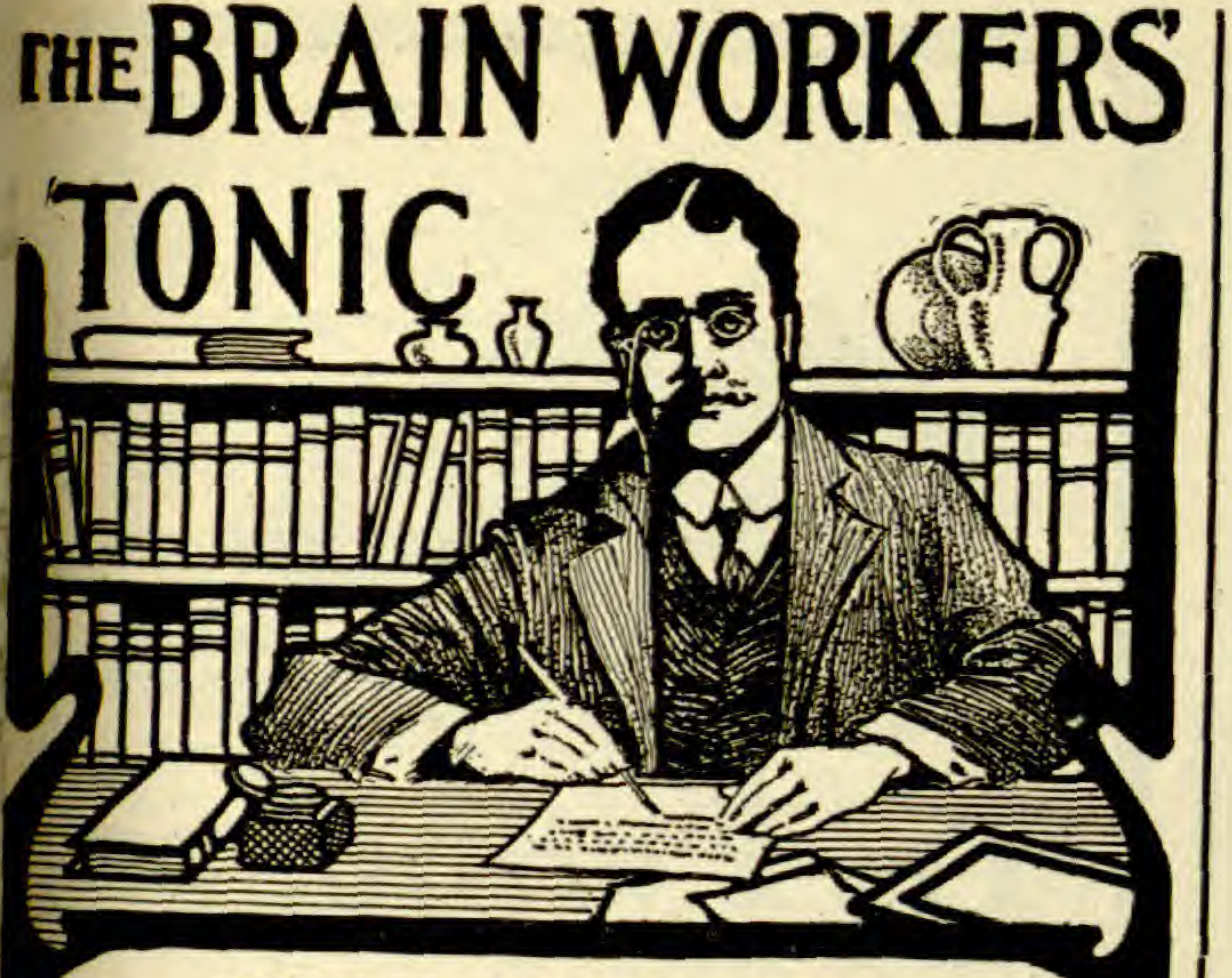
A NEW PERIODICAL has made its appearance as the organ of an "Association of Representatives of Applied Botany," which is devoted to the advancement and deepening of scientific knowledge in the service of agriculture, forestry, trade, and industry by botanical investigation. The Association begins auspiciously, with a membership of over 100. Any botanist is eligible who is active or interested in the objects of the society. The first volume (1903) of the *Jahresbericht der Vereinigung der Vertreter der angewandten Botanik* can be obtained from Gebrüder Bornträger for *M* 4.

A BARE STATEMENT of the facts leading to the closing of the New York State College of Forestry is given by the editor in the *Forestry Quarterly* **2**:42. November 1903. This statement throws little direct light upon the matter, though one may read between the lines. Apparently the governor's veto of the appropriation for the College was secured by the "pull" of certain owners of Adirondack lands whose estates adjoined the reserve, because they were not pleased with the logging and other operations inaugurated by the College. This is practically acknowledged by Governor Odell in his recent message to the legislature. From this message it is apparent that the veto was not based upon condemnation of the practice of the College by expert foresters, but upon the "disapproval" of its work by "many citizens of the state." The plea he makes is that the object of the state was to conserve the water supply by retaining the forest cover, while the College was completely denuding its experimental forest! Surely the people of New York will not accept such a worthless defense.

THE CATALOGUE DIVISION of the Library of Congress has sent to press, and will issue shortly, through the office of card distribution, a set of analytics for Engler-Prantl's *Die natürlichen Pflanzenfamilien*. Each article (family) in this important set of monographs will be represented by a separate catalogue card, which contains full bibliographical information, including exact dates of publication for undated signatures. Beside subject headings, all added entries will be printed in full.

The cards covering the unfinished portions of the work will be issued upon the completion of the volumes in question. The number of titles now going to press is 458, and the total number of cards necessary for main entries, subjects, and added entries will be 936. These may be obtained at the office of card distribution.

The task of analyzing this and other collective works of similar importance, titles of which will be announced later, has been performed by Mr. J. Christian Bay. Owing to the exacting demands of necessary work in other directions, the Library has so far undertaken but little work of this character.



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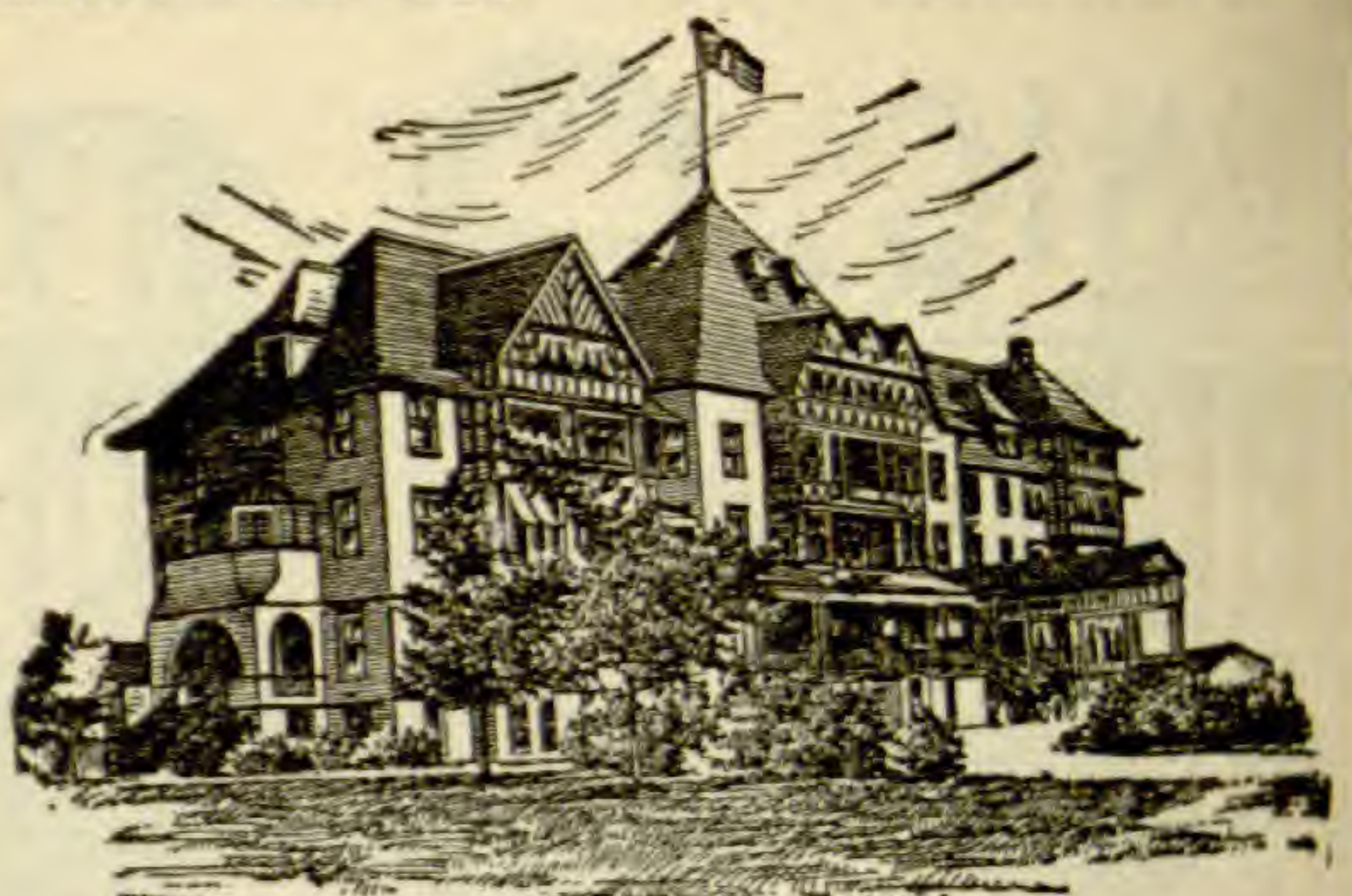

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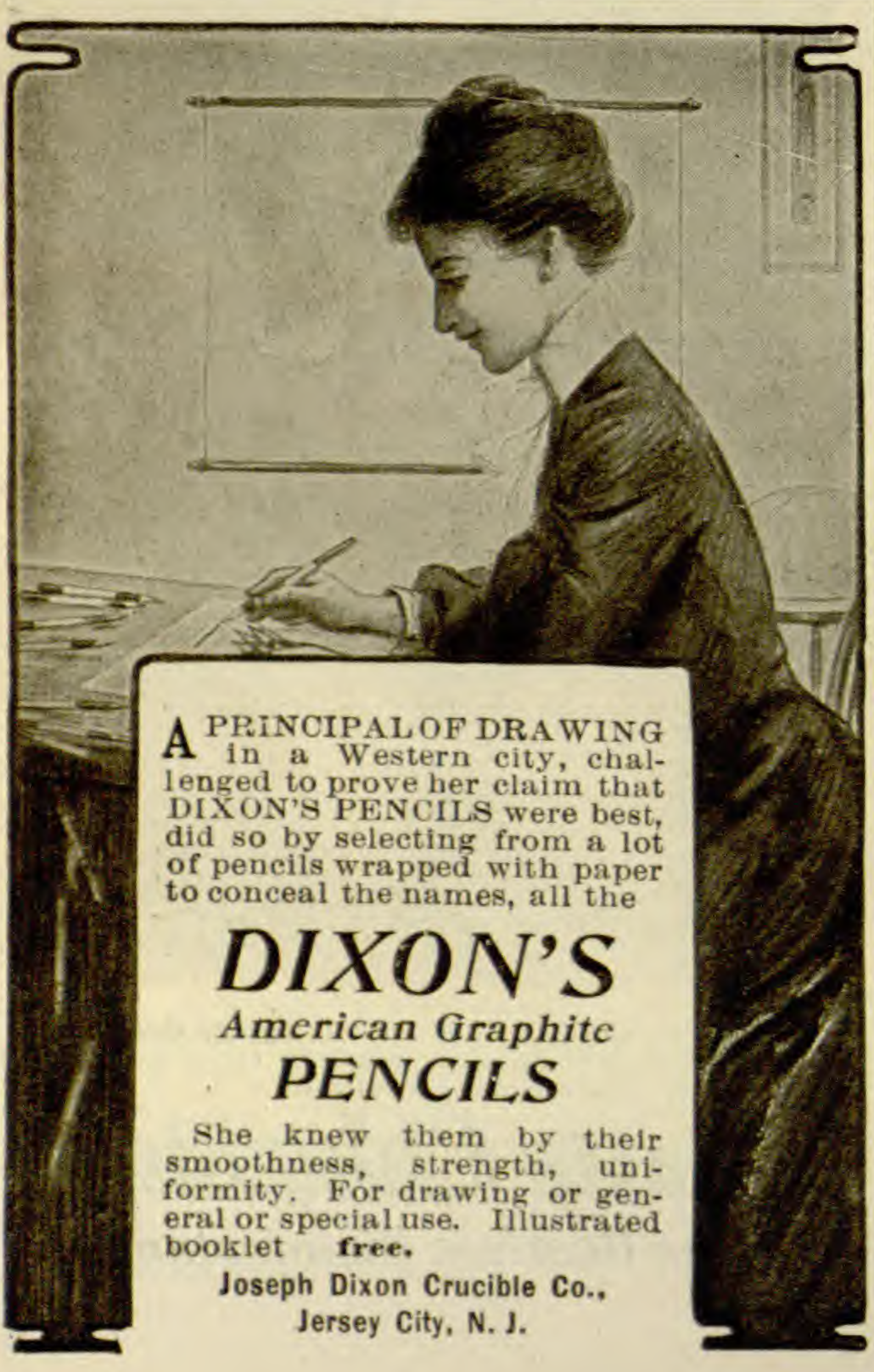

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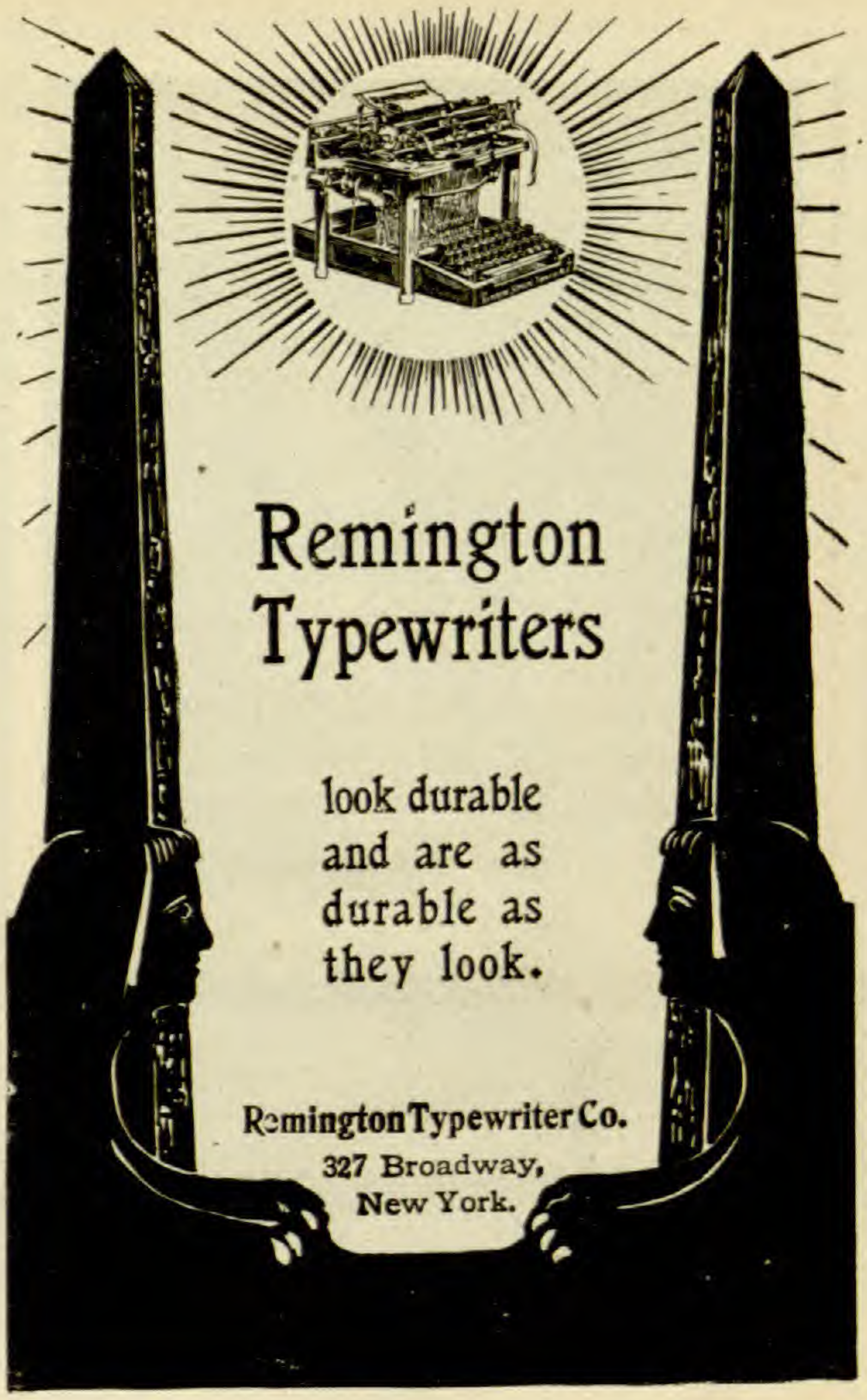

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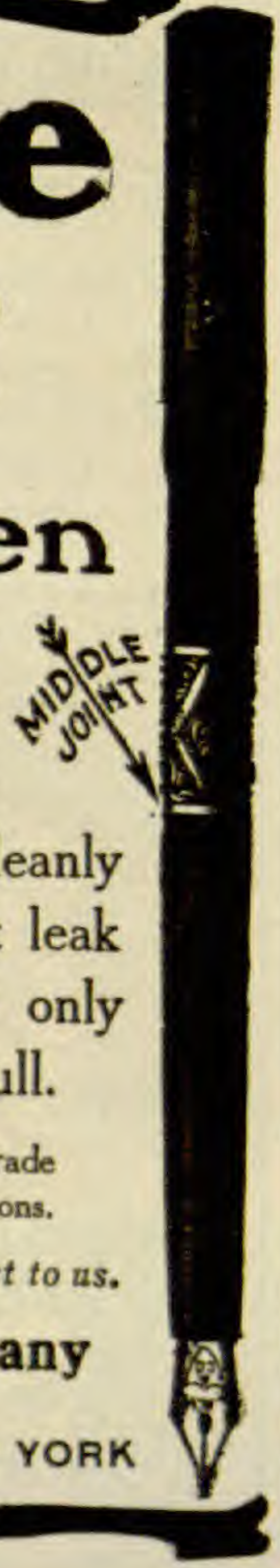

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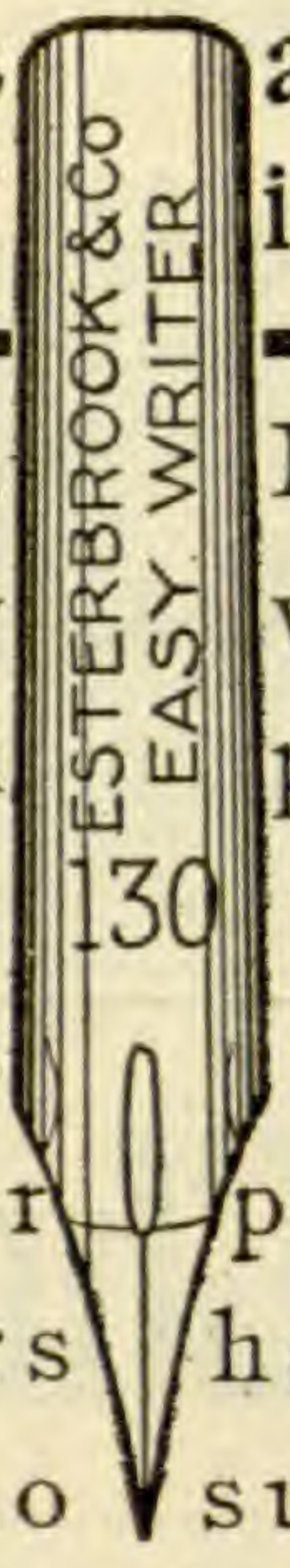

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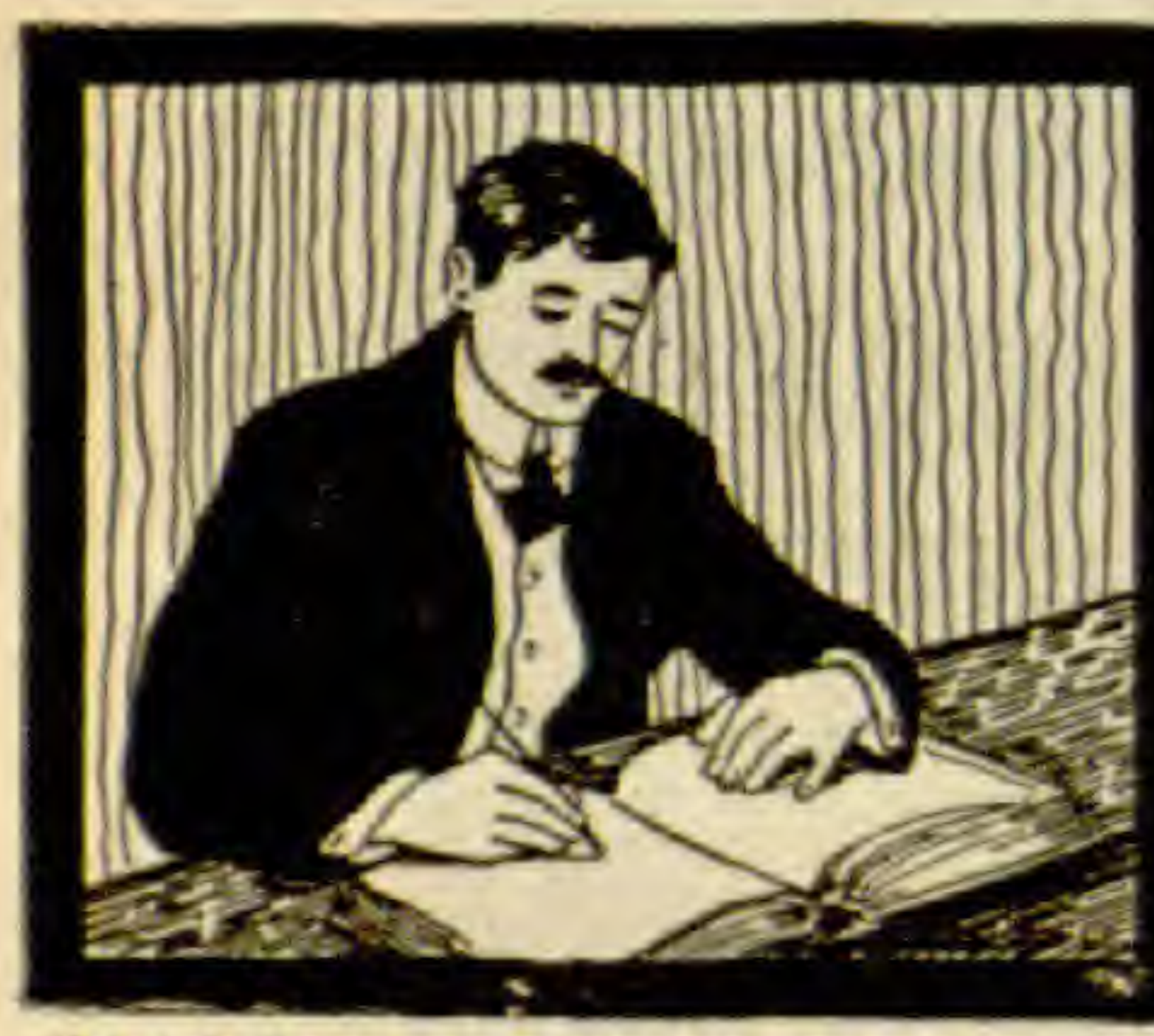


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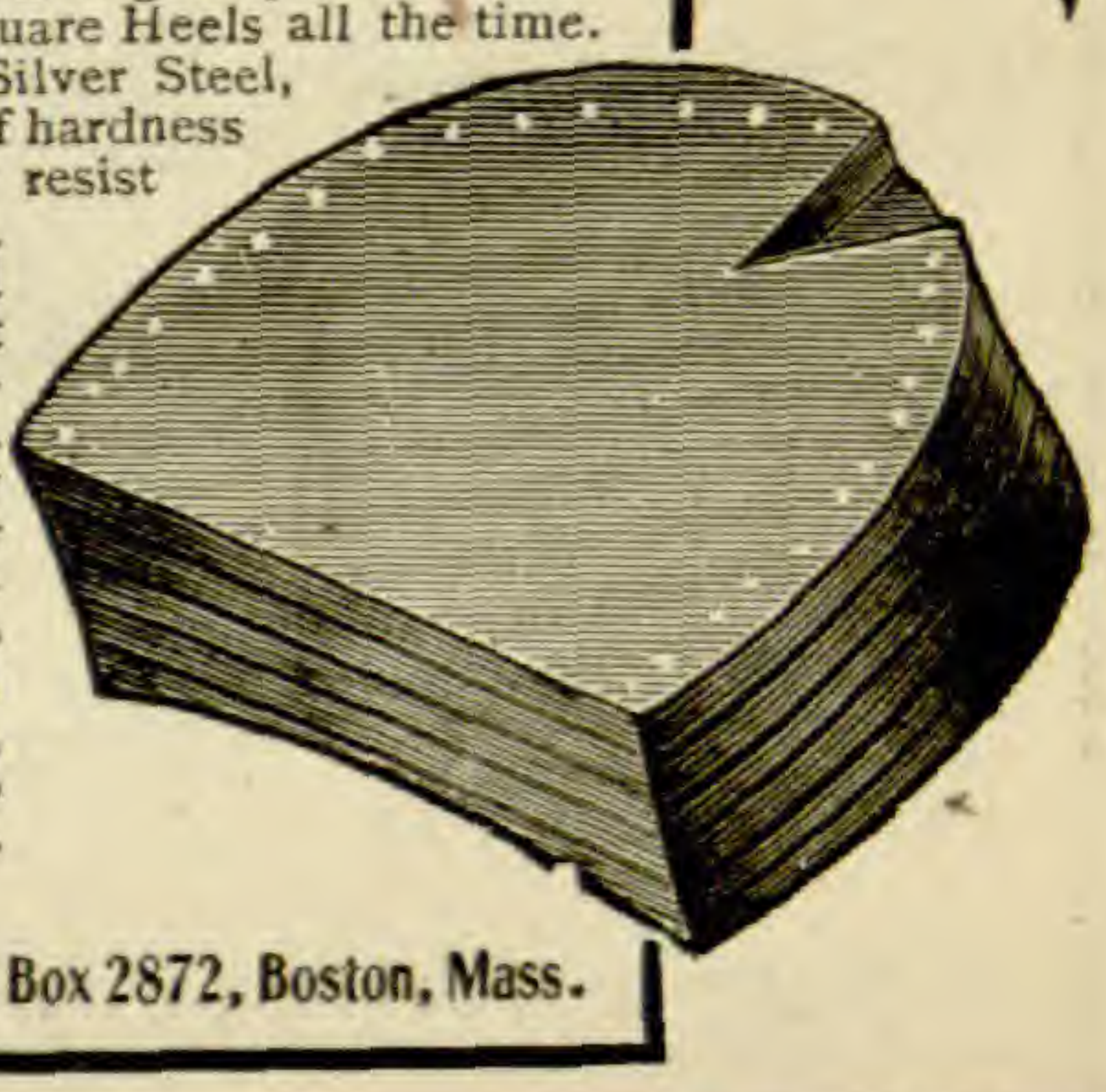

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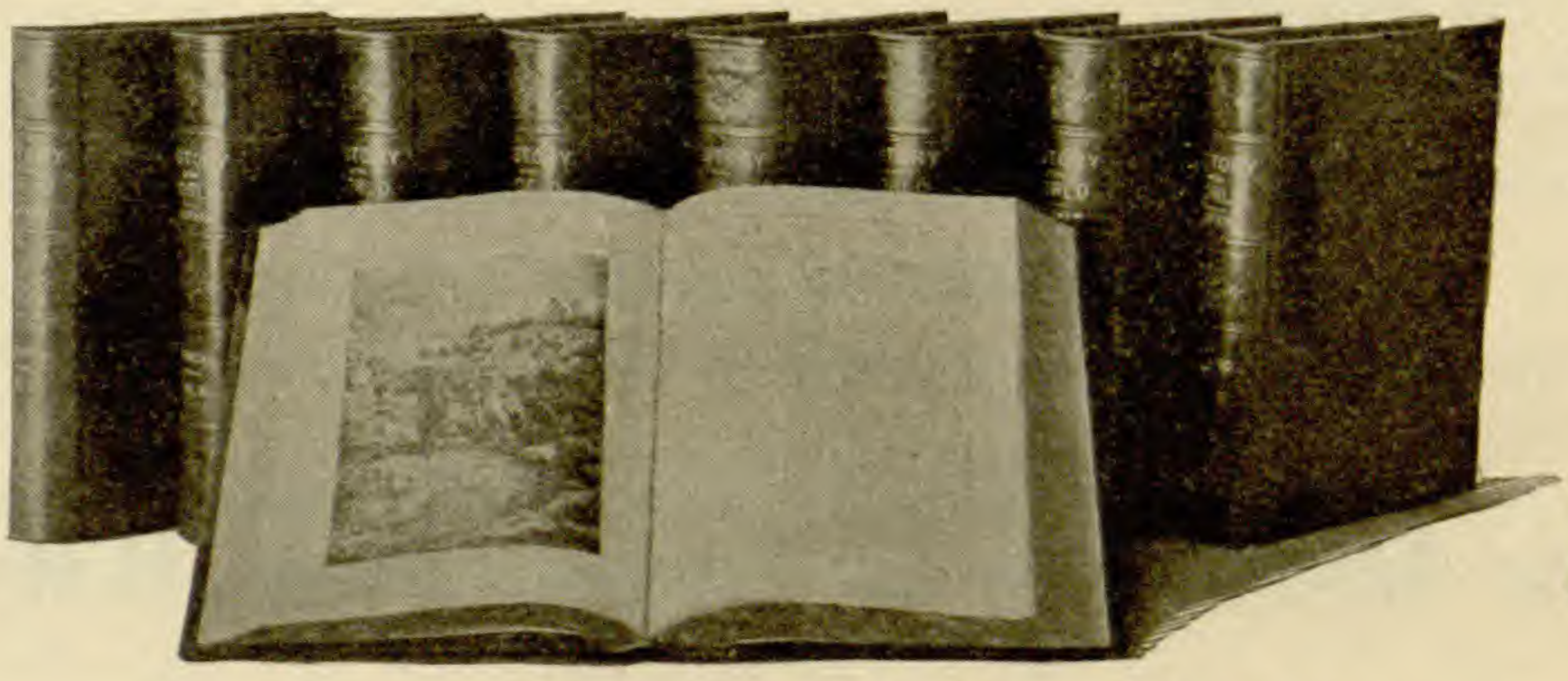

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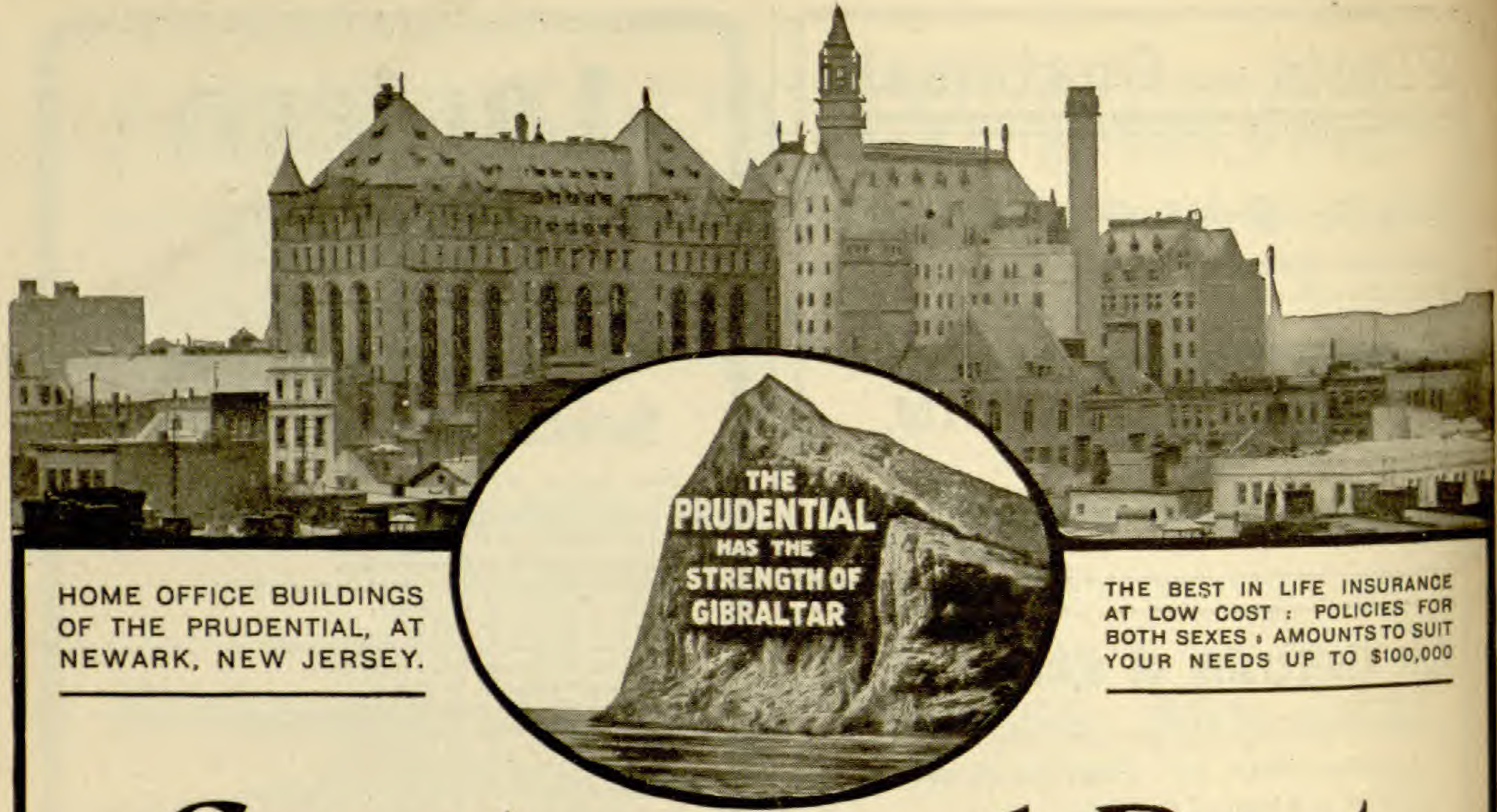
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VOLUME XXXVII NUMBER 3

BOTANICAL GAZETTE

MARCH, 1904

THE LIFE HISTORY OF RICCIOCARPUS NATANS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LIV.

JOHN F. GARBER.

(WITH FOUR FIGURES AND PLATES IX AND X)

THE beginning of the exact knowledge of the morphology of the Hepaticae dates from Hofmeister (1), who in 1850–62 published important investigations upon this group. Having discovered the egg cell in the archegonium, he traced the sperm to the surface of the egg and thus showed that the egg is fertilized by the sperm. He had previously announced his conclusion that the ordinary vegetative plants of mosses are the morphological equivalents of the prothallia of ferns, and that in mosses as well as in ferns there is a true alternation of generations.

Kny (2) gives a résumé of the literature on the morphology of Hepaticae up to 1867. He detected the apical cells and their method of segmentation in building up the thallus. He also described some stages in the development of the sex organs, and discovered the origin and manner of growth of the ventral scales. The thallus to him represented a fusion of stem and leaf.

Strasburger (3) mentions and figures the canal cells, but saw no walls separating them. He does not mention the ventral canal cell as different from the others, though one of his figures clearly shows it.

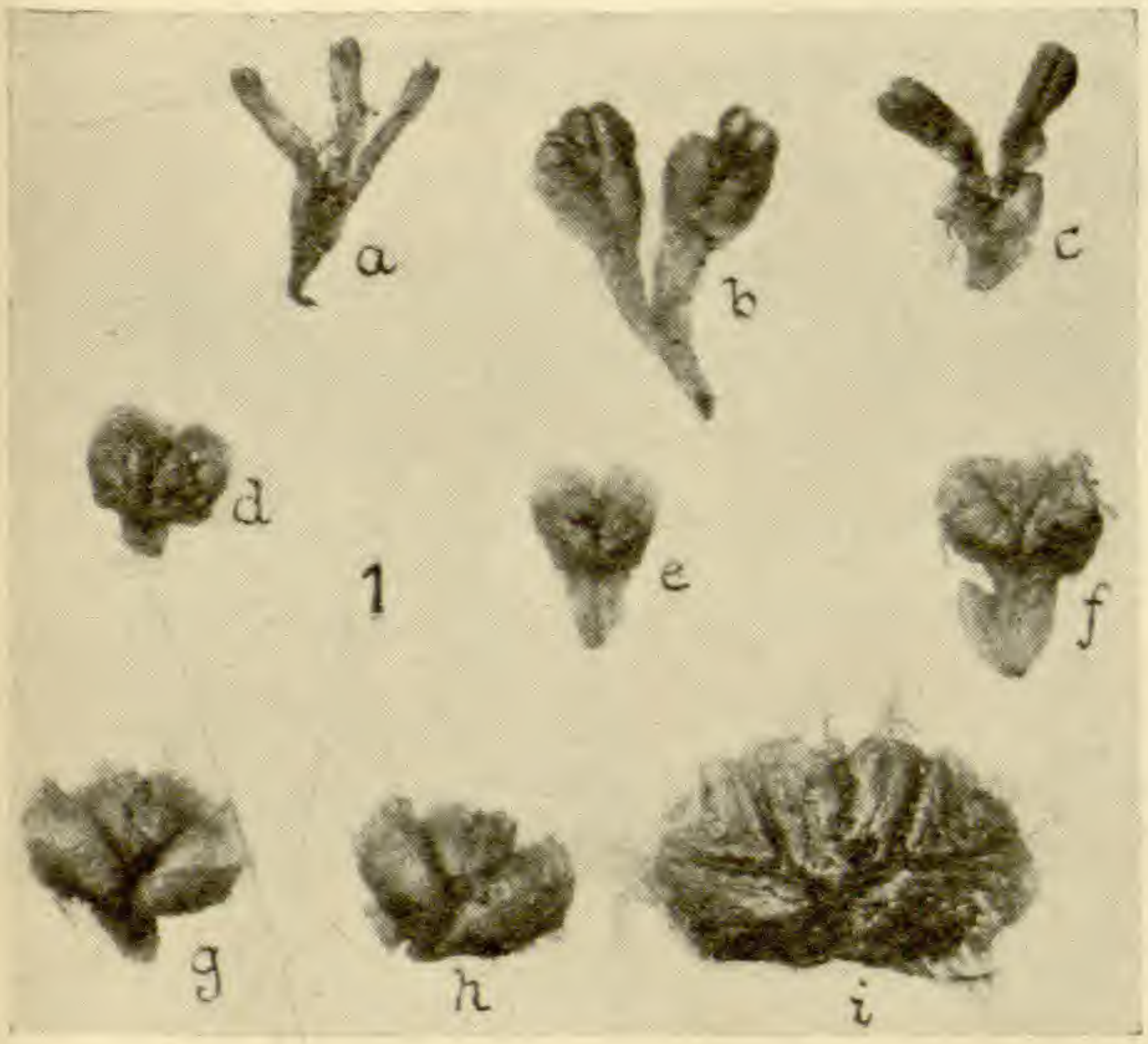
Leitgeb (6) in 1874–82 published comparative studies of the entire group of Hepaticae. In the Ricciaceae and Marchantiaceae he described the structure of the thallus and its method of growth, the formation of air chambers and pores, and showed that the ventral scales are homologous with the walls separating the air chambers. Corda had previously suggested the separation of *Ricciocarpus natans* from Riccia as an independent genus. Leitgeb, after examining Ricciocarpus, gives the following as distinguishing characters: (1) the constant presence of definitely formed air pores similar to those of Corsinia and Boschia; (2) numerous ventral scales which are formed independently and have long-continued basal growth; (3) a rudimentary integument (Hülle) around the sporogonium; (4) antheridia collected into groups similar to those of Marchantiaceae. Leitgeb lays stress on the grouping of sex organs, and suggests a progressive series in which the lowest member has the sex organs scattered indiscriminately over the upper surface and the highest has the definite group of sex organs terminating a branch.

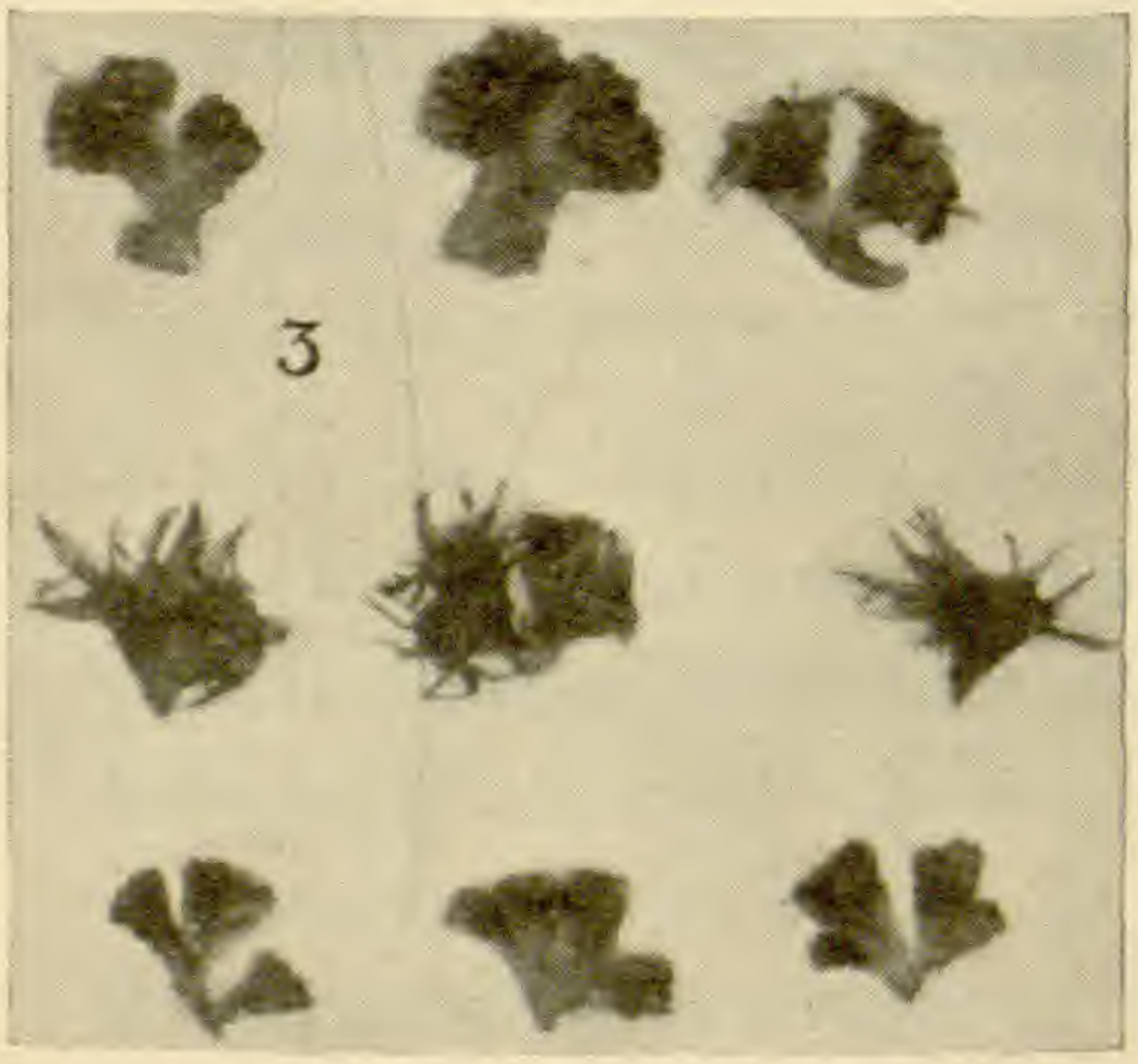
Fellner (**14**) studied the germination of the spore and the development of the thallus in *Riccia glauca*.

MATERIAL AND METHODS.

The material for the present study was collected during the spring and summer of 1902, and was fixed in a chrom-acetic acid mixture (1 per cent. of each) for twelve to twenty-four hours. After washing thoroughly in running water for a few hours, the plants were brought gradually into 70 per cent. alcohol. Pieces including an apex of a branch and a dorsal furrow were cut from these preserved plants. Since the loose, delicate tissues are very likely to collapse, the material should be hardened and dehydrated gradually, and the absolute alcohol should be renewed once or twice to insure perfect dehydration before any xylol is added. It is well to have xylol grades of 25, 50, and 75 per cent. in absolute alcohol, through which the material is passed with intervals of an hour between successive grades. After a short time in pure xylol, paraffin is added as fast as it is dissolved by the xylol. The paraffin should be changed three or four times during the three hours in the bath, after which the material may be imbedded. Sections perpendicular to the flat surface of the thallus and also to the median furrow are best for all purposes except to show a series of stages in a single section, in which case the sections should be parallel to the furrow.

Delafield's haematoxylin or Heidenhain's iron-alum haematoxylin proved excellent for young stages of the sex organs, and the latter stain was especially good for older stages of the sporophyte. Flemming's safranin gentian violet combination was most satisfactory for nearly mature archegonia and the process of fertilization.





Ricciocarpus natans.

FIG. 1.—*a* and *c*, plants injured by insects, the apical cells growing independent branches; *b*, single branch of soil plant like *fig. 2; d–i*, successive stages in the growth of fruiting plants.

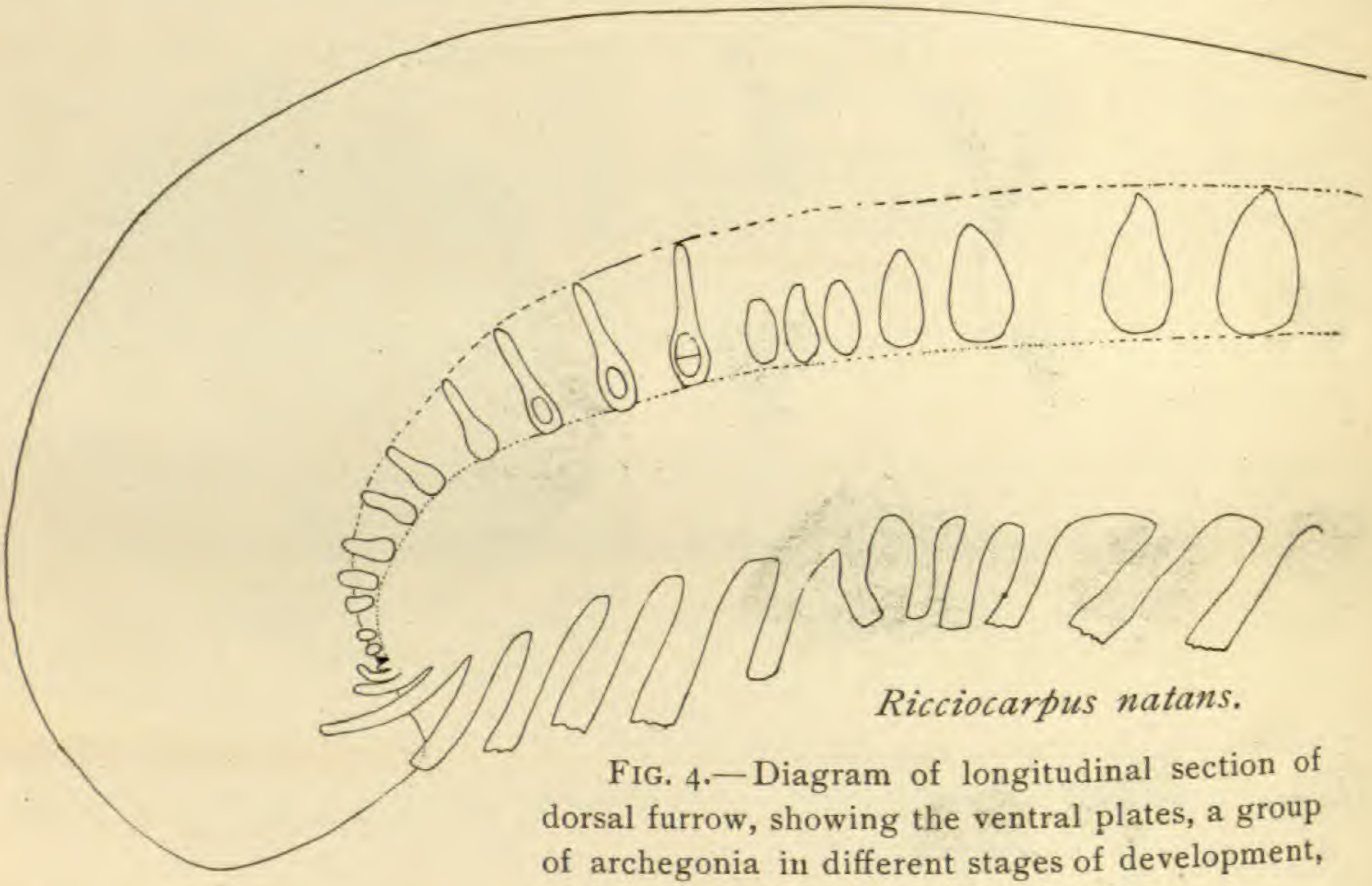
FIG. 2.—A rosette growing on the soil.

FIG. 3.—Vegetative water plants in autumn.

THE THALLUS.

The common floating form of Ricciocarpus is so familiar, and has been so well described by Bischoff (**13**) and others, that no further description of external appearance seems necessary. A series of stages in the development of the floating form is shown in *fig. 1* (*d–i*).

The upper surface of the plant is divided into small areas as in Marchantia, and in the center of each of these areas Leitgeb discovered a simple air pore surrounded by about six guard cells (*figs. 10, 11*). Two or three tiers of air chambers compose the green tissue, the walls and roofs of the chamber being composed of chlorophyllose cells. The storage tissue, composed of about ten layers of colorless, starch-filled cells, forms a strip beneath each dorsal furrow. The method of growth of the thallus and the formation of air chambers, air pores, and ventral scales has been so thoroughly worked out by Leitgeb (**6**) that there is little to add to his account. The number of apical cells at the anterior end of each furrow is larger than he supposed, averaging about five in our plants, as may be seen from the number of rudiments of ventral scales in a nearly horizontal section taken just below the apex (*fig. 9*). The position of the apical cells and their relation to the ventral scales is made clear by the sections represented in *figs. 4, 7, 8, 9*.



Ricciocarpus natans.

FIG. 4.—Diagram of longitudinal section of dorsal furrow, showing the ventral plates, a group of archegonia in different stages of development, and further back a group of antheridia.

The dorsal furrow in cross section has somewhat the form of an inverted Y, with a more or less prominent median longitudinal ridge between the arms. Early observers supposed this ridge to be produced by the enlarging of the sporophyte, but it occurs independently of this and is not present in purely vegetative plants. As growth proceeds, the plants become broader and thicker, and at the same time the older posterior parts decay (*fig. 1*). The decay sets free the ripened spores and provides for vegetative multiplication by separating the branches. No vegetative multiplication occurs during the spore-producing season.

THE SEX ORGANS.

It is a common statement that Ricciocarpus fruits only when in contact with the soil. In this vicinity no stranded fruiting plants have ever been collected except such as showed clearly that the fruiting process was already far advanced before the plant came to rest. A careful examination of abundant material in numerous localities shows that the fruiting plants normally float free on the surface of the water from germination of the spores until the spores of the next generation are ripened and discharged. The untimely withdrawal of the water often leaves mature plants stranded, and although they develop rhizoids very quickly, no change of form occurs until the spores have been discharged.

Ricciocarpus is described by Schiffner, Leitgeb, and Campbell as being strictly dioecious. Our investigations prove conclusively that it is strictly monoecious. The error of previous observers doubtless arose from the exclusive examination of mature plants, which normally bear only sporophytes because the antheridia have been lost by the decay of the older portions of the thallus. A very few plants usually produce antheridia only, and retain these until the plants are full grown, while still other plants may be quite sterile. Young plants and those formed from broken-off floating tips of soil plants very soon begin to produce antheridia in from three to five rows. The antheridia are at first superficial on the floor of the dorsal furrow just behind the apical cells. They gradually become sunken in cavities by the upgrowth of the vegetative tissue surrounding them (*figs. 4, 5*). The series may be interrupted at intervals so that the antheridia may occur in more or less definite groups, and late in the season on plants that fail to produce sporophytes these groups may be inclosed in definite common integuments terminating above in a sort of beak. It was this kind of a group on which Leitgeb (**6**) based his classification. The plants marked *d* and *e* in *fig. 1* have completed the series of antheridia and, if growth should continue, at once there would begin a series of from three to five rows of archegonia in position and arrangement a continuation of the antheridial rows (*figs. 4, 6*). The archegonial series is complete in a plant like *h* (*fig. 1*), from which the diagram (*fig. 4*) was made.

The cavities inclosing the sex organs are morphologically air chambers. The organ is graduated in length to the depth of the cavity, so that its apex is always approximately on a level with the floor of the dorsal furrow (*figs. 5, 6*). It may be noted that most of the antheridia are found in the narrower and less fleshy portions of the plants, while the archegonia are located in the more vigorous portions. The antheridial portions of the plant are produced early in the season, when conditions for growth are comparatively unfavorable. In this it reminds one of the prothallium of a polypod fern, which while young and delicate or in unfavorable conditions produces only antheridia, but if circumstances become more favorable, the enlarging, more vigorous plant begins the production of archegonia. Antheridia are produced during April, and by May 1 the youngest ones are half developed, the oldest having already discharged their sperms. The mature organ is a short-stalked, oval body, conical at the apex, with a wall consisting of a single layer of cells. Though antheridia are produced earlier in point of time than archegonia, their development is so much slower that both are mature at the same time. The sperms are of the usual biciliate type and have two complete coils.

A complete series of stages in the development of the archegonium was found on plants collected May 1. The course of development is the same as that outlined by Janczewski (**11**) for the typical liverwort archegonium. In the outer cell of the archegonium rudiment three successive vertical walls inclose a triangular cell which shortly divides by a transverse wall (*fig. 15*) into an upper cover cell, and a central cell which is to give rise to the axial row. This latter division is quickly followed by divisions in the outer wall cells, when the archegonium is composed of two tiers of four cells each. Successive divisions in the outer cells lengthen the neck and enlarge the venter.

The upper of the first two cells of the central row by two successive divisions produces regularly four neck canal cells, the same number as that reported for the species of Riccia which have been studied. The lower of the first two cells enlarges very rapidly and shortly before fertilization divides, giving rise to a small ventral canal cell and the egg cell (*figs. 20–22*). The egg fills the entire venter of the archegonium, except the small portion occupied by the ventral canal cell. Its protoplasm is at first somewhat vacuolate, but it rapidly becomes denser by the increase of food materials. Starch grains inclosed in plastids are so numerous at the time of fertilization as to be conspicuous even with moderate magnification. The surface of the egg next to the ventral canal cell is concave, and this condition disappears only with the resorption of the ventral canal cell, when the egg assumes a nearly spherical or a somewhat oval shape. The breaking down and resorption of the ventral canal cell seem to be dependent upon the entrance of the sperm, for the degenerate ventral canal cell is still to be recognized in archegonia that have failed to be fertilized, and in which the egg is rapidly shrinking and approaching complete disorganization, as in *fig. 26*.

The basal cell is larger than the outer one which forms the archegonium proper (*figs. 12, 13*). Two vertical walls very early divide it into four cells (*figs. 14–16*). Later divisions in various directions form a prominent mass of cells imbedded, with the exception of the short stalk, in the storage tissue beneath (*fig. 39*). This mass of cells appears to digest the abundant starch of the storage cells, so that it may be readily transferred to the growing sporophyte. The appearance and position of this tissue in relation to the storage mass indicates that it is the physiological equivalent of the foot of the sporophyte in higher forms.

Campbell (7) states for Riccia in general that the basal cell divides but a few times, forming the short stalk. For *Riccia hirta* in particular he says that "the basal cell finally divides into a single lower cell which remains undivided, completely sunk in the thallus, and an upper cell which divides into a single layer of cells forming part of the venter." For Targionia the same author says that "the basal cell undergoes irregular divisions and its limits are soon lost." Strasburger figures and describes the basal cell in *Marchantia polymorpha* as almost or quite superficial, forming only the stalk.

The arched ring of cells surrounding the opening through which the archegonium neck protrudes at the bottom of the dorsal furrow, regarded by Leitgeb as a rudimentary integument, appears to be merely the guard cells of the air pore belonging to the cavity in which the archegonium grows.

FERTILIZATION.

Soon after the ventral canal cell is cut off, the neck canal cells break down and the resulting mass extrudes from the tip of the neck between the separated cover cells at the bottom of the furrow. The pressure being removed from above, the cytoplasm of the egg may withdraw slightly from the venter walls and round off somewhat, the upper surface always remaining concave. The egg fills about three-fourths of the venter cavity. The shrinkage is not nearly so much in the healthy egg of Ricciocarpus as is figured in texts for Riccia, only degenerate archegonia having eggs so much shrunken (*fig. 26*). Sperms swim to the archegonium through the small quantity of water held in the furrow, which acts as a capillary tube whose ends dip to the water level. Numerous sperms were observed entangled in the mass extruded from the neck of the archegonium. The male and female nuclei were seen in various stages of fusion near the center of the egg (*figs. 23–25*). The diameter of the male nucleus is about one-half that of the female nucleus, and at the time of fusion stains darker because the chromatin elements are crowded more closely together. The male nucleus presses in the side of the membrane of the female nucleus until almost completely imbedded.

So far as I know, the observation of the phenomena of fertilization in a liverwort has been recorded only for Riella, studied by Kruch (9). He was, however, unable to get stages of actual fusion of the nuclei. With the entrance of the sperm, marked changes begin both in the egg and in the surrounding tissues. The oospore develops a cellulose membrane and quickly enlarges so as to fill completely the cavity of the venter. The cells of the venter begin dividing by walls parallel to the surface and make a complete double layer before the first division of the fertilized egg. A two-layered calyptra seems to be the rule among Ricciaceae, but as many as four layers occur among the Marchantiaceae.

THE SPOROPHYTE.

The first division in the sporophyte is usually transverse (*fig. 27*), but it may be oblique (*fig. 28*). The next wall may appear first in either the epibasal or hypobasal cell, and may be perpendicular to the first wall, thus forming a quadrant, or may be parallel to it, producing a row of four cells (*fig. 30*). Divisions then occur in all directions, producing a mass of thirty or forty cells, after which the amphithecium becomes distinguishable as a regular layer enclosing the spore-producing cells. Further divisions, not simultaneous (*fig. 32*), produce approximately four hundred spore mother-cells.

Up to this point the sporophyte has been a solid mass. Now the calyptra and amphithecium expand, leaving the spore mother-cells free, rounded, and separated from one another. At the same time there is excreted from the surrounding tissues a large quantity of nutritive material which fills the spaces around the mother-cells, giving them the most favorable conditions for rapid growth. Most of this nutritive material is absorbed by the spore mother-cells as they rapidly enlarge to fill again the amphithecium, and the remainder is pressed into thin plates adhering to the surface of the tetrads of spores (*fig. 38*).

The inner layer of the calyptra collapses shortly after the formation of the tetrads. The outer layer persists, while the amphithecium is distinguishable until the spores are almost ripe. All of the spore mother-cells produce spores, with no indication of elaters or sporophyte foot of any kind. Thus, as in Riccia, Ricciocarpus presents the simplest of hepatic sporophytes, which fact, I think, should be associated with a strictly aquatic habitat. To my knowledge, all floating liverworts have this simple form of sporophyte, while nearly all of those normally living and fruiting on the soil (including the submerged Riella) have to some degree developed sterile structures in addition to the simple capsule wall. The soil contact rationally appears to be a necessary stimulus to any extensive sterilization of sporogenous tissue in the progressive manner contemplated by Bower (15), because only on the soil does it seem possible so to establish an independent sporophyte.

A summary of the fruiting period about Chicago in 1902 is approximately as follows:

April 10–20. Formation and development of antheridia.
April 20—May 5. Formation and development of archegonia.
April 25—May 5. Fertilization.
April 25—June 20. Growth of sporophyte, production and shedding of spores.

Any given sporophyte matures in about three weeks from the time of fertilization, and when mature exceeds the volume of the egg from which it is derived about five hundred times. In the structure of its thallus Ricciocarpus is much more complicated than any Riccia. But the most important points in classification are connected with the arrangement of the sex organs on the thallus and the structure of the sporophyte. In the lowest species of Riccia the sex organs are scattered indiscriminately over the surface, while in *Riccia fluitans* there is said to be a regular alternation of single antheridia and archegonia. Leitgeb based his classification of the plant on old, isolated, exceptional groups of antheridia. The antheridia should be considered as being produced in a definite region of the plant in one large group, which is followed by the production of a similar group of archegonia. These groups may be compared to the arrangement found in Asterella, Sauteria, etc., and mark the farthest advance made by Ricciocarpus. On the basis of its complicated thallus and definitely limited regions of sex organs, I should place Ricciocarpus, as did Leitgeb, intermediate between Riccia and Marchantia, but with a distinct difference in conception of the arrangement of sex organs. He supposed the antheridia to be in several small groups and the archegonia to be scattered along the furrow with no attempt at grouping. All of his small groups of antheridia really belong together in one large group. The archegonia are also produced in a single region and should be regarded as a definite group.

A series of increasing concentration of sex organs into groups in specialized regions of the plant may be traced up to Marchantiaceae. Beginning with the lowest species of Riccia, sex organs are indiscriminately scattered. In *Riccia fluitans* there occurs a regular alternation of single sex organs. Ricciocarpus produces first all antheridia in a group and then all archegonia in a similar group, but with less apparent specialization of the areas bearing them than occurs in Targionia, which has the groups in special pits, and Corsinia which bears them on elevations.

On the other hand, the simple sporophyte, together with the feeding tissue derived from the basal cell of the archegonium, indicates primitive conditions not far removed from the simple sporophyte of Coleochaete.

Counts of chromosomes gave four for the gametophyte and eight for the sporophyte (*figs. 21, 35*). Kruch (9) gives eight and sixteen for Riella, and the same numbers are given by Farmer (5) and others for Pellia. The sporophyte spindle has very prominent and beautiful asters, but no centrosomes could be distinguished. The asters are identical with those of Pellia as described by Farmer (5), Davis (8), and Chamberlain (16), but no attempt was made to study their development.

BIOLOGY.

For biological data recourse was had to three sources, namely (1) the records of past collections, (2) the careful observation of various patches during one full season, and (3) experimentation in the laboratory.

The records of collections furnish facts as to dates and localities of fruiting in former years. With these data and by personal observation it was learned that in certain localities Ricciocarpus reproduces sexually every year at approximately the same season, while in other localities it is to be found continually, but never reproducing sexually. The chief factor which brings about this difference seems to be the relative permanency of the water, spores being produced on temporary ponds and no spores on permanent ones.

The heavy-walled resting spore is suited to endure unfavorable conditions. When the water withdraws, the spores are left on the mud or even on dry soil, a condition which may be a necessary preparation for germination. The spores germinate early in the spring of the year following their maturity, that is, nearly a year after they have been shed. The water may remain long enough after the fruiting season for a period of vegetative multiplication to intervene, and thus many plants may be left to grow on the mud. If the mud remains very wet, there are produced beautiful rosettes like *fig. 2*, formed of numerous slender branches that remain connected at the center of the rosette.

As a rule, there seems to be little chance of survival for the stranded plants. From the under surface there is put forth a dense mass of rhizoids which anchors the plant firmly to the soil. Soil contact causes the older ventral plates to wither, but new ones continue to be produced at the apex in the usual way, though they cannot become prominent because the rhizoids pull the plant down close to the soil. If the water should return, these plants would be submerged, and, unable to float to the surface, would very likely perish, as most of the plants growing on the soil probably do. In special cases, however, the land plants have been able to endure the submergence, until by decay of the older portions the young tips of the branches are set free, when they rise to the surface and develop into the floating form again. By taking large healthy branches from the soil and placing them in water, it was found that only the extreme tip remains slightly above the water surface. The remainder extends vertically into the water and soon decays, while the young tip develops the usual floating form of the plant.

If the body of water is permanent, the surface may be covered with small plants that multiply vegetatively throughout the season, so that countless numbers may extend over acres of water surface when the pond freezes. Large numbers of these plants probably die, but many of them, as the light and heat diminish, gradually become accustomed to submergence. The cold weather finally causes the plants to become black and apparently dead, in which condition they may float, become partially submerged, or even sink to the bottom. In this hibernating condition the plants have been taken from beneath the ice in early spring. When brought to the laboratory, the extreme apical region of each dorsal furrow grew out into a new plant. These new plants soon assume the vegetative water form and separate themselves from the old plant. Bischoff (13) mentions that *R. natans* lives over winter in a similar manner in Europe.

Rhizoids should be regarded as structures called forth by soil life, but in no sense as taking the place of ventral plates, which are always present.

The older parts of the plant possess no plasticity, but the meristematic region about the apical cell has a plasticity practically unlimited. If the plants are very much crowded, so that some are forced below the surface of the water, very commonly one or more of the apical cells will produce slender branches, which grow immediately to the surface. This is evidently an adaptation to get the plant into a favorable position again with the least possible expenditure of energy and tissue. A similar result occurred with some plants that were being kept in the laboratory. An insect ate out most of the vegetative tissues about the apex, and the restraining pressure being removed from them the apical cells grew out into independent branches (*fig. 1, a, c*). The great plasticity of the apical region in Ricciocarpus gives it the possibilities that one would expect to find in a transition form from aquatic to terrestrial liverworts. The gametophyte on the soil has the essential characteristics of terrestrial forms like Marchantia, except that it has not yet acquired the power to produce sexually there. If Ricciocarpus should acquire the power to produce sexually while on the land, it would become independent of the water.

A fungus belonging to the Ustilagineae frequently attacks the young sporophytes, completely destroying them and filling the venter of the archegonium with a dense mass of the smut spores. These spores are so much smaller and so much more numerous than the Ricciocarpus spores that the infected sporophytes are recognized at a glance. Although the fungus enters the archegonium soon after fertilization, the young sporophyte continues to grow, apparently following the normal course of development up to the spore mother-cell stage, and even to the formation of spores. By this time, however, the mycelium and numerous spores of the fungus are tightly packed about the Ricciocarpus spores, which soon break down and are destroyed by the encroaching fungus (*fig. 40.*)

The life history of the fungi inhabiting various liverworts was carefully followed by Cavers (**10**). He states that the fungal hyphae usually grow down the neck of the fertilized archegonium, but they may pierce the venter and thus enter the sporogonium directly. In all cases where the sporogonium is invaded the relation of host plant and fungus is regarded as pure parasitism. Where the fungus penetrates only gametophyte tissue it may form a mycorhiza, the host plant living as a saprophyte, the relation of fungus and host being apparently that of symbiosis.

I am under obligations to Professor J. M. Coulter and Dr. C. J. Chamberlain for suggestions and advice during this study.

SUMMARY.

1. When fruiting, Ricciocarpus is essentially a free floating plant.

2. The genus is strictly monoecious, though a small number of plants fail to produce archegonia.

3. Sex organs are produced in single definite groups as in Asterella, etc. Antheridia are produced on very young plants, which later produce archegonia and sporophytes.

4. The basal cell of the archegonium develops a structure which is partially imbedded in the storage tissue and acts as the physiological equivalent of the sporophyte foot in higher forms.

5. There is no rudimentary integument of the archegonium.

6. The diameter of the male nucleus is about one-half that of the female nucleus.

7. The first division of the sporophyte is transverse or oblique. The early subsequent divisions are irregular.

8. A large quantity of nutritive material is excreted into the capsule among the mother-cells.

9. There is no indication of elaters or sporophyte foot of any kind, which fact is associated with the aquatic habitat.

10. The fruiting period occurs in spring and occupies about ten weeks.

11. The gametophyte number of chromosomes is four, the sporophyte number eight.

12. Permanency of the water appears to be unfavorable to sexual reproduction.

13. Plants once established on the soil are usually unable to resume the floating condition, but under exceptional circumtances they may do so.

14. Vegetative plants hibernate at the bottom of the pond, producing new plants the following spring.

15. Rhizoids do not replace ventral plates, but are an addition to adapt the plant to a life on the soil.

16. The apical region is exceedingly plastic.

17. The sporophytes are frequently invaded and destroyed by a fungus belonging to the Ustilagineae.

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EXPLANATION OF PLATES IX AND X.

The magnifications are as follows: *figs. 10* and *11*, × 600; *fig. 20*, × 1600; *figs. 21* and *35*, × *ca.* 2500; *fig. 36*, × 850; all others, × 1000. In reproduction the drawings are reduced one-half.

FIG. 5. Diagram of cross section of dorsal furrow passing through a group of nearly mature antheridia.

FIG. 6. Diagram of cross section through group of archegonia; dotted lines indicate the limits of the starch-bearing tissue.

FIG. 7. Longitudinal section through the apex of a plant.

FIG. 8. Cross section through apical cell region.

FIG. 9. Horizontal section just below the apical cells with five rudiments of ventral scales.

FIGS. 10–11. Stages in the development of the archegonium before ventral canal cell is cut off; showing also development of tissue from basal cell.

FIGS. 20–21. Cutting off ventral canal cell.

FIG. 22. Archegonium nearly ready for fertilization.

FIG. 23. Fertilization; nuclei in contact, the male nearer to the eye in the section; egg with concave apex.

FIG. 24. Fertilization; starch grains in the plastids large and prominent.

FIG. 25. Fertilization further advanced; the male nucleus almost completely imbedded in the female nucleus, and the egg swollen out to fill compactly the venter.

FIG. 26. An unfertilized archegonium with egg and ventral canal cell degenerating.

FIG. 27. First division of the sporophyte by a transverse wall.

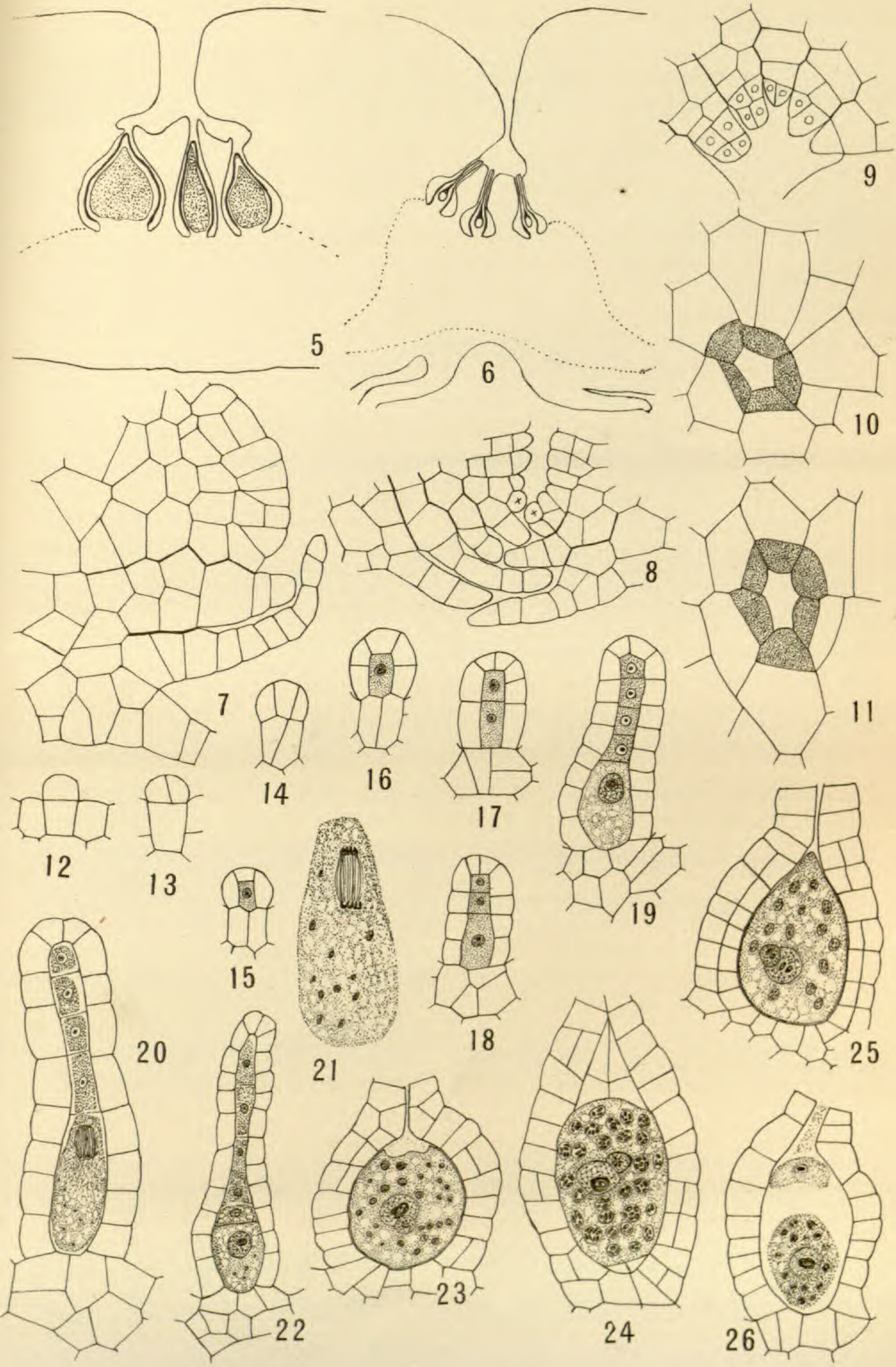
FIG. 28. First division of the sporophyte by an oblique wall.

FIG. 29. Four-celled embryo in form of quadrant.

FIG. 30. Four cells of embryo in a row.

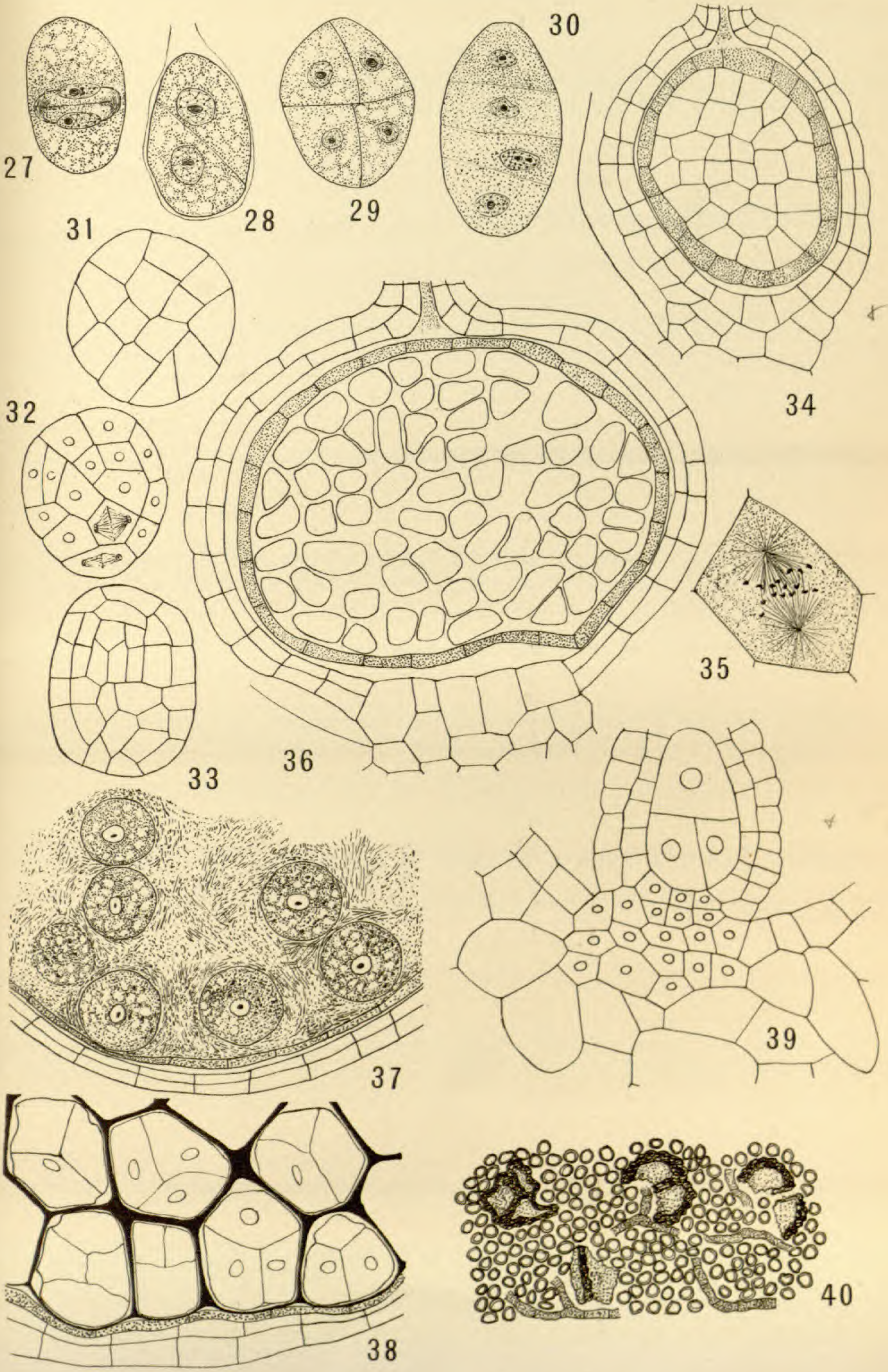
FIG. 31. Older embryo in which quadrant can still be distinguished.

FIG. 32. Embryo beginning to form amphithecium.



J. F. GARBER, DEL.

GARBER on RICCIOCARPUS.



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GARBER on RICCIOCARPUS.

FIG. 33. Sporophyte with amphithecium almost complete.

FIG. 34. Sporophyte with amphithecium clearly differentiated.

FIG. 35. Sporophyte cell division; spindle has very prominent asters with eight chromosomes attached to each.

FIG. 36. Spore mother-cells free and rounding off.

FIG. 37. Spore mother-cells surrounded by nutritive material.

FIG. 38. Spore mother-cells forming tetrads surrounded by framework remaining from nutritive substance shown in *fig. 37*.

FIG. 39. Young sporophyte in an archegonium having a "foot" derived from basal cell imbedded in nutritive tissue of gametophyte.

FIG. 40. Diagram. Fungal hyphae and spores surrounding broken-down spores of Ricciocarpus.

VEGETATIVE CELL DIVISION IN ALLIUM.

MABEL L. MERRIMAN.

(WITH PLATES XI–XIII)

BEFORE the controversies which have arisen over the occurrence of reduction in plants can be settled or the problems as to the nature of fertilization can be attacked, a detailed study of dividing and quiescent plant cells is made necessary. The vegetative or typical division of plant cells from which the factors of sexuality and reduction are eliminated must be understood before deductions can be made as to the significance of the mode of origin and distribution of the chromosomes occurring in atypical divisions.

Accordingly, this research was undertaken with the hope of adding to our knowledge of the processes of vegetative cell division, and also of paving the way for further investigation of these processes as affected by variation of external conditions. The material used is Allium root tips, already known as exceptionally favorable for the study of karyokinesis. It was also considered an advantage, in order to secure a more thorough survey of the subject, to employ material which had furnished the text of other publications.

TECHNIQUE.

The following solutions were used for the fixation of the cells: chrom-acetic-osmic, both the weaker and stronger solutions as employed by Flemming, chrom-acetic acid (chromic acid 0.9 per cent. and acetic acid 0.1 per cent.); the solution recommended by Carnoy as composed of one part glacial acetic to six parts absolute alcohol and three of chloroform; and finally a solution made up of saturated picric acid one part, sublimate one part, to two parts of water. Cedar oil and xylol were used as clearing fluids. The best differentiation of the chromatic substance was obtained with Heidenhain's iron alum haematoxylin in combination with some cytoplasmic stain. The triple stain, safranin gentian violet and orange G, followed by clove oil as a clearing agent, gave the best results in differentiating the nucleoli.

CELL DIFFERENTIATION.

The transition of meristem cells into permanent tissue is to be noted not only in the changes taking place in the nuclei, but also in the cytoplasm. As the cells develop into permanent tissue, large vacuoles appear in the cytoplasm, and the nuclei retreat into positions next to the walls, becoming then elliptical. Among the foremost of the problems suggested by watching the cells of the meristem pass out from their embryonic condition was that of the part played by the chromatin and nucleoli in this transformation of an embryonic cell into a tissue element.

A median longitudinal section reveals the large central cells and elongating cells which constitute the plerome. These large cells have correspondingly large nuclei and vacuoles in the cytoplasm and a relatively smaller amount of chromatin (*figs. 50, 51*). In the differentiation of these cells the chromatic substance first diminishes, and with this diminution it gradually loses the power of forming the karyokinetic figures. The great increase of the nucleoli follows from the quantitative reduction of the chromatin, while the energy that would have produced new cells becomes diverted into the expansion of the nucleus and cell body. The central cells reach a maximum of enlargement and then enter upon slow disorganization.

The cells of the plerome elongating to form procambium are early conspicuous, being marked off from the large central cells of the plerome on the one side and the periblem cells on the other by their narrow dimensions and elongating nuclei (*figs. 51–56*). An examination of these cells when in the act of dividing shows that the same general changes take place as in the meristem cells. The spireme stage is to be frequently seen, as well as the separation of the chromosomes. No cell, however, was seen which showed the chromosomes drawn into an equatorial plate. Their passage to the poles seems to follow directly upon the breaking of the spireme (*fig. 55*).

The changes leading to the formation of the elongated cells must be sought in the meristem cells from which these are derived. Cells such as those shown in *fig. 53*, situated within the borders of the meristem region, whose shapes vary but slightly from the typical embryonic cell, have noticeable differentiations ushered in even before the membranes of the daughter nuclei are formed. In the cell shown in *fig. 53* of the anaphase the daughter chromosomes can be seen pushing into the cytoplasm as the spireme coils are being formed. This is the first visible elongation of the nucleus.

It cannot be said, then, that the peculiar shape of the nucleus is an adaptation to the shape of the cell, as in this case no appreciable elongation of the cell body has yet appeared. The causes which lead to this differentiation must be inherent in the chromatic substance where it is initiated.

In *figs. 52, 54* of the telophase the elongation of the daughter spiremes can be seen. These early elongations give to the daughter nuclei an amoeboid shape. Such appearances in the various stages furnish evidence that the chromatic substance is here of a fluid nature, with the power of independent motion, and not a substance passively drawn by contractile threads of kinoplasm.

When the cells by successive division have reached their maximum of elongation, further changes can be seen to have taken place within the nucleus. The chromatin, instead of being separable into groups of fours, as in the earlier stages of elongating cells and as described in this investigation for the meristem cells, becomes vacuolar, the chromatin irregularly massed, while the nucleoli, which up to this time have been undergoing a considerable increase in size, suffer fragmentation.

The observations then drawn from the anatomical differentiation in both types of cells found in the plerome point to the conclusion that the chromatic substance must play the chief rôle in the transformation of an embryonic cell into a tissue element.

The same general statements as to the part played by the chromatin in the transition of the meristem cells into periblem and dermatogen can be made. The shape assumed by the chromatic figure in karyokinesis determines the shape of the daughter cells. As the chromatic substance may elongate in the meristem cell to form the elongated cell of the procambium, so it may assume a square figure and produce the daughter cell of the dermatogen.

In case of meristem cells destined to form the protecting cap, the chromatic substance gradually dwindles in amount without being accompanied by further increase of the cell body. The cytoplasm as well becomes reduced until finally both disappear.

The process of division of meristematic cells without regard to the problems suggested by differentiation will now be treated in sections.

THE ACHROMATIC FIGURE.

The enlargement of the nucleus due to the growth of the chromatin in the prophase of division is accompanied by significant changes in the appearance of the cytoplasm. In *figs. 2–5, 8, 9*, which show stages in the formation of the spireme, the cytoplasm appears to be uniform in structure. A comparison of the shapes of the nuclei indicates that the nuclei in the living cells must be amoeboid in these stages. As nearly as could be determined, the changes in the structural appearance of the cytoplasm in the immediate vicinity of the nucleus just precede or accompany the transverse breaking of the spireme coil into chromosomes.

The first indications of the achromatic figure are to be seen in the aggregations of cytoplasm which appear first and remain the densest at the poles of the nucleus. The shape which these aggregations assume, and hence the final shape of the achromatic figure, is dependent upon the shape and nature of the cell, as also possibly upon the fixative employed. The nucleus taken together with these cytoplasmic aggregations may be spherical, (*fig. 24*), or ovate (*fig. 18*), or elliptical (*fig. 19*). Occasionally these aggregations appear in such manner as to cause the chromatic figure to be obliquely oriented, and hence to alter the division plane from the usual one at right angles to the long axis of the cell.

Cells were seen in certain preparations, notably those fixed in chrom-acetic, in which the segments of a hyaline sphere seemed to cap either pole of the nucleus (*fig. 11*) of a cell cut somewhat obliquely, the cytoplasmic aggregations appearing to extend over and around these segments (see also *fig. 24*). In such figures the clear space presents the same appearance and the same staining reaction as the nuclear interior.

A study of the nuclei in the prophase stages did not furnish satisfactory evidence that such hyaline segments capping the nucleus are regular stages in the formation of the achromatic figure. Although such appearances are to be frequently met with in material fixed in chrom-acetic, similar nuclei in the prophase show no hyaline sphere segments, but merely enlargements with cytoplasmic polar aggregations. Hence a question can be raised as to the existence of the hyaline polar caps in the living cells. Is this appearance a normal phenomenon produced by a withdrawal of cytoplasm from the pole of the nucleus, and to be referred to the turgescence of the living cell which causes the formation of a plasma membrane around the nuclear membrane? Or has this appearance been caused by fixation, the nucleus having become distorted and the membrane split or swollen? Or, thirdly, are these polar caps only optical effects resulting from looking down upon sections of an irregularly shaped nucleus, the lower boundary being projected beyond the upper boundary and hence producing the appearance of polar caps? A section of a nucleus shaped like a truncated cone can be conceived as presenting such an appearance.

In order to solve this problem, examination was made of many preparations fixed and stained by the methods previously outlined. If the hyaline caps are not produced by fixation, or are not optical effects produced from looking down upon sections of an amoeboid-shaped nucleus, but, on the contrary, are normal phases in the growth of the achromatic figure, their presence should be established in similar prophase stages and in all fixations which otherwise preserve the character of the cell contents. Preparations fixed in chrom-acetic showed such phenomena frequently, but by no means so constantly as to warrant their being considered a normal feature of division. *Figs. 19* and *20* represent a periblem cell drawn at upper and lower focus and taken from a series fixed in picro-sublimate solution. No nuclei in the prophase showing hyaline caps at the poles were found in this series. In the drawing of the upper part of the nucleus the cytoplasmic aggregations may be seen at the poles. The nucleus has elongated in the direction of the long axis of the cell. Indications are also present of the ingrowing cytoplasmic fibrillae which later meet the linin strands that join the spireme coils to each other and to the nuclear membrane. *Fig. 18* from a series fixed by the same method represents a plerome cell in similar stage where the nuclear membrane has pushed out at the poles into the cytoplasmic aggregations. *Fig. 28* from the same series may be taken as a later stage, where the nuclear reticulum has completely joined with the cytoplasmic fibrillations. The stages in material fixed in Flemming presents configurations similar to those in the material fixed in picro-sublimate. An early stage from these preparations showing the pushing out of the nuclear membrane at the poles is seen in *fig. 26;* a somewhat later stage in *fig. 27*, where the cytoplasmic fibrillations can scarcely be distinguished from the nuclear reticulum. In *fig. 6*, from another series fixed in Flemming's solution in which the chromatin is well preserved, it would seem as though a vacuolization had taken place around the nucleus. There is no evidence of such vacuolization in *figs. 17* and *25*, taken from another series fixed in Flemming's solution, both cells being in the same section of the root tip. In both these cells the nuclear membrane can be clearly traced, marking out the nuclear space from the cytoplasm. *Fig. 25* is of a stage later than that shown in *fig. 17*. Here there are no signs of hyaline caps, but there is unmistakable evidence that the achromatic figure is formed by the elongation of the nucleus accompanied by the ingrowing of fibrillations from the cytoplasm. *Fig. 30*, from a preparation fixed in chrom-acetic, is a still later stage, where there is but the vaguest trace of a nuclear membrane. The achromatic figure is well formed and indistinctly multipolar. The term "monaxial multipolar," as applied by Hof to distinguish this form from the type of multipolar spindle found in the dividing macrospore, better describes the achromatic figure at this stage.

When the chromosomes are being drawn into an equatorial plate figure, as also when they have begun to recede to the polar figures, the fibers are more frequently found converging to a single point, though multipolar monaxial figures are the more characteristic. Certain cells from material fixed in Flemming show but traces of the achromatic figure, such traces being confined to the linin connecting adjacent chromosomes (*figs. 32, 33*). Fixatives such as chrom-acetic accentuate the fibrillar character of the plasm, while that of Flemming accentuates the granular character, showing fewer intercytoplasmic spaces. Compare *fig. 33* Flemming with *fig. 37* chrom-acetic.

Thus the evidence from the preparations examined points to the conclusion that the achromatic figure in Allium is derived from both cytoplasm and the elongated nucleus; that the cytoplasmic fibrillae normally fuse with the nuclear reticulum without the intervention of periplast formation, and form a multipolar monaxial spindle which may secondarily become bipolar.

The observations of other investigators regarding the achromatic figure in the division of meristematic cells is as follows:

Rosen (8) stated that in the cells of root tips of hyacinth a homogeneous plasm collects in a thin hyaline layer about the nucleus destined to divide. This layer he found to be concentrated at the opposite poles in the form of two conical caps in which rows of fibrillae originated close to the nuclear membrane.

Hof (11) stated that in Ephedra kinoplasmic bodies forming caps appeared simultaneously at the two diametrically opposite points of the nuclear surface. The polar caps soon took on the shape of sharp pointed spheres. In the interior of these spheres delicate threads form which finally fasten to the nuclear surface.

Němec (9) describes the fundament of the spindle as being bipolar in orientation from the beginning, appearing as a hyaline formation surrounding the nucleus and in the form of caps at the poles. He designated such caps as "periplasts." In another contribution upon the nuclear division of *Solanum tuberosum* he stated that, whereas in normal cells a hyaline periplast is formed as in Allium, in cells taken from wounded tubercles the threads grew out directly from the nuclear surface. He considered that the reason for the failure of the hyaline periplasts to appear in the cells of the wounded tubercles is because of the greater size of the nuclei. Nuclei occurring in the tubercles experimented upon were 30 per cent. larger than those found in the growing points of root and stem.

His statement as to the cytoplasmic fibrillae in the cells of wounded tubercles growing out directly from the nuclear surface agrees with what I found in normal cells from the root tips of Allium fixed in Flemming and picro-sublimate solution. As to the appearance of the periplast, I cannot agree with Němec in considering it a normal feature in the process of vegetative cell division, and its absence caused by experimentation or otherwise disturbed conditions. In some cases its presence seems to be due to the action of fixatives or to the sectioning of an irregularly shaped nucleus.

Also as to the cytoplasmic aggregations which Strasburger and Hof consider as being made up of a specific substance, kinoplasm, the evidence derived from comparing the structural appearance of these aggregations with the appearance of the remainder of the cytoplasm in the various preparations does not seem to uphold such a conception. Their appearance rather justifies the view expressed by Wilson (5) and others that alveolar spheres, microsomes, granules, and fibrillae may be morphologically considered as but gradations of one structure.

CENTROSOMES.

In one case only, out of the many preparations of Allium examined, was there a substance visible which could be construed as a possible centrosome. This case is shown in *fig. 34* of a nucleus in the spireme stage with a dumb-bell-shaped body lying a little at the right of the lower pole. No astral rays are present, there being only a clear space about the body inclosed by a plasma membrane. The fact that the body was discrete and that its shape might indicate its undergoing a process of direct division led me to think that here might be a centrosome which by reason of its temporary character had before eluded observation. The section was from material killed in chrom-acetic and stained with eosin and iron alum haematoxylin. After this cell was seen the material similarly treated was re-examined for bodies which might be interpreted as centrosomes, but with negative results.

The centrosome-like body was stained red by the eosin, as was the cytoplasm. As the centrosome of animal cells in all cases that I have observed stains black by the iron alum haematoxylin method, like the chromatin, the staining reaction argues against the interpretation of this body as a centrosome. The presence of the nuclear membrane still intact, together with the nucleolus within the spireme, shows conclusively that this body cannot be interpreted as a nucleolus. Whenever a nucleolus cast out into the cytoplasm is treated with iron alum and haematoxylin it takes on an intensely black stain (*fig. 36*).

On the examination of other cells on the same slide the cytoplasm was seen to contain bodies with similar staining reaction. These, however, showed no signs of division and their position in reference to the nucleus was inconstant. *Fig. 35*, of two cells in distinctly different phases of division, shows these appearances in the cytoplasm and indicates that their presence is not to be considered significant, but is caused by some imperfection in preservation, or else is due to some abnormal conditions in the cells such as the presence of parasites. Such appearances were not found in other material treated by the same or different methods.

Guignard (**2**) maintained the existence of centrosomes as dynamic organs in the cells of higher plants; Schaffner (**13**) described them as existing in Allium root tips; but Strasburger (**14**) and many other investigators find no evidence of their presence and have concluded that the centrosomes described as existing in the higher plants are in reality nucleoli, microsomes, or fixation products. Ch. Bernard (**16**) affirms the existence of centrospheres in *Lilium candidum*, but admits that they are variable in appearance. His figures showing bodies in the cytoplasm with clear spaces about them resemble mine of nucleoli degenerating in the cytoplasm.

The results of this investigation upon Allium can furnish no positive evidence of bodies in the cytoplasm which can be interpreted as centrosomes.

THE NUCLEOLI.

The nucleoli, generally two in number, can be seen in fixed preparations of quiescent cells lying within a clear space surrounded by the chromatic network.

The size and shape of the nucleoli vary with the size and nature of the cell. Elongated cells have elongated nuclei and nucleoli (*fig. 55*), while the large central cells of the plerome have large, more or less spherical nuclei.

This power of accommodation of the nucleolus to the shape of the nucleus, together with its vacuolization and amoeboid contour, are direct indications of its essentially fluid nature. Referring to *fig. 50*, the large nucleoli in a central cell of the plerome can be seen. As these central cells recede in their multiplication from the zone of greatest growth, the nucleoli become relatively larger, the chromatic substance less conspicuous and abundant.

From these observations two conclusions might be drawn. The nucleoli, enlarging either by intussusception or apposition of particles coming from the cytoplasm, by their own growth may rob the chromatin elements of the nutriment necessary to enable them to develop the chromatic figure. Hence degeneration results, the line of broken-down cells giving rise to the central cylinder. Or the nucleoli may be thought of as accumulations of a substance which results from the reduction and degeneration of the chromatin. The latter seems more probable, as all the evidence obtained from cells which retain to the last their capacity for division points in the direction of a nucleolus arising from the disintegration of chromosomes into individual chromatin granules.

Rosen (8) states that in the hyacinth the nucleolus melts away during the formation of the spindle. In one series of sections only obtained from the hyacinth he found nucleoli cast into the cytoplasm. He offers the two following explanations for the difference in these series: special conditions of growth and nourishment might bring about the expulsion of the nucleoli from the mitotic figure, or karyokinesis might vary in this particular point on account of the many varieties of the cultivated hyacinth.

This persistence of the nucleoli after the formation of the achromatic figure, which Rosen found in only a small portion of his hyacinth material, I found in all the material examined, from tips of Allium just started within the bulb and from those grown in water or solutions for some time. The duration of the nucleoli varies. I have never seen any signs of the presence of the nucleolus as a stainable body in the spindle space or in the cytoplasm after the daughter chromosomes have begun their movement toward the poles. *Figs. 2–30* show the condition of the nucleoli as the formation of the achromatic figure advances; *figs. 36, 37* are chosen from the many cases observed showing their dissolution in the cytoplasm. These go to prove that in Allium at least the nucleoli do not furnish to any appreciable degree the material for the achromatic figure, as Strasburger (14), Hof (11), and Němec (9) have claimed.

Neither did any cells yield evidence, such as Němec (9) gives in his work upon Allium, that the new nucleoli arise from the substances coming from the degeneration of the mantle fibers. The degenerating mantle fibers appear rather to be streams of granules which become diffused in the cytoplasm, to gather again at the line where the cell plate forms. In *figs. 45* and *46* are two periblem cells in stages closely succeeding one another and approximating the time for the appearance of the nucleoli. No aggregations of granules which stain like nucleoli could be observed in these cells or in any similar stages. If we consider the mantle fibers and the like in the living cells as streams of albuminoids and other substances issuing from the nuclear elements in their activity, then the apparent degeneration of the fibers merely indicates a diffusion of these dissolved substances and a lessening of their flow. These streams, after the chromosomes have arrived at the poles, are mainly directed in their course to the equatorial zone, separating the two daughter nuclei where the deposited substances lead to the building of the cell plate.

As stated in the section upon the chromatic figure, at the time of the fusion of the chromosomes to form the spireme in the daughter nuclei, the spaces between the coils can be seen to be occupied by a diffusible and slightly stainable substance (*figs. 42–46*). This substance becomes denser at last, resolving into the bodies which are known as the nucleoli of the resting nucleus. I think that this substance results from the mere deposition of particles coming from the disintegration of chromosomes into tetrad chromatin granules and the reduction of the latter in size. These particles, of a more or less plastic nature, increasing in proportion to the reduction of the chromatin granules, are entangled in the chromatic network only to be released with the dissolution of the nuclear membrane at the next mitosis.

In connection with this view of the close relation of chromatin, linin, and nucleoli, it may be well to cite results of other investigators which accord in some measure with those secured in Allium.

In the case of Spirogyra, Meunier (4) and Mitzgewitsch (12) have claimed that during mitosis the nucleoli become converted into chromosomes and in the reconstructing daughter nuclei the chromosomes are transformed into nucleoli. Wisselingh (15) found that ten of the chromosomes arise from the nucleus, while the remaining two arise from the nucleolus. Hertwig (10) states in regard to the nuclear division of Actinosphaerium that the nucleoli may be classed as of two kinds, those containing chromatic material and those free from chromatin. The latter he terms plastin nucleoli. They originate as small vesicles within the chromatin bridges. His conclusion is the same as I reached in this investigation, namely that the material of the nucleoli was originally contained in the chromatin bridges. I would also add that in Allium the chromatin bridges are in turn derived from material originally contained in the chromosomes and result from their quantitative reduction.

Since Strasburger (14) holds that the nucleoli of the higher plants are converted into the kinoplasm of the achromatic figure, he considers that the plastin nucleoli described by Hertwig are not at all analogous to those found in higher plants.

Researches upon forms of the lower plants and animals indicate that chromatin, linin, and nucleoli are of the same substance, the form and amount of which vary as the nucleus is quiescent or actively dividing. If then the nucleoli of the higher plants are not genetically derived from the chromatic substance, but, as Strasburger holds, come from the degeneration of the mantle fibers, then the function and mode of origin of these nucleoli must have undergone a radical change in the course of evolution. Strasburger attributes this difference in the function of the nucleoli in the higher plants from that found in lower forms to the absence of centrosomes.

The view expressed in this investigation that the nucleoli are accumulations resulting from the quantitative reduction of the chromatin is not only in harmony with the evidence derived from lower forms, but better explains the conditions observable in the plerome cells which have no use for material with which to manufacture achromatic figures.

THE CHROMATIC FIGURE.

The chromatic granules of meristematic cells that are in a quiescent state are distributed in the linin network, but lie at the periphery of the nucleus rather than uniformly distributed, while the linin strands can be seen anastomosing with the more centrally lying nucleoli. In these nuclei the granules appear so minute even with the one-twelfth inch homogeneous immersion that no satisfactory evidence was obtained as to whether they have a definite arrangement. That they do not always appear to be of equal size can be seen by inspecting the lower right-hand cell shown in *fig. 1*. This variation may be only apparent, due possibly to inequalities of fixation or staining, or in some cases to an optical appearance produced by looking upon several granules overlying one another in the successively superimposed strands of the network. In cells, however, where the beginning of the enlargement of the nucleus indicates an approaching division, the network appears to consist of strands each of which is double; the granules that lie opposite each other in each of the halves of the strand are connected by cross bridges of linin. *Fig. 2* shows a cell cut crosswise, in which appear the first indications of the double nature of the strands of this network.

This condition is especially to be observed in a few of the strands which are more favorably placed near the periphery. *Fig. 3* represents a similar cell cut lengthwise. As the nucleus enlarges still more, these double strands become more evident and regular in their arrangement, until we have the condition shown in the two periblem cells (*fig. 4*). Here the strands pass around the inner surface of the nucleus in what appears to be a more or less regular and continuous spiral, while the nucleolus still holds its central position within.

While bridges of the linin substance appear at first sight to connect the granules in pairs only, it is possible that the conditions are more complicated even at this stage, and that the chromatic thread which seems to be composed of only two parallel threads is in reality made up of four such parts. Such quadripartite thread with chromatic granules regularly arranged might give the appearance of being only bipartite, owing to the fact that, when viewed in certain directions obliquely to the axis of the thread, the pairs of granules in the distant half might appear to alternate with those of the nearer half.

In Allium tips treated with Flemming fixative (weaker solution), and not overstained by the iron alum haematoxylin method, the linin connecting the granules is less conspicuous. The granules, although they can still be traced as lying in strands, are more isolated, and thus separated are seen to lie, not in groups of two, but in groups of four. The stages shown in *figs. 5* and *6* (Flemming fixative) are directly comparable with the stage in *fig. 4* (chrom-acetic fixative). The cell shown in *fig. 5* is a somewhat later stage of a periblem cell treated with Flemming fixative, while *figs. 7* and *8* show later stages from tips similarly treated. The effect of the osmic acid in combination with the chrom-acetic then, as seen by these figures, is to bring out with greater distinctness the arrangement of the granules into tetrads. The linin can be distinguished in the cells thus treated, but it is more obscure than in the cells treated with chrom-acetic alone.

It would be natural, from our preconceived ideas of the individuality of the chromatin granules and of the necessity of an equal distribution of substance to the two daughter nuclei, to assume that this arrangement of granules into an apparently double strand results from the splitting of a single thread or series of granules, but the very minuteness of the granules in the stages preceding the formation of the spireme precludes any direct observation of such a division even if it takes place.

There are two ways in which one might explain the formation of quadripartite threads out of the network of the quiescent nucleus. We might imagine that in a row of self-propagating units each divides into two, the result being two parallel rows, and that then each of the resultants again divides into two, thus giving rise to the groups of four which are joined into strands by the linin. Judging, however, from what it is possible to observe in the quiescent nucleus and in the later stages of division, there is some evidence in favor of another explanation. The grouping of the granules into pairs, which are at least double and probably quadruple, can be seen in early stages back to the point where the granules are so fine and so closely massed together that they cannot be said to have any definite arrangement. It is conceivable, therefore, that such a tetrad condition may be permanent, the granules having an inherent tendency to group themselves into fours.

An examination of the large cells of the plerome, which by their extreme size and presence of large vacuoles indicates the loss of the power of division, yields evidence that the tetrad condition may be permanent. In *fig. 50*, taken from a large plerome cell which is later to break down to form a central vessel, and *fig. 51*, of cells elongating to form wood fibers, fixed in Flemming and stained by the iron alum haematoxylin method, the chromatic network has the appearance of strings of vacuoles, the borders of the vacuoles consisting of the chromatin substance. A comparison of these figures with those of the early prophase, such as *figs. 7* and *8*, shows similarity of structure. The condition seen in the plerome cells may be interpreted as the result of the linin connecting the successive groups of tetrads having become more stretched, the tetrad granules less conspicuous; the space in the center of each group of granules acquiring the appearance of a vacuole, one of a series in a network. As the nucleus enters into a quiescent condition then, the spaces in the centers of the groups of tetrads become more marked, and the boundary lines of the chromatin granules more and more indefinite.

The history of the chromatin shows that up to the time of the formation of the equatorial plate the whole process can be summarized as consisting of the growth, aggregation, and fusion of tetrads into chromosomes; whereas the period from the formation of the equatorial plate to that of the daughter nuclei can be summarized as a process consisting of the disintegration of chromosomes into tetrads and the reduction of the latter in size. The times of the appearance and disappearance of tetrads then correspond with those of appearance and disappearance of a definite arrangement of the chromatin, and this holds for the nuclei which are about to divide as well as for those which have just arisen from division.

From the time when the double strands of granules are first evident until the spireme is conspicuous, there is an increasing stainability, condensation, and enlargement of the component granules. *Figs. 9* and *16* represent successive stages in the growth of the spireme thread before it has broken up into chromosomes. The linin connecting the coils is seen to persist, but the connecting bridges are reduced in number.

These linin connections never completely disappear, although the quantity of linin varies with the stage of division. The linin strands which persist in the late spireme are more deeply stainable than the earlier connecting bridges. This suggests that this reticulum may arise, concomitantly with the growth of the chromatin, from the fusion of some of the earlier connections, while other connections are torn apart with the growth and consequent pulling apart of the coils. A cross-section of the spireme loop taken in early stages shows it to consist of four granules joined by the linin in the form of a square; a cross-section taken at stages immediately preceding that of its maximum size shows that the granules have approached one another in their growth. Its structure is thus seen to be, not that of a homogeneous single or double thread, but that of a band composed of a series of chromatin masses joined together in rings, each ring being separable into four primary masses of chromatin. Later, at the time of the formation of the equatorial plate and when the chromatin has reached its maximum size, the four masses have by their growth fused with one another into a ring, the succession of rings resulting in the formation of a more or less continuous tube. In *figs. 13* and *16*, longitudinal sections of periblem cells giving surface views of the coils in the nucleus, some of the loops have been cut transversely and thus give end views of the spireme. Views of both the ends and sides of the threads are of course necessary for the formation of an opinion as to the real condition of the chromatic substance at this stage. From a comparison of such views it is evident that the thread is now a tubular structure, the walls being composed of the four more or less completely fused elements of the quadripartite stage. The more completely fused the chromatin masses, the straighter and more sharply defined is the edge of the spireme thread. Its contour varies with the age of the spireme and with the nature of the cell. In many cases (*fig. 10*) the spireme appears as a double homogeneous thread with clean-cut edge. In other cases (*fig. 9*) it has a moniliform appearance, the ring structure being more evident as the component chromatin masses are further apart. In the cross-section of the cell shown in *fig. 7* all the sections of the coil are transverse to the direction of the spireme thread. Groups of the enlarging tetrads can be seen joined to one another by the connecting linin substance. When the chromatin is not overstained and a surface view of the spireme is obtained, its appearance is that of a longitudinally split thread, the split, however, never being sharply defined. *Figs. 11* and *16* show this apparent longitudinal splitting, while in *figs. 9* and *14* the appearance, instead of resembling a split, is like a series of separate vacuoles. The apparent longitudinal splitting results from looking down upon the succession of rings formed by the incomplete fusion of the tetrads. The rings are less dense at the junction of the component masses, so that a surface view is that of two dense chromatin masses joined by the less dense linin;

or if the linin has broken down as in later stages, the split is the result of looking down upon the vacuoles which were formerly inclosed by the tetrads. That the split is not sharply defined is due to the persistence of the less deeply stained linin substance, which still connects in an uneven manner the masses of chromatin.

The growth and extension of the chromatic figure imply a correlated extension of the nucleus until the nuclear membrane breaks as a result of the interior pressure. Previous to the disruption of the nuclear membrane, the coils of the spireme have been quite regularly arranged within the nucleus, as shown in *figs. 14* and *15*, following the same arrangement that is to be seen in the early spireme, *fig. 4*. With the weakening of the membrane or closely following its dissolution, and with the consequent changes in pressure, the coils of the spireme break transversely at the places where they were bent. This breaking does not imply that the segments of the spireme have become completely separated, for, as *fig. 30* shows, the linin substance may still connect the segments of the spireme into a more or less continuous thread.

The number of segments thus arising seems to be inconstant, apparently varying from ten to thirty or more. There is a great deal of uncertainty, however, as to the number of segments, because many of them are cut in sectioning, and thus the apparent number is increased. A study of *fig. 30*, which shows thirty-eight such segments, would seem to indicate that none of the chromosomes there has been cut by the knife, because there exists linin between the successive segments of the bands. If a chromosome had been cut off square by the knife, its end would appear sharply truncated, with no linin substance connecting it with an adjacent chromosome. Such evidence as this and that presented by the cells shown in *figs. 37*, *a* and *b*, leads to the conclusion that in vegetative cells of Allium the spireme is not invariably broken into sixteen chromosomes, as has been maintained by other investigators, but that the number of segments is dependent upon the size and course of the spireme in the nucleus. This transverse breaking of the spireme into segments can be of no significance in the distribution of the chromatin, as each chromosome is yet a tubular structure resulting from the fusion of the tetrads, unaffected by the breaking of the spireme.

After the nuclear membrane has become dissolved and the interchange of material between nucleus and cytoplasm is complete, the rings of chromatin split, causing the separation of the associated chromatin masses. *Figs. 32* and *37* show stages where the separation of the associated chromatin masses is well under way, while *fig. 33* shows a similar stage where some of the segments have been cut crosswise. The pairs of chromatin threads separate first from each other at the middle, while the ends may remain for some time attached.

In cells shown in *figs. 37a, 38*, we have the last stages in the separation of the chromosomes in the spireme segment. The ends of the chromosomes are still connected by the linin substance, though the separation is nearly complete. The structure of each chromosome at this stage, as seen both in surface view and in cross section, presents exactly the same appearance as that of the mother segment of the spireme, the only difference being that of size. After the splitting the chromatin closes up to form again the rings, thus making the tubular structure of the daughter chromosomes of the spireme. The end of each chromosome shows the ring formed of chromatin masses, the margin becoming indefinitely four-sided; the surface view gives the same vacuolar or longitudinally split appearance throughout their length. *Fig. 38* is of a stage showing the beginning of their movement toward the poles. The ring-like form, as seen from the end, and the split or vacuolar appearance, as seen in surface views, are here clearly marked, while in *fig. 41* the component tetrads can be traced. In *fig. 39* the cell was cut in such a plane as to give a longitudinal section of the chromosomes at one pole of the diaster and a cross section at the other pole. It can thus be seen from these figures that the disintegration of the rings into tetrads proceeds with the drawing apart of the chromosomes and with the beginning of their passage toward the poles.

The chromosomes having arrived at the poles become coiled, while their ends begin to approach one another. *Figs. 42–45* represent sections of a cell, one drawn at high, the other at low, focus, so as to allow a complete reconstruction of the chromatic figure. At the right-hand upper pole of *fig. 44* it can be seen that one chromosome cut in cross section reveals the tetrad structure. The chromosomes can be seen now to have become more vacuolated. The adjacent chromosomes are being drawn together by the linin substance, which is more deeply stainable than the remains of the spindle fibers. A reconstruction of the sections of the cell indicate that in the fundament of the daughter nuclei a more or less continuous spireme coil is being formed.

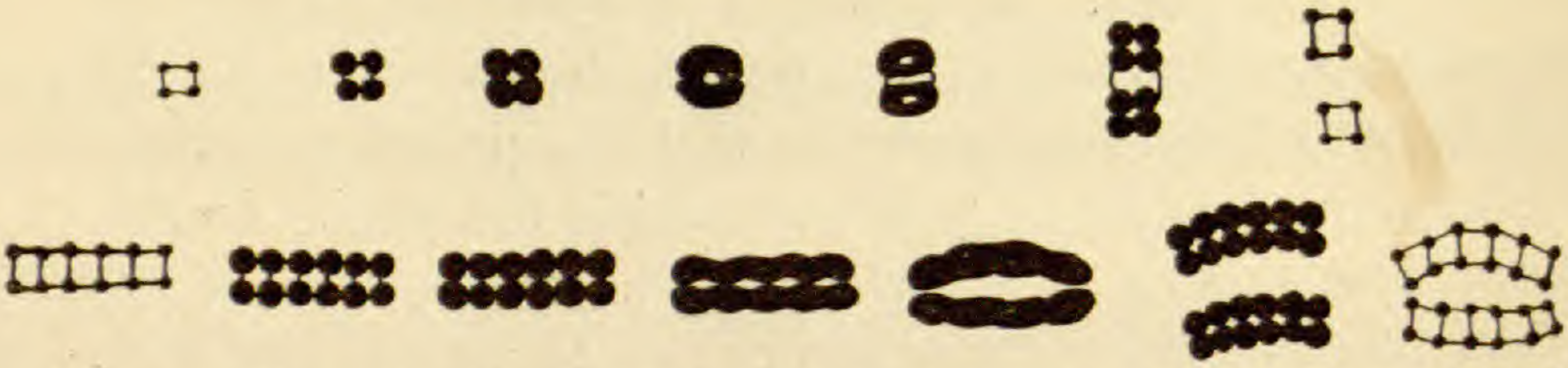
An opaque diffusible substance slightly stained by haematoxylin and other nuclear stains can be discovered between the chromosome coils. It appears to become denser as the vacuole-like spaces in the chromosomes increase in number (compare *figs. 42–46*). This substance has not before been recognizable. The chromosomes as they pass to the poles lie in a perfectly clear field, and it is not until they begin to fuse to form the spireme that this substance makes its appearance.

There is not a true vacuolization of the chromosomes, since the spaces are defined in too regular a fashion. This regular formation of the vacuoles in the rings is well illustrated in *fig. 46*. What we actually have is a resolution of the chromosomes into the component tetrads, with a gradual decrease in size of the chromatin bodies, apparently accompanied by an increase in volume of the linin. The loss of material accompanying the reduction in the size of the chromatin bodies is correlated with the increase of the linin and also with the presence of the diffusible substance which is deposited within the coils. In *fig. 47*, a longitudinal section of a periblem cell, are shown the first indications of a discrete body which can be termed a nucleolus. In *fig. 48*, where there is a continuous spireme, this is seen to lie within the coils and to occupy the same central position that the nucleoli of the quiescent nucleus hold after the nuclear membrane is completed. This nucleolus is only a condensation of the opaque substance to be seen in earlier stages between the chromosomes. In my opinion, it owes its origin to the chromatic bodies, being but a waste product of their activity.

In *fig. 49*, where the cell plate is nearly completed and the nuclear membranes are beginning to appear, the spireme coil is still to be traced. It is now seen to be composed of a double strand of granules which are connected with each other in pairs and with the adjacent strands by the linin. With the complete separation of the daughter nuclei by the cell plate these strands become finer and the grouping more indistinct, until finally all that can be discerned in the quiescent nucleus are the chromatin bodies in a network and the nucleoli.

A review of all the changes of the chromatic figure is now in order. A comparison of the stages which led up to the formation of the equatorial plate with stages extending from that point to the formation of the daughter nuclei shows that the first series represents a gradual growth of tetrads and their fusion to form chromosomes; these latter split, half passing to each pole and in its passage suffering disintegration into tetrads. The changes in the two series are identical, but take place in the reverse order. The conditions in *fig. 2*, a mother-cell preparing to divide, are directly comparable with those shown in the daughter nucleus represented in *fig. 49*. Similarly, *fig. 14* is comparable with *fig. 45*, and the chromosomes at one pole of the diaster in *fig. 41* with those in *figs. 7* and *8*.

The following diagrams show the order in which the changes in the chromatic figure occur.



Diagrams illustrating the morphology of the chromatic substance during karyokinesis: the diagrams in the upper series represent end views of a portion of the thread; those in the lower series, side views.

In reviewing the literature of the chromatic figure in plant cells, no account of such an origin, structure, and development as has just been described for Allium was found. The literature on the botanical side has been mainly concerned with controversies over the number of chromosomes, the various shapes that they assume during division, and the manner of separation.

The work of Brauer (3) on the spematogenesis of *Ascaris megalocephala* has a direct bearing upon the results attained in the investigation of Allium. He states that in the passive nuclei of the spermatogonia the first preparation for the formation of the chromosomes is to be seen in the arrangement of the irregularly distributed granules into definite lines. The distinguishing feature of these nuclei in comparison with those which show no preparation for division is the presence of a sharp line between the chromatin granules, whereby these become arranged into two rows. In regard to the spermatocytes, he states also that when two threads do not lie directly over one another, or when through other change in their position an insight into their arrangement is made impossible, a division of the granules is everywhere to be seen. When a polar view of isolated groups of granules is obtained, each group can be seen to consist of four granules which lie arranged near one another in the same plane, each one being marked off from the neighboring ones by a well-defined fissure.

Brauer raised the question whether the splitting of the granules was from the beginning double, or whether the two splittings followed each other. He states that the granules in the earlier stages are too small and too numerous to allow a settlement of this question, yet he could discover in individual cases isolated granules composed of four elements.

The same question can be raised regarding the origin of the quadripartite granules of Allium in the earliest stages of the active nuclei in which any definite arrangement can be detected. Here too the evidence is of the same incomplete nature. Brauer does not describe for the early anaphase a resolution of the chromosomes first into double strands and then into quadripartite strands, each composed of a series of granules. Hence he has not raised the question, which I have previously discussed, whether, instead of a process of division of granules into fours to form the strands of the spireme, it may not be that from the beginning we have to do with a fusion of granules in fours.

Rosen (8) considered the formation of the spireme as due to the fusion of chromatic granules, but failed to get a polar view of the thread showing its quadripartite structure.

Němec (9) states that when the chromosomes have arrived at the poles, the chromatin coils send out pseudopodia-like continuations which bind opposite sides net-fashion. The chromatic substance gathers next on the periphery of the chromosomes, and dissolves into granules which wander into the pseudopodium-like continuations. In regard to the cell division of Solanum, Němec states that at the time when the spindle surrounding the nucleus is finished, the nuclear membrane vanishes and varicosities are to be seen in the chromatic threads. He thinks that the longitudinal splitting must occur at this time, as he found in thin sections of chromatin pieces in pairs extending into the periplast.

Hof (11) has a brief reference to what is doubtless the same condition which I have described in Allium. In stages of the dispireme, where the daughter nuclei are found, signs of a longitudinal splitting are rarely to be seen in the threads. The daughter nuclei present a structure similar to that shown by the nuclei of the prophase, except that they do not yet show the beginning of the enlargement of the nucleus. He thinks that very likely, owing to the quick succession of divisions in the cells of the meristematic tissue, those cells in which the longitudinal splitting is to be seen in the dispireme stage are to be considered as preparing for the ensuing division without the intervention of a resting stage. He does not hold this splitting to be a characteristic feature of the anaphase, as I do. Hof figures but two cells with signs of longitudinal splitting in the anaphase.

The fact that after this apparent longitudinal splitting has occurred in the chromosomes of the dispireme all stages can be found showing gradual reduction in size of the chromatin bodies and increase of the linin, is evidence that this is not a temporary phenomenon. A criterion for removal of all doubt that these stages in the late anaphase may have been mistaken for those of the early prophase is the presence of the incomplete cell plate.

Meves (17) describes vesicular chromosomes occurring in Paludina. The peculiar behavior of these chromosomes in their relation with the centrosomes makes it difficult to draw any analogies with the conditions found in Allium.

The interpretations which I have made do not refute what is a fairly well established fact, that in the rapidly dividing cells of meristematic tissue the daughter nuclei in the late anaphase often proceed to divide without the intervention of a resting stage or the formation of a nuclear membrane. It only reasserts, what Flemming (1) and other investigators have held, that the chromatin undergoes after the metaphase the same changes as before the metaphase, but in the reverse order. The history of the chromatin in cell divison can be characterized as made up of periods of growth, aggregation, and fusion, followed by periods of separation, disintegration, and reduction.

The literature now remains for consideration which bears upon the shape of the chromosomes and the manner of their separation.

Ishikawa (7) studied division in the epidermal cells of Allium buds. He found that coil to break up into sixteen pairs of chromosomes, generally of an equal length.

Belajeff (6) stated that in vegetative cell divisions, while the daughter chromosomes are yet bound to each other at their ends, a rhomboidal figure is formed. The U-forming daughter segments move apart and form daughter stars, one at each pole of the nuclear spindle. Belajeff maintains that this U-shape of the chromosomes is characteristic and peculiar to vegetative cell divisions, and that in the heterotypical form of division there are V-, Y-, and X-shaped figures which show longer and shorter arms.

Hof (11) finds that the chromosomes in the stage of the mother star in vegetative cell division have mostly the figure of J-forming threads, with arms of unequal length, although rhomboidal figures also occur.

Strasburger (14) criticises Belajeff's characterization of the three types of nuclear division based upon the form of the chromosomes. Neither the manner of insertion of the chromosomes in the spindle nor the definite lengths of the chromosome branches are considered by Strasburger as furnishing satisfactory marks for contrasting typical and atypical division in metaphytes. Strasburger found in the pollen mother-cells of Lilium and also of other forms that the daughter chromosomes at the beginning of the metaphase undergo a second longitudinal splitting. This takes place at right angles to the first.

Guignard (2) came to the same view as did Strasburger in regard to a second longitudinal splitting in the pollen mother-cells of *Najas major*.

This second longitudinal splitting described as occurring in the atypical divisions of cells Strasburger would make a distinguishing feature of their division, marking them out from typical divisions by this rather than by the form of the chromosomes or by the manner of insertion. Belajeff does not assent to the view that there is a second longitudinal splitting, but holds such V's as consisting of two chromosomes bound together.

It is not within the province of the present investigation to go into the details of atypical divisions in plants. A comparison of Strasburger's figures with the structures seen in the typical division stages of Allium confirms me in the belief that even in the presence of this second longitudinal splitting, we have no feature which will distinguish atypical from typical division.

I think that this second longitudinal splitting, described by Strasburger and by other investigators as peculiar to atypical division, is the same phenomenon as that described by me as occurring in the typical division of Allium cells, namely, the apparent longitudinal splitting seen in the surface view at the beginning of the metaphase, and that it is due to the changing of the daughter chromosomes from tubular structures into the quadripartite threads. This change is but a reversal of the change which occurred before the metaphase.

Future research, I believe, will establish that the mechanism of cell division in both the typical and atypical forms is essentially the same.

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EXPLANATION OF PLATES XI–XIII.

FIG. 1. Cross section showing stages after the spireme has broken into chromosomes, and a quiescent nucleus; cells killed in Flemming fixative

(weaker solution); stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG 2. Cross section of meristem nucleus where the spireme is first becoming evident; cell killed six hours in Flemming (weaker solution); stained with iron alum, eosin, and Heidenhain's haematoxylin. ×2440.

FIG. 3. Longitudinal section of periblem cell showing quadripartite structure of the early spireme; Flemming twenty-four hours; iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 4. Longitudinal sections of two dermatogen cells showing the early spireme; fixed in chrom-acetic; stained with eosin, iron alum, and Heidenhain's haematoxylin. × 2440.

FIG. 5. Longitudinal section of a periblem cell showing the quadripartite structure of the early spireme; killed in Flemming's weaker solution twenty-four hours; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 6. Longitudinal section of two periblem cells showing quadripartite structure of early spireme; killed in Flemming's weaker solution; the upper cell showing the withdrawal of the cytoplasm from the poles of the nucleus, giving the appearance of hyaline caps; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 7. Cross section of periblem cell showing the quadripartite structure of the spireme; killed in Flemming's weaker solution six hours; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 8. Longitudinal section of a periblem cell showing the quadripartite structure of the spireme in a somewhat later stage; killed with chrom-acetic; stained with orange G and Heidenhain's haematoxylin with iron alum. × 2440.

Fig. 9. Cross section of periblem cell showing a later stage of the spireme and the nucleus beginning to elongate; killed with chrom-acetic and stained with orange G in combination with Heidenhain's haematoxylin and iron alum. × 2440.

FIG. 10. Longitudinal section of a periblem cell with the spireme of smooth contour; killed in chrom-acetic; stained with safranin, gentian violet, and orange G. × 2440.

FIGS. 11–12. A longitudinal section of a periblem cell drawn at upper and lower focus, showing the appearance of hyaline polar caps and ingrowing cytoplasmic fibrillations; killed with chrom-acetic; stained with safranin and gentian violet. × 1750.

FIG. 13. Longitudinal section of a periblem cell; the cell is sectioned in such manner as to give at the same time an end and surface view of the spireme thread; the end view shows the quadripartite structure, while the surface view shows the fusion of the component granules into a continuous thread; the elongation of the nucleus can also be noted here; killed with Flemming's weaker solution; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 14. A longitudinal section of a periblem cell showing a late stage in the spireme, where it has a vacuolar appearance with prominent connecting linin bridges; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 15. A longitudinal section of a periblem cell showing the elongation of the nucleus: killed in chrom-acetic; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 16. Longitudinal sections of two periblem cells in the late spireme stage; the lower nucleus shows the appearance of hyaline caps; killed with chrom-acetic; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 17. Longitudinal section of periblem cell showing ovoid enlargement of the nucleus; killed in Flemming's weaker solution; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 18. Longitudinal section of a periblem cell showing the elongated nucleus after the breaking of the spireme thread, also the aggregation of cytoplasm at the poles; killed in picro-sublimate; stained with Heidenhain's haematoxylin and iron alum in combination with eosin. × 2440.

FIG. 19. Longitudinal section of a periblem cell with the cell surface in focus, showing the elongated shape of the nucleus and its relation to the aggregations of cytoplasm; killed in picro-sublimate; stained with Heidenhain's haematoxylin with iron alum in combination with eosin. × 2440.

FIG. 20. The same cell with the central portion in focus.

FIG. 21. Longitudinal section of a periblem showing the beginning of the dissolution of the nuclear membrane; killed in chrom-acetic; stained with Heidenhain's haematoxylin in combination with orange G. × 2440.

FIGS. 22–23. Longitudinal section of a periblem cell showing the lower and upper part of the cell; killed in chrom-acetic; stained with safranin, gentian violet, and orange G. × 1750.

FIG. 24. Longitudinal section of a dermatogen cell showing the hyaline cap appearance; killed in chrom-acetic; stained with Heidenhain's haematoxylin in combination with eosin. × 2440.

FIG. 25. Longitudinal section of a periblem cell showing the fusion of the fibrillations from the cytoplasm with the nuclear reticulum; killed in Flemming's weaker solution 24 hours; stained with Heidenhain's haematoxylin in combination with eosin, × 2440.

FIG. 26. Longitudinal section of two periblem cells after the spireme has broken up into chromosomes, showing the disappearance of the nuclear membrane and the ingrowing of the fibrillations of the cytoplasm; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 27. Longitudinal section of a periblem cell showing an early stage in the formation of the achromatic figure; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 28. Longitudinal section of a periblem cell showing early stage in the formation of the achromatic figure; killed in picro-sublimate; stained with Heidenhain's haematoxylin in combination with eosin. × 2440.

FIG. 29. Longitudinal section of a periblem cell showing the formation of a bipolar spindle; killed in chrom-acetic; stained with safranin and gentian violet. × 1750.

FIG. 30. Longitudinal section of a dermatogen cell showing the last vestiges of a nuclear membrane and the union of the fibrillations from the cytoplasm with the nuclear reticulum to form the achromatic figure; a nucleolus somewhat reduced in size can be seen in the spireme; killed in chrom-acetic; stained in safranin, gentian violet, and orange G. × 1750.

FIG. 31. Longitudinal section of a dermatogen cell in a later stage showing the chromosomes beginning to form into equatorial plate; killed in chrom-acetic; stained with Heidenhain's haematoxylin and iron alum in combination with orange G. × 1750.

FIG. 33. Longitudinal section of a dermatogen cell showing the formation of equatorial plate and the beginning of the separation of the chromosomes; absence of kinoplasm is to be noted in this preparation; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 33. Longitudinal section of a periblem cell, in stage just following the preceding; some of the chromosomes have been cut transversely in the act of separation; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin and iron alum in combination with eosin. × 2440.

FIG. 34. Longitudinal sections of two periblem cells in the stages of spireme and diaster; the upper cell shows a centrosome-like body below and at the right of the nucleus; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with eosin. × 2440.

FIG. 35. Two cells from the same slide as the preceding showing similar bodies in the cytoplasm.

FIG. 36. Longitudinal section of dermatogen cell showing late persistence of the nucleolus in the achromatic figure; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with orange G. × 2440.

FIG. 37. Longitudinal section of periblem cell showing separation of chromosomes; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 38. Longitudinal section of periblem cell showing the passing of the daughter chromosomes to the poles, the vacuolar appearance and the beginning of their disintegration into tetrads; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 4240.

FIG. 39. Periblem cell cut obliquely, giving both cross and longitudinal sections of the diaster; the apparent second longitudinal splitting is to be

PLATE XI

MERRIMAN, DEL.

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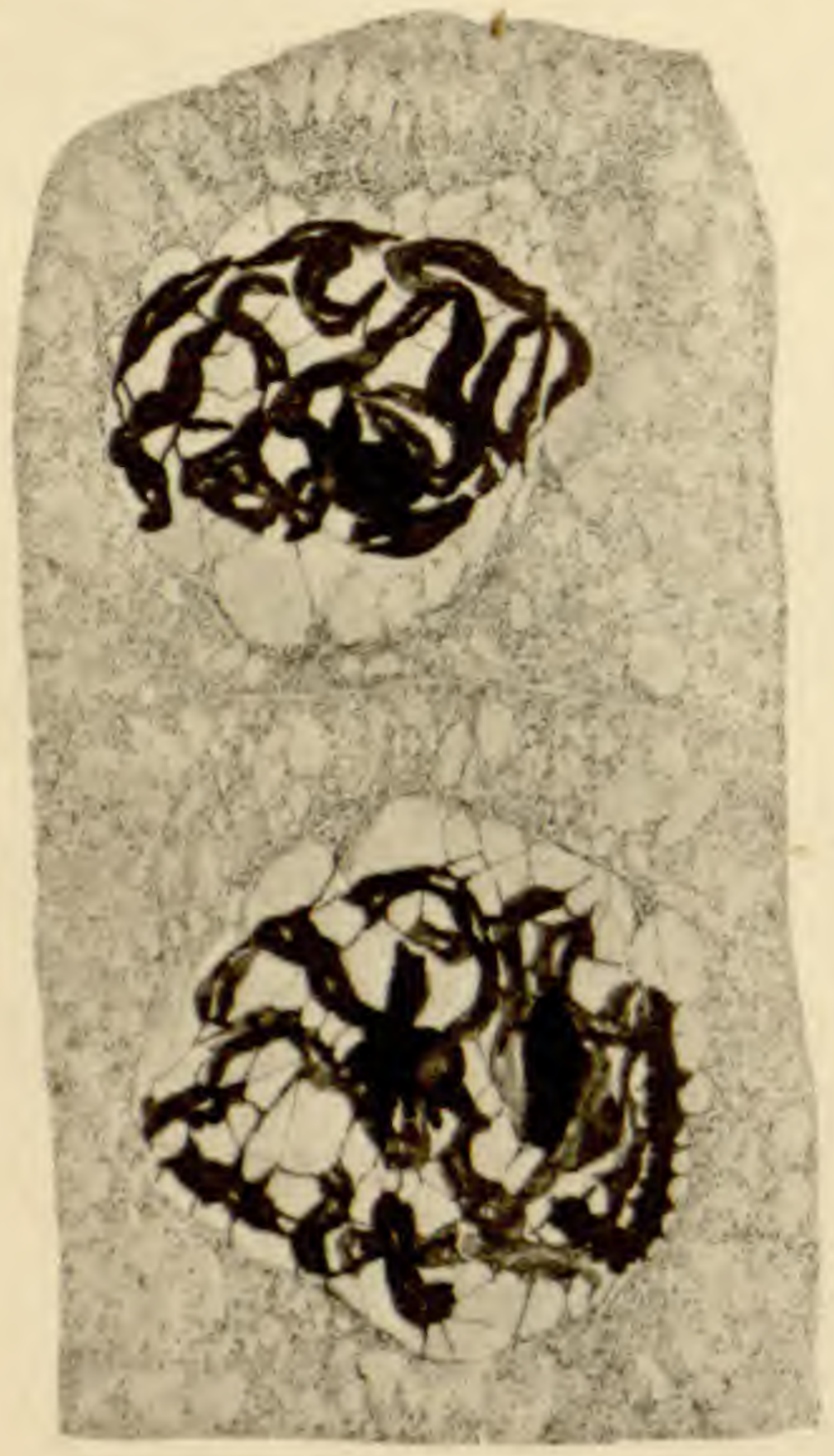
MERRIMAN on ALLIUM.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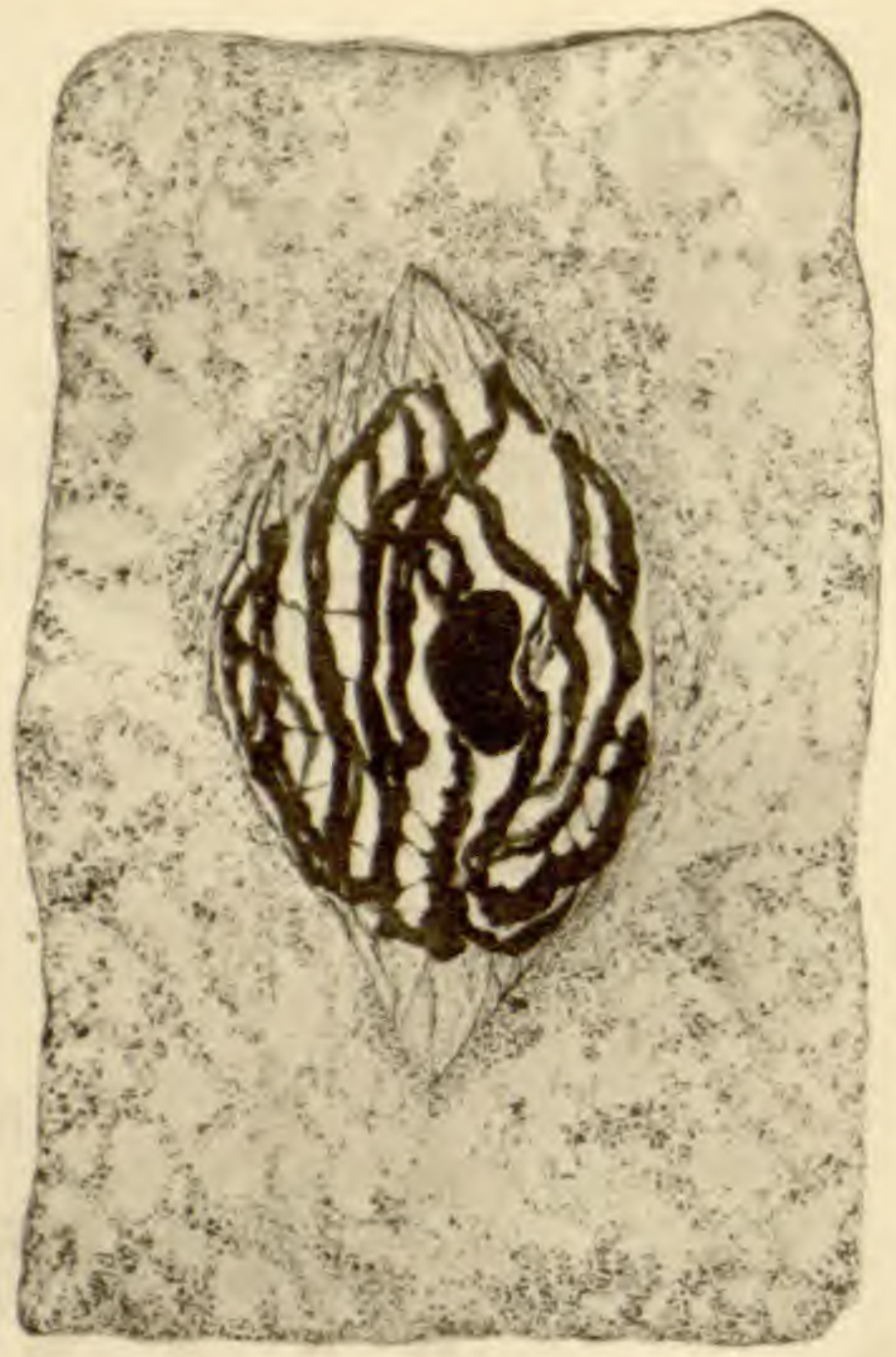
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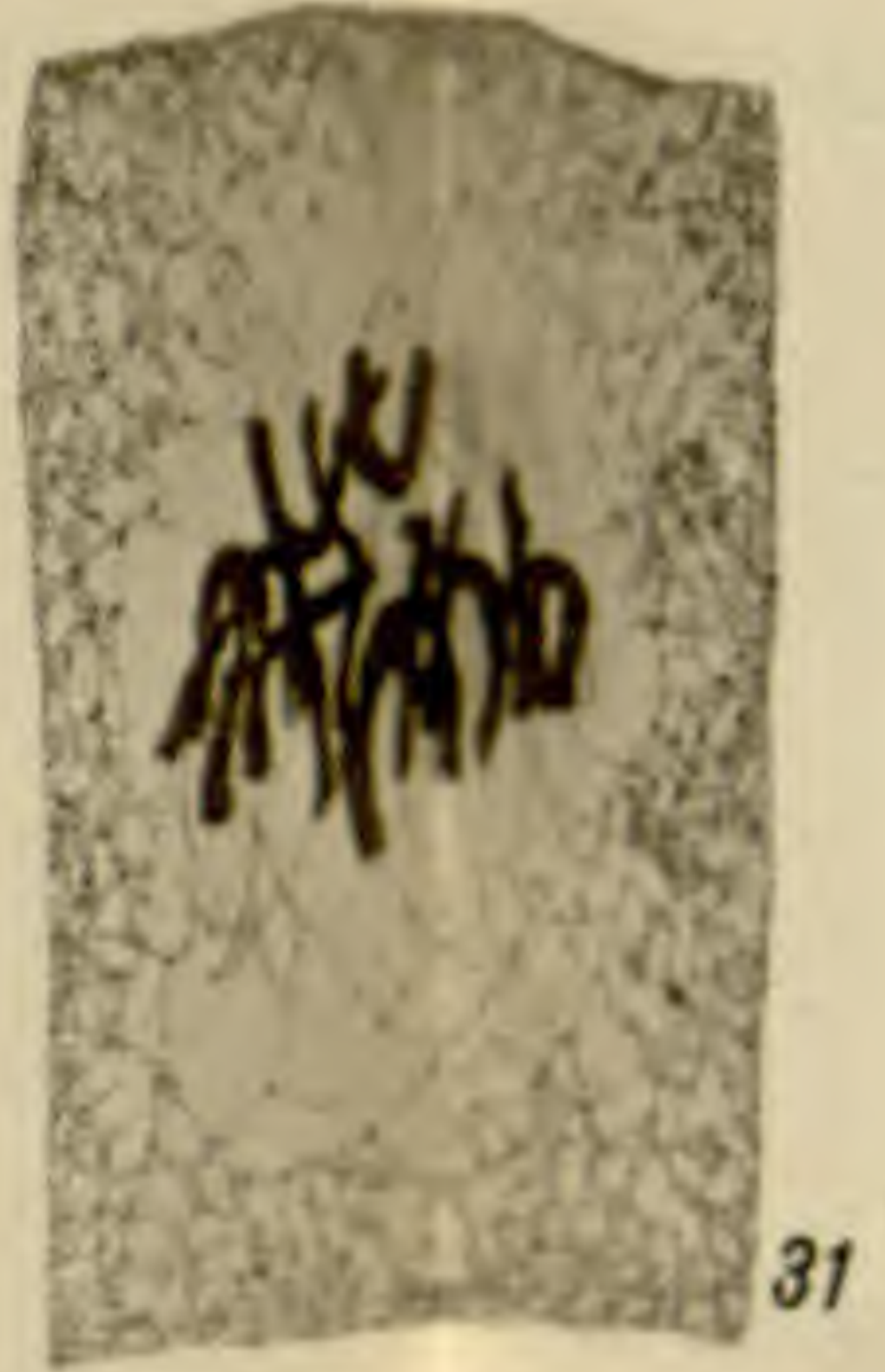
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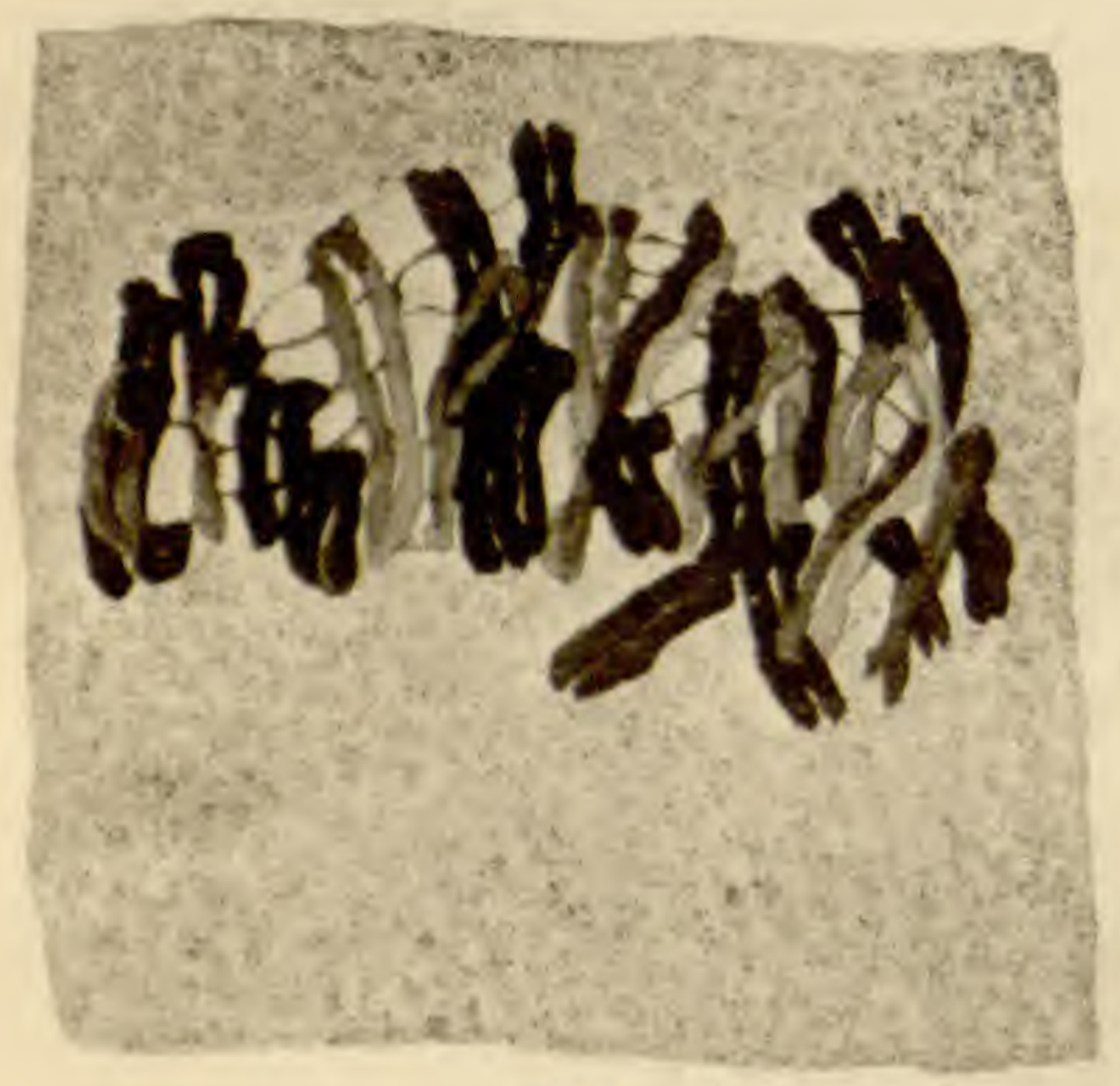
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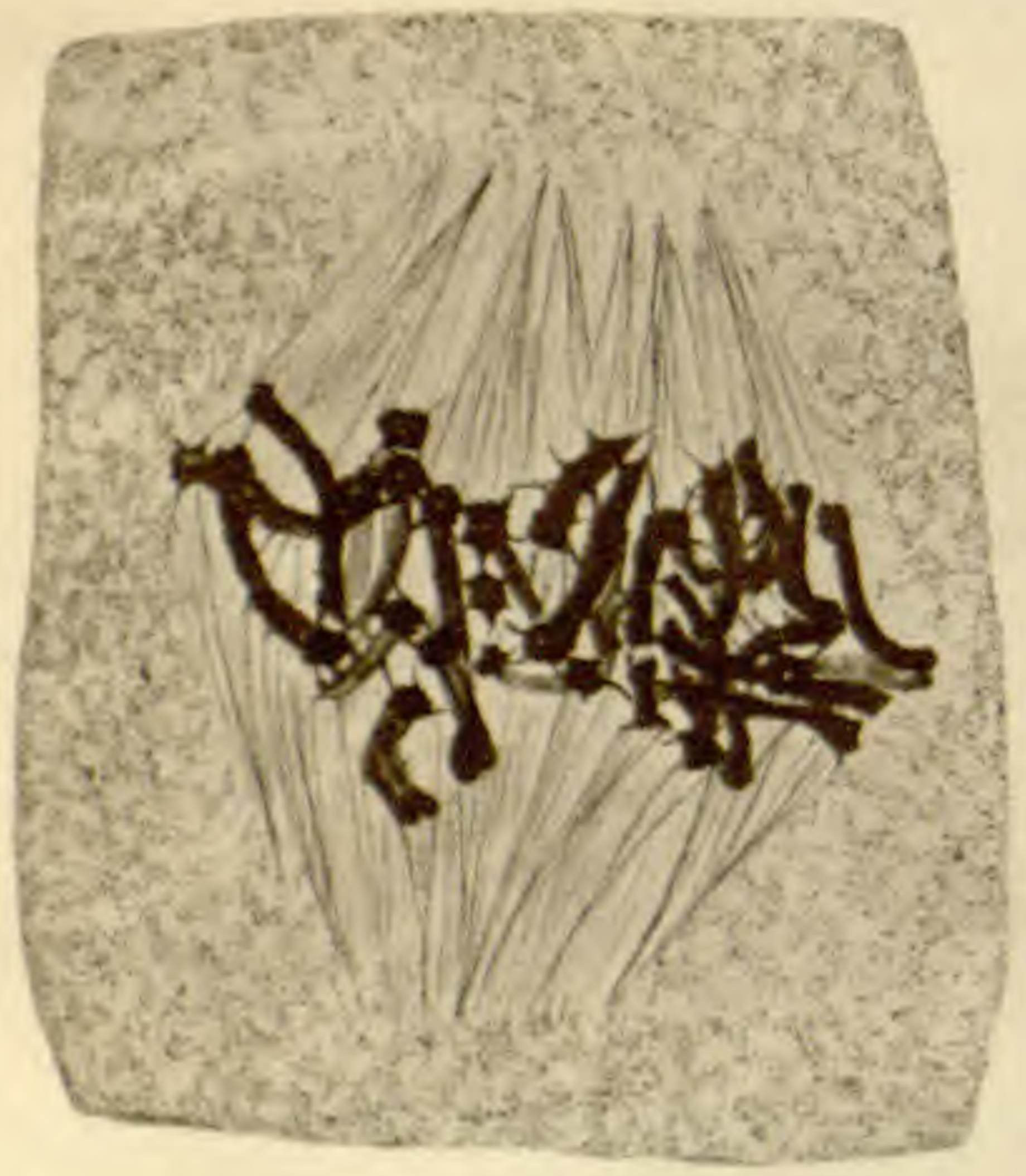
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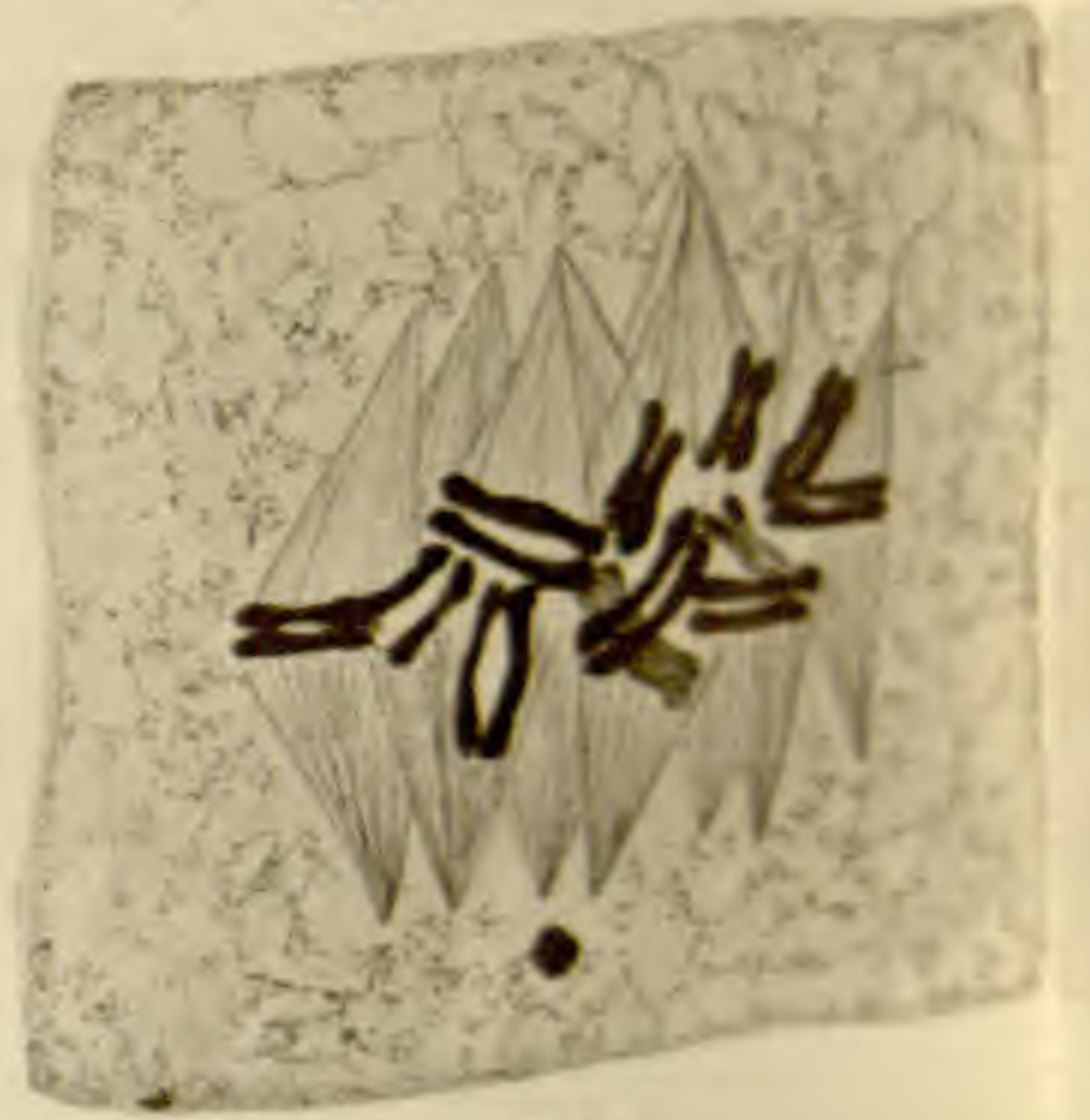
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MERRIMAN, DEL.

MERRIMAN on ALLIUM.

HELIOTYPE CO., BOSTON.

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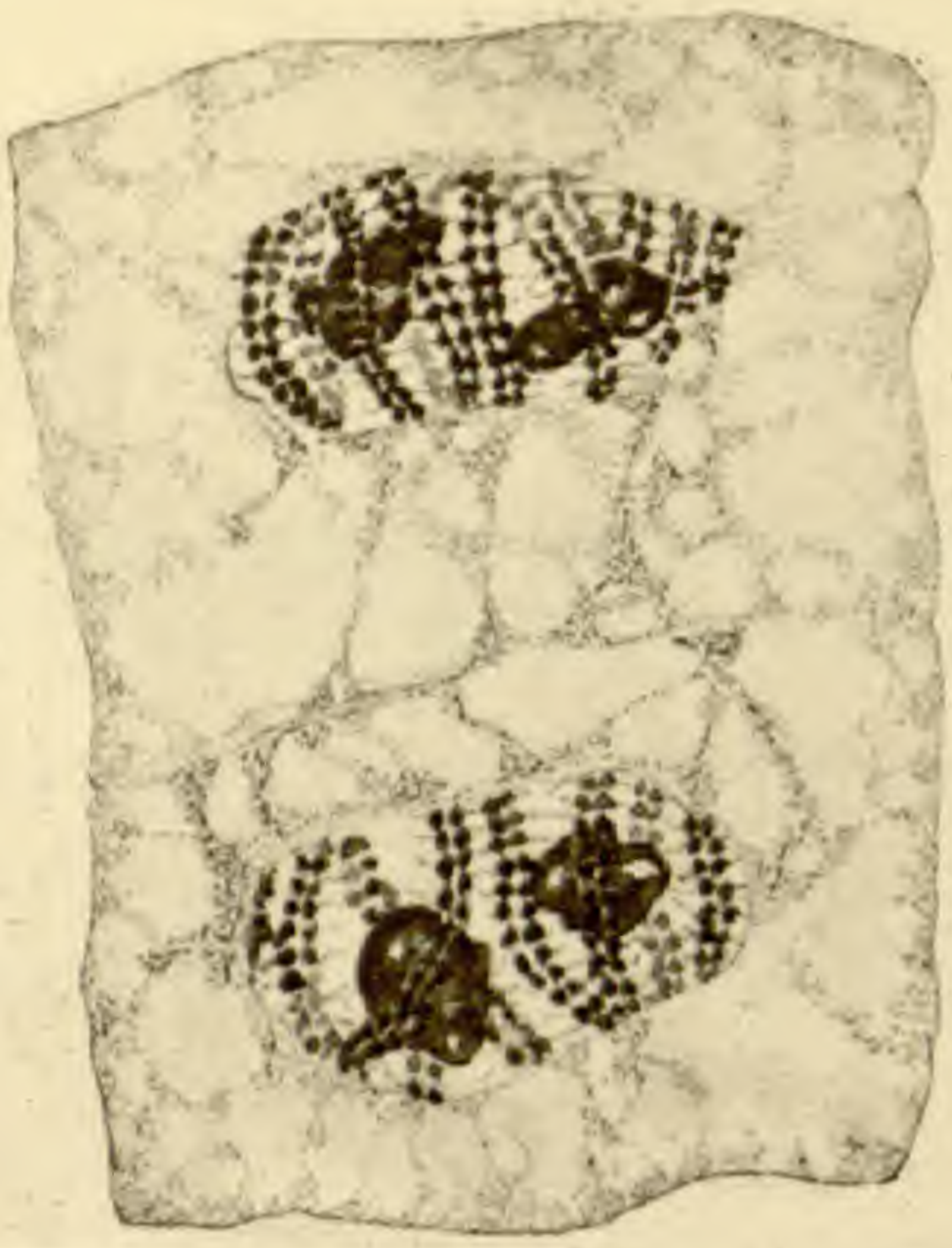

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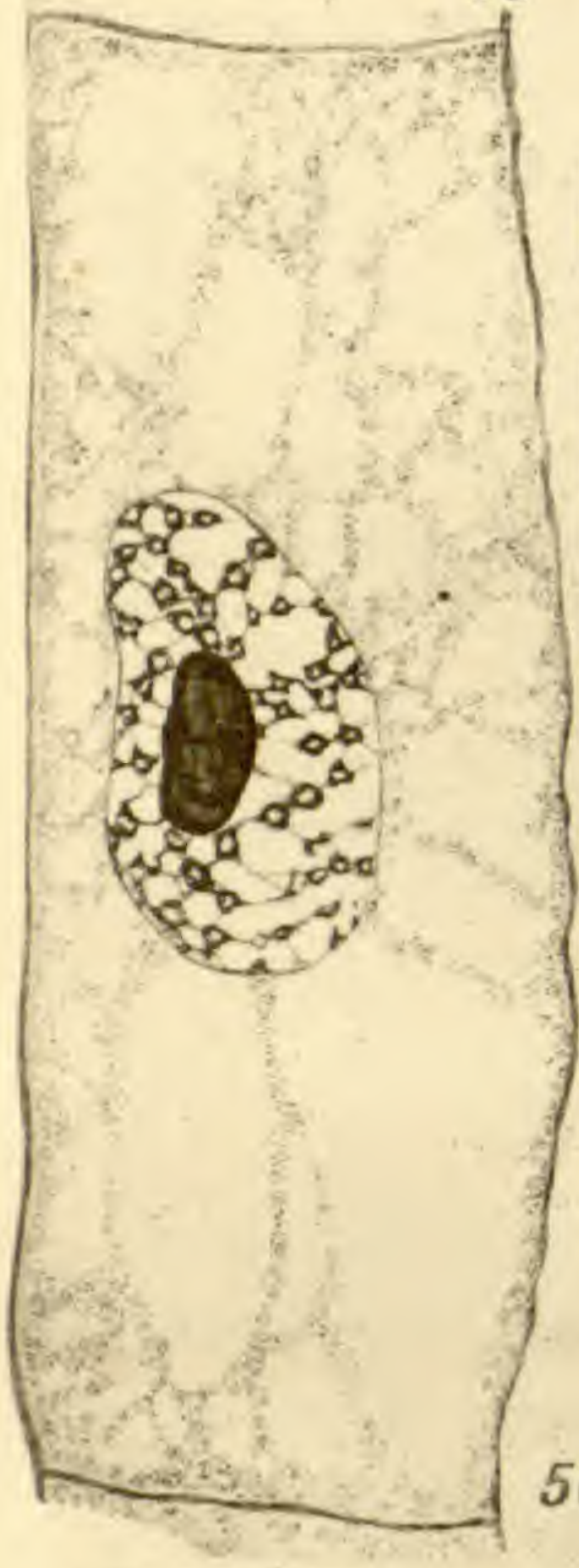

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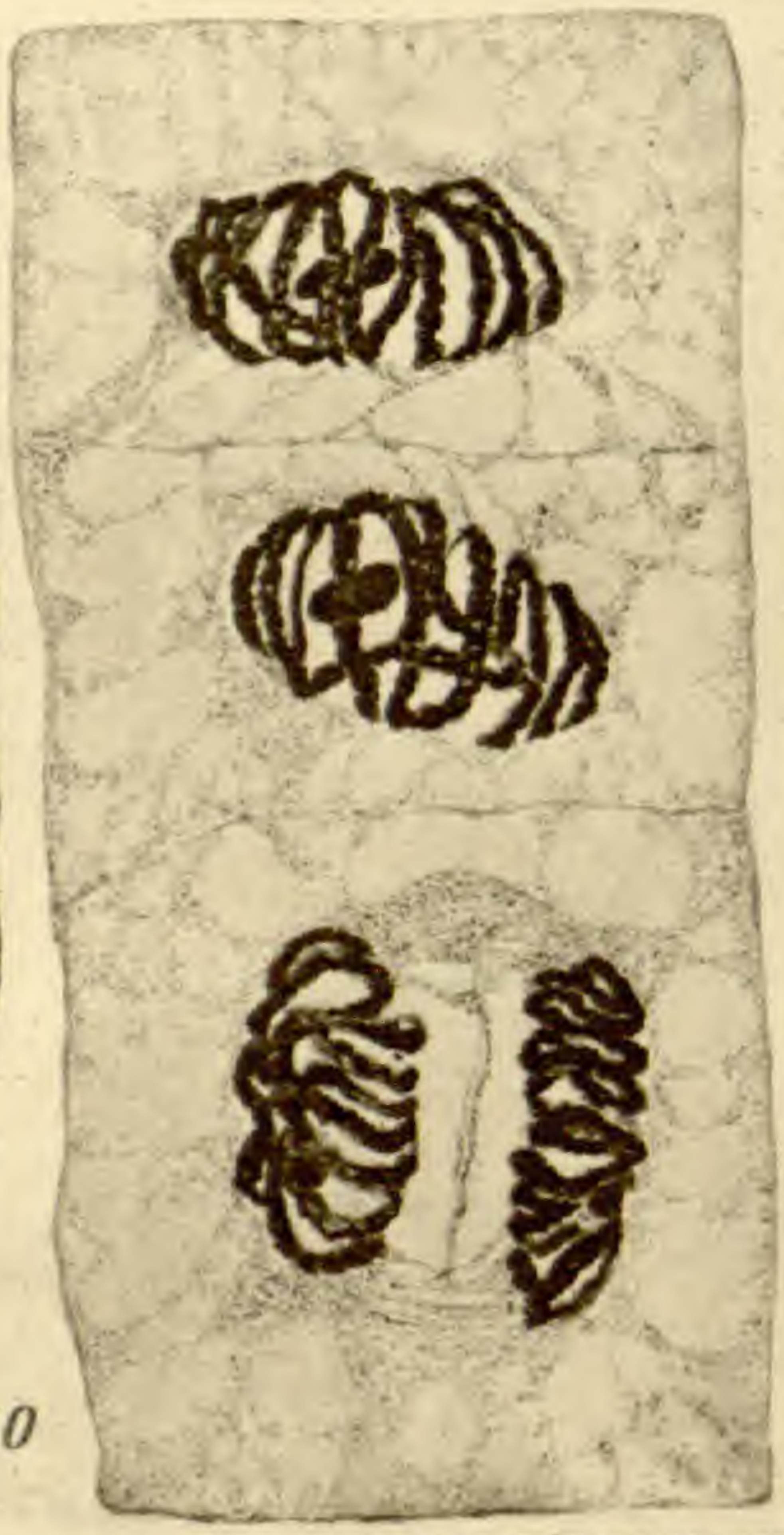

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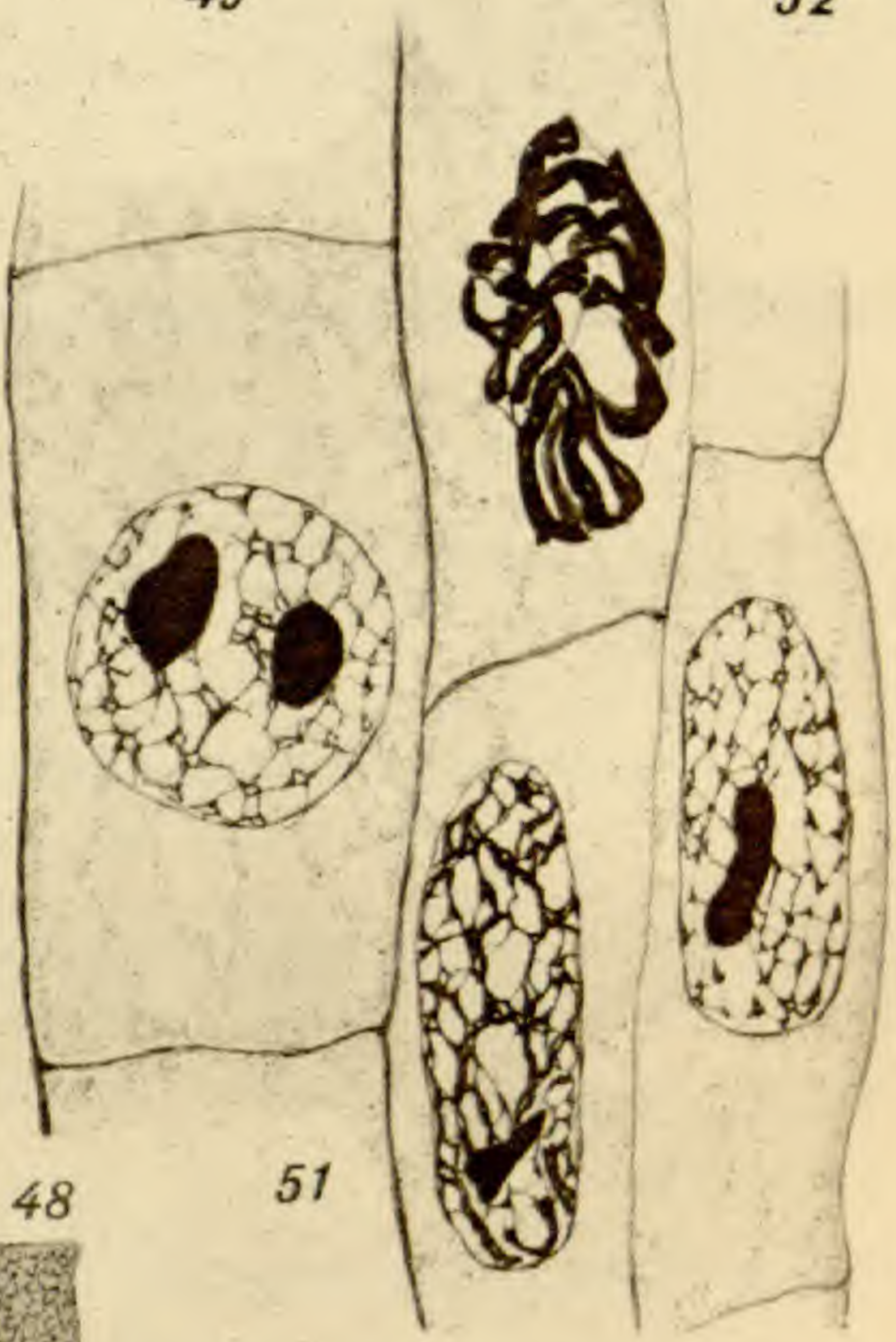

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MERRIMAN, DEL.

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MERRIMAN on ALLIUM.

noted here in surface view, the tetrad structure in the end view; killed in Flemming's weaker solution six hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 40. Longitudinal section of a periblem cell in the metaphase; killed in chrom-acetic; stained with Heidenhain's haematoxylin and orange G. × 2440.

FIG. 41. Longitudinal section of a periblem cell in the metaphase showing the disintegration of the chromosomes into tetrads; killed in chrom-acetic; stained with Delafield's haematoxylin in combination with eosin. × 2440.

FIGS. 42–45. From a longitudinal section of a periblem cell, drawn in order of sectioning so as to admit of reconstruction; this stage was considered important as showing the disintegration into tetrads of the chromosomes, their fusion into spireme, the appearance of the linin interspireme bridges, and the substance which later resolves into the nucleoli; killed with chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 46. Longitudinal section of periblem cell showing the chromatin masses arranged in rings; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIGS. 47–48. Longitudinal sections of periblem cells in the anaphase; the nucleoli have appeared as discrete bodies; the nuclear membranes are as yet unformed; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with orange G. × 2440.

FIG. 49. Longitudinal section of periblem cells in the late anaphase; the double thread in the spireme is conspicuous in the reconstructing daughter nuclei; the cell wall is nearly completed; drawn with Leitz one-twelfth oil immersion and Zeiss ocular 12.

FIGS. 50–51. Longitudinal sections of cells of plerome, the large central cells and the elongating cells showing the structure of the chromatic network; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIGS. 52–56. Longitudinal sections of the elongating cells of the plerome, showing the peculiarities in structure and behavior of the chromosomes; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum.

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

JOHN DONNELL SMITH.

Sloanea meianthera Donn. Sm. (§ AXILLIFLORAE BRACHYSTACHYAE Benth.).— Folia opposita lanceolato-elliptica caudato-acuminata basi acuta supra glabra subtus nervis puberula, petiolis apice subtus incrassatis. Racemi cinereo-pubescentes, floribus inter minimos. Stamina glabra sepalis longiora antheras minimas muticas 3–4-plo superantia. Discus orbicularis. Ovarium cano-pilosum, stylo apice 4-fido.

Arbor, ramulis superne sulcatis et petiolis cinereo-pubescentibus. Folia subcoriacea integra 8–18^{cm} longa medio 2.5–5.5^{cm} lata, nervis lateralibus utrinque 7–8, petiolis 1–2^{cm} longis, stipulis minutis caducis. Racemi subsessiles 1.5–3^{cm} longi laxe 5–9-flori, bracteolis oblongo-ovatis 1^{mm} longis, pedicellis infimis 5–7^{mm} longis, superioribus quam flores brevioribus. Sepala 4 pubescentia ovata vel lanceolato-ovata 2–2.5^{mm} longa. Stamina 2.5–3.8^{mm} longa, antheris oblongo-ellipsoideis 0.8^{mm} longis rima elongata dehiscentibus. Discus crassus 2–3^{mm}-diametralis pubescens. Ovarium pilis densis obtectum ovoideum cum stylo aequilongo glabro adjecto 3–4^{mm} longum. Capsula desideratur.— Ad *S. obtusifoliam* Schumann et *S. obtusam* Schumann floribus accedens ab utraque foliis recedit.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Febr. 1902, *von Tuerckheim*, n. 8191 ex Pl. Guat. &c., quas ed. Donn. Sm.

Platymiscium dimorphandrum Donn. Sm.— Foliola 5 membranacea minutissime reticulata oblongo-elliptica obtuse acuminata basi acuta. Racemi fasciculati longissimi fere e basi floribundi. Calyx majusculus obpyramidalis, dentibus 3 acuminato-triangularibus, 2 superioribus in unum obtusum bidenticulatum coalitis. Stamina alterna sterilia, vexillare liberum.

Arbor. Stipulae ovatae vel oblongae 10–14^{mm} longae. Folia cum petiolo 3.5–6^{cm} longo adjecto 15–22^{cm} longa, foliolis 6–12^{cm} longis 2–4^{cm} latis, petiolulo terminali 2–2.5^{cm} longo lateralibus bis terve longiore. Racemi glabri 16–25^{cm} longi, pedicellis singulis 1–1.5^{mm} longis, bracteis bracteolisque vix ullis. Calycis tubus 3–3.5^{mm} altus basi acutus, dentes inferiores 1–1.5^{mm} longi. Vexillum orbiculare basi cuneatum 1^{cm} longum alas vix superans

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[1] Continued from BOT. GAZ. 35:9. 1903.

carina longius. Stamina fertilia 7^{mm} longa, sterilia paulo breviora antheris parvulis cassis instructa. Ovarium stipite brevius stylo aequilongum. Legumen ignotum.— Species et calyce et staminibus insignis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Mart. 1092, *von Tuerckheim*, n. 8199 ex Pl. Guat. &c., quas ed. Donn. Sm.

Cassia anisopetala Donn. Sm. (§ CHAMAESENNA DC.).—Aculeis stipularibus recurvis armata. Folia eglandulosa, foliolis 4-jugis rarius hinc inde 2–3-jugis lanceolato-ellipticis vel -oblongis utrinque acutis supra nitidis subtus pubescentibus. Racemi foliis sublongiores, pedicellis filiformibus. Petala stipitata valde inaequalia, inferiorum biformium altero maximo incurvato concavo basi rotundo, altero cum superioribus eo minoribus et longius unguiculatis obovato-oblongo basi attenuato. Stamen infimum ceteris majus.

Frutex undique praeter faciem superiorem foliolorum et flores primum aureo-deinde cinereo-pubescens. Folia cum petiolo $3–5^{cm}$ longo adjecto $10–18^{cm}$ longa, foliolis $4–8^{cm}$ longis $2–3^{cm}$ latis, inferioribus minoribus et magis ellipticis, petiolulis $5–6^{mm}$ longis. Racemi cum pedunculo $4–8^{cm}$ longo adjecto $13–21^{cm}$ longi, pedicellis 2^{cm} longis. Sepala interiora ovalia circiter $5–6^{mm}$ longa 2 exterioribus oblongis dimidio longiora. Petalorum inferiorum majus 2^{cm} longum 8^{mm} latum basi ascendens oblongum inferne dimidiatum stamen maximum complectens, minus 14^{mm} longum, superioribus $8–10^{mm}$ longis. Stamina perfecta 7 sepalis interioribus subaequilonga, infimum 7^{mm} longum, antheris $3.5–4^{mm}$ longis poro duplice apiculatis pilosiusculis. Staminodia 3 staminibus aequilonga, antheris cassis oblongis quam filamenta brevioribus. Ovarium glabrum stipitatum, ovulis verticaliter compressis. Legumen desideratur.— Inter species aculeatas paueas adhuc cognitas haec et foliis et petalis optime distincta.

In planetiebus ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Mart. 1902, *von Tuerckheim*, n. 8194 ex Pl. Guat. &c., quas ed. Donn. Sm.

Miconia involucrata Donn. Sm. (§ JUCUNDA Naud.).— Folia subsessilia oblongo-vel obovato-elliptica caudato-acuminata basi rotundata vel basi ipsa anguste obtusa subintegra supra glabra subtus minutissime puberula 7-plinervia. Panicula stellato-canescens laxe ramosa, ramis secundariis brevissimis apice capituliferis, capitulis trifloris bractea singula involucratis, floribus lateralibus unibracteolatis, centrali ebracteolato.

Arbor, ramis fistulosis. Folia subcoriacea discoloria $24–35^{cm}$ longa $10–16^{cm}$ lata nonnunquam disparia subtus pallide cinnamomea, nervis lateralibus prope basin limbi utrinque 3–6 tenuibus brevibus, superioribus apicem limbi attingentibus utrinque 3, summis 5–10^{cm} supra basin a costa secedentibus, petiolis 5–6^{mm} longis. Panicula terminalis pyramidata cum pedunculo 6–10^{cm} longo adjecto 20–25^{cm} longa, inflorescentiae nondum evolutae capitulis glomeratis vel breviter spicatis, bractea orbiculari bracteolisque 1^{cm} longis stellato-canescentibus jam ante anthesin caducis, floribus 6-meris. Calycis canescentis tubus 7^{mm} longus, lobi lanceolati 5^{mm} longi. Petala oblonga 7^{mm} longa obtusa alba. Stamina violacea, antheris 1^{cm} longis filamenta superantibus, loculis undulatis, connectivo ecalcarato basi incrassato. Ovarium tubo calycis 3-plo brevius 4-loculare, stylo 17^{mm} longo. Bacca ignota.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Sept. 1901, *von Tuerckheim*, n. 8204 ex Pl. Guat. &c., quas ed. Donn. Sm.

Arthrostemma apodocarpum Donn. Sm.—Folia parva lanceolata vel lanceolato-elliptica vel ovata sursum subsensim acuminata in petiolum longiusculum contracto-acuminata et decurrentia supra sparsim setulosa subtus glabra et pallida opaca 5-nervia, margine appresse arguteque ciliato-serrulato. Flores subsessiles. Stamina parum inaequalia, filamentis complanatis glandulari-pilosis. Capsula cylindrica basi attenuata.

Caules e rhizomate repente ascendentes 3–5.5^{dm} longi herbacei sicut inflorescentia pilis glanduliferis passim conspersi. Folia 28–45^{mm} longa 15–22^{mm} lata nervis basilaribus latis fuscis subtus tantum notata ceterum enervia, petiolis 10–15^{mm} longis. Cyma dichotoma laxe pauciflora. Calycis tubus clavato-oblongus 8^{mm} longus, limbus patulus triangulari-dentatus 3^{mm} latus. Petala 15^{mm} longa. Staminum majorum filamenta 5^{mm}, minorum 4^{mm} longa, antheris parvulis. Capsula sessilis 16-18^{mm} longa calycis fructiferis tubum aequans eique adhaerens.—*A. parvifolio* Cogn. proximum.

Inter rupes ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1902, *von Tuerckheim*, n. 8208 ex Pl. Guat. &c., quas ed. Donn. Sm.

Oreopanax meiocephalum Donn. Sm.—Praeter inflorescentiam glaberrimum. Folia simplicia integra lineari-lanceolata longe acutissimeque acuminata basi acuta breviter trinervia cum petiolo bis terve breviore utrinque incrassato subgeniculato-articulata. Panicula parva laxiflora, pedicellis gracilibus, capitulis subglabris parvis laxe 5-8-floris.

Ramuli cortice exfoliante pallidi. Folia crasse coriacea utrinque nitida 14–23^{cm} longa 3–4.5^{cm} lata, costa valida, nervis basilaribus prope marginem ascendentibus et 5–6^{cm} longis, petiolis validis 5–12^{cm} longis. Panicula leviter stellulato-pubescens circiter 8^{cm} alta, ramis inferioribus 5-6^{cm} longis, pedicellis 5–8^{mm} longis, capitulis 3^{mm}-diametralibus. Petala saepius 5 filamentis aequilonga 1.25^{mm} longa. Styli coaliti. Flores feminini fructusque desunt.

Pansamalá, Depart. Alta Verapaz, Guat., alt. 1250^{m}, Apr. 1889, *J. Donnell Smith*, n. 1743 ex Pl. Guat. &c., quas ed. Donn. Sm.—(Sub *O. oligocarpo* Donn. Sm. olim distributum.)

Solanum evolvulifolium Greenman.—Caulis scandens gracilis parce ramosus bifariam pubescens. Folia alterna petiolata solitaria oblongo-ovata vel oblongo-lanceolata. Flores in cincinno simplici vel bifurcato dispositi. Calyx cyathiformis breviter 5-lobatus. Corolla rotata.

Folia $1.5–3.5^{cm}$ longa $0.6—1.8^{cm}$ lata breviter acuminata acuta integra vel repando-undulata ad basin rotundata vel subcordata supra glabra vel solum in nervo medio hinc inde pilosula subtus glabra. Petioli $1.5–4^{mm}$ longi pubescentes. Calyx $3–4^{mm}$ altus breviter 5–lobatus, lobis submucronato-acutis. Corolla rotata circiter 12^{mm} longa alba, lobis lanceolato-oblongis 8^{mm} longis acutis plus minusve prope marginem puberulis ciliatis. Stamina 5 (cum vel absque sexto perabortivo) aequalia. Antherae filamentis longiores apice biporosae tardius longitudinaliter dehiscentes. Gynoecium glabrum. Bacca ovata vel subrotundata $7–14^{mm}$ longa. Semina circiter 2.5^{mm} longa.—*S. boerhaavifolio* Sendt. Brasiliensi habitu simile differt petiolis brevioribus et foliis cordatis.

La Palma, Prov. San José, Cost., alt. 1460^{m}, Sept. 1898, *H. Pittier*, n. 7413 ex Pl. Guat. &c., quas ed. Donn. Sm. (n. 12615 herb. nat. Cost.); Nov. 1897, *C. Wercklé*, n. 11599 herb. nat. Cost.

Solanum mitratum Greenman.—Caulis herbaceus glaber flexuosus. Folia solitaria vel gemina ovata vel lanceolata in petiolum brevem attenuata. Flores axillares solitarii vel gemini. Pedicelli plerumque petiolo longiores. Calyx turbinatus truncatus vel crenatus glaber. Corolla 5-partita purpurea.

Folia $5–15^{cm}$ longa $1.5–6^{cm}$ lata acuminata acuta integra supra viridia subtus pallidiora utrinque glabra. Pedicelli $1.5–2^{cm}$ longi plerumque ad apicem incrassati. Calyx $2–3^{cm}$ altus 10–nervatus paullo costatus. Corolla 5–partita purpurea, tubo brevi $3–4^{mm}$ longo, lobis lanceolatis acutis 3–nervatis. Antherae in tubo subconniventes. Bacca immatura subglobosa 8^{mm} diam., matura non visa.—*S. synanthero* Sendt. proximum differt caule herbaceo, petiolis brevibus, floribus paucioribus et pedicellis ad apicem incrassatis.

Atirro, Prov. Cartago, Cost., alt. 600^{m}, Apr. 1896, *J. Donnell Smith*, n. 6673 ex Pl. Guat. &c., quas ed. Donn. Sm.—San Pedro Sula, Depart. Santa Bárbara, Honduras, alt. 300^{m}, Maj. 1890, *C. Thieme*, n. 5375 ex Pl. Guat. &c., quas ed. Donn. Sm.

Solanum Sanctaeclarae Greenman (§ MEIOMERIS Dunal.).—Arbuscula parva. Rami teretes cum foliis subferruginosi stellatopubescentes. Folia gemina inaequalia ovata ovato-elliptica vel obovata. Inflorescentia axillaris. Flores solitarii vel gemini. Calyx urceolatus persistens. Corolla rotata glabra.

Folia gemina inaequalia utrinque sparse stellato-pubescentia subferruginosa supra atroviridia subtus pallidiora, majoribus ovatis vel ovato-ellipticis 1.2–2^{dm} longis 7–10^{cm} latis acuminatis acutis ad basin in petiolum brevem angustatis, minoribus ovatis vel subovatis subsessilibus. Flores circiter 2^{cm} longi solitarii vel gemini. Pedicelli usque ad 1^{cm} longi. Calyx urceolatus 10–12^{mm} altus latusque subtruncatus vel crenato-lobatus carnosulus et persistens extus stellato-pubescens. Corolla rotata glabra, tubo brevi quam lobi valvati circiter 3-plo breviore. Baccae maturae ignotae.—*S. synanthero* Sendt. habitu simile.

La Emilia, Llanuras de Santa Clara, Cost., alt. 250^{m}, Apr. 1896, *J. Donnell Smith*, n. 6783 ex Pl. Guat. &c., quas ed. Donn. Sm.

Solanum Tuerckheimii Greenman.—Folia alterna petiolata solitaria vel rarius gemina et maxime inaequalia oblongo-lanceolata. Flores minimi in cincinno simplice dispositi. Calyx 5–lobatus. Corolla rotata.

Frutex erectus circiter 3^{m} altus undique glaber. Folia 1–2^{dm} longa 3–7^{cm} lata breviter-acuminata obtusa vel acuta integra ad basim in petiolum sensim angustatis supra livido-viridia subtus pallidiora subcoriacea, petiolis 1–2^{cm} longis. Inflorescentia subopposititifolia 3–4^{cm} longa multiflora, pedicellis gracilibus usque ad 1.5^{cm} longis ad apicem paullo incrassatis. Calyx 1.5–2^{mm} altus persistens, lobis ovatis obtusis. Corolla rotata circiter 7^{mm} diam., lobis lanceolato-triangularibus acutis et mox recurvatis. Stamina 5 aequalia, filamentis in tubo breviter coalescentibus. Antherae 2–2.5^{mm} longae apice biporosae. Gynoecium glabrum. Bacca immatura subrotundata glabra.—*S. tristo* Jacq. habitu simile, differt foliis utrinque glabris et inflorescentia longiore et floribus minoribus. *Solano Lindenii* Rusby foliis persimilis a quo inflorescentia longiore et corolla valde minore recedit.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1903, *von Tuerckheim*, n. 8492 ex Pl. Guat. &c., quas ed. Donn. Sm.

Brachistus lanceolatus Greenman.—Caulis suffruticosus. Folia gemina inaequalia lanceolata vel ovata acuminata vel acuta ad basin in petiolum brevem attenuata. Flores axillares solitarii. Calyx breviter 5–lobatus. Corolla alba 5–lobata. Stamina corollo breviora.

Caulis teres, ramis parce pubescentibus. Folia gemina, majoribus lanceolatis 3–8.5^{cm} longis 1–2.5^{cm} latis acuminatis acutis ad basin sensim attenuatis, minoribus lanceolatis et acutis vel ovatis et obtusis. Flores circiter 1^{cm} alti et lati axillares solitarii. Pedicelli 1.5–2.5 ^{cm} longi filiformes ad apicem incrassati primo erecti vel ascendentes deinde reflexi. Calyx corolla circiter quater brevior. Baccae globosae 7–10 ^{mm} diam. in sicco plus minusve rubrae vel flavae.—*B. diversifolio* Miers affine foliis, &c., multo recedit.

Chucaneb, Depart. Alta Verapaz, Guat., alt. 1850 ^{m}, Apr. 1889, *J. Donnell Smith*, n. 1837 ex Pl. Guat. &c., quas ed. Donn. Sm.

Coccoloba Tuerckheimii Donn. Sm. (§ PANICULATAE Meissn.).—Folia oblongo-obovata abrupte brevissimeque acuminata basi acuta supra glabra subtus puberula, ocreis amplis glabris subrhomboideis insigniter nervosis paulo infra apicem cum petiolo articulatis. Panicula sessilis, axe primario brevi, secundariis simplicibus vel prope basin furcatis, pedicellis singulis ocreola multo longioribus.

Arbor grandis speciosa. Internodia ad apicem versus ramulorum brevissima ocreis imbricantibus obtecta striata glabra. Folia 13–34 ^{cm} longa 7.5–17 ^{cm} lata, nervis lateralibus utrinsecus 10–12 ad axillas subtus fusco-barbatis, venulis minutissime anastomosantibus, petiolis striatis 1.5–3.5 ^{cm} longis, ocreis praeter marginem membranaceum 6–9 ^{mm} latum coriaceis reticulato-nervosis circiter 3 ^{cm} longis et 2.5 ^{cm} latis 6–8 ^{mm} supra articulationem petioli productis. Paniculae axis 2–4 ^{cm} longus, racemi approximati 10–15 nonnunquam prope basin semel vel bis furcati suberecti vel nutantes 18–24 ^{cm} longi folia proxima superantes 2–3 ^{mm} crassi sulcati fusco-puberuli densiflori, pedicelli 1.5–2 ^{mm} longi. Perianthium fructiferum 13 ^{mm} longum 8 ^{mm} crassum, lobis late rotundatis arcte conniventibus fructum ovalem apice obtusatum velantibus. Flores desunt.

In apricis inundatis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 ^{m}, Jul. 1903, *von Tuerckheim*, n. 8493 ex Pl. Guat. &c., quas ed. Donn. Sm.

Croton pyramidalis Donn. Sm. in BOT. GAZ. **35**: 7. 1903.—Diagnosi adde: Dioicus. Inflorescentia feminina masculae similis. Calycis denique retroflexi segmenta 5–6 fere sejuncta oblonga intus glabra. Disci annularis glandulae distinctae conspicuae. Ovarium longe ciliato-lepidotum.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 ^{m}, Jul. 1903, *von Tuerckheim*, n. 8457 ex Pl. Guat. &c., quas ed. Donn. Sm.

Zebrina pendula Schnizl., var **villosa** C. B. Clarke.—Foliis subpetiolatis, elongatis, lanceolatis, in utrâque facie fulvo-villosis; inflorescentiis quasi sessilibus; filamentis glabris.

Robustior. Folia 11 ^{cm} longa, 3.5 ^{cm} lata; pili 3–4 ^{mm} longi. Calycis segmenta scarioso-brunnea apice fulvo-pilosa. Corollae tubus 5 ^{mm} longus, segmenta in sicco pallide coerulea laete brunneo-venosa.—Ad n. 766 *Bernoulli et Cario* accedens.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350$^{\mathrm{m}}$, Jan. 1902, *von Tuerckheim*, n. 8326 ex Pl. Guat. &c., quas ed. Donn. Sm.

Meliosma Donnellsmithii Urban.—Foliis alternis, ad apicem ramorum confertis, 3–7$^{\mathrm{mm}}$ longe petiolatis, obovato-oblongis, apice rotundatis, nunc brevissime acuminatis, ab $\frac{3}{4}$–$\frac{4}{5}$ longitudinis usque ad basin longe et sensim angustatis, basi ipsa abrupte in petiolum contractis v. subcordatis, 25–45$^{\mathrm{cm}}$ longis, 8–12$^{\mathrm{cm}}$ latis, cr. 3-plo longioribus quam latioribus, planis, nervo medio supra subimpresso, lateralibus supra vix prominulis v. subimpressis, subtus crassiuscule prominentibus, chartaceis v. subcoriaceis, margine integris v. superne parvissime dentatis; petalis exterioribus 2.2–2.5$^{\mathrm{mm}}$ longis, interioribus parce et minute pilosulis integris; cupula antherifera apice rotundata, leviter sublongitrorsum dehiscentibus; disco vix evoluto; stylo integro.

Arbuscula 3–4$^{\mathrm{m}}$ alta (ex *Donnell Smith*). Rami hornotini subglabri; gemmae brevissime pilosulae. Folia nervis lateralibus 15–20, subangulo 45–55° abeuntibus, utrinque reticulato-anastomosantibus, supra in sicco glauco-olivacea, subtus pallide brunnea, ad nervum medium brevissime pilosa, caeterum glabra. Paniculae cr. 6$^{\mathrm{cm}}$ longe pedunculatae, cr. 25$^{\mathrm{cm}}$ longae, ad basin glabratae, caeterum brevissime et subadpresse pilosae; bracteae triangulares v. triangulari-lanceolatae, cr. 1$^{\mathrm{mm}}$ longae; rami horizontaliter patentes; flores sessiles v. subsessiles, prophyllis 3–5 semiorbicularibus v. breviter orbicularibus 0.5–0.6$^{\mathrm{mm}}$ longis suffulti. Sepala semiorbicularia v. suborbicularia, apice rotundata, margine brevissime ciliata, 0.8$^{\mathrm{mm}}$ longa, 0.8–1$^{\mathrm{mm}}$ lata, chartacea. Petala exteriora suborbicularia coriacea, margine glabra, subinaequalia, interiora sublinearia, obtusiuscula, 1.8$^{\mathrm{mm}}$ longa, vix 0.5$^{\mathrm{mm}}$ lata, 1-nervia. Staminodia 1$^{\mathrm{mm}}$ longa, in $\frac{1}{5}$ alt. petalis adnata, apice truncata. Filamenta latiuscule linearia, 1.2$^{\mathrm{mm}}$ longa; cupula antherifera breviter, orbicularis, basi emarginata, 0.6$^{\mathrm{mm}}$ lata. Discus vix indicatus. Ovarium suborbiculare apice in stylum contractum. Stylus 0.8$^{\mathrm{mm}}$ longus, ovario duplo longior, subaequicrassus, basi oblique insertus. Stigma punctiforme.—Ambitu foliorum *M. Itatiaiae* Urb. a Brasilia valde similis.

Ad oras Río Turrialba, Prov. Cartago, Cost., alt. 500$^{\mathrm{mm}}$ Mart. 1896, *J. Donnell Smith*, n. 6852 ex Pl. Guat. &c., quas ed. Donn. Sm.

BALTIMORE, MD.

BRIEFER ARTICLES.

CRATERELLUS TAXOPHILUS, A NEW SPECIES OF THELEPHORACEAE.

WHILE collecting fungi on the steep bank of Fall Creek within the Cornell University campus on October 19, 1903, I found several specimens of a delicate fungus growing upon moist and very rotten leaves and twigs. Returning the next day, I found a considerable number of specimens from which a photograph (*fig. 1*) was obtained, natural size. Careful examination of the locality showed that the specimens were found only under or near the prostrate branches of *Taxus canadensis.* Continued search in all directions justified the conclusion that the fungus must depend in some manner upon the Taxus. Specimens were found under isolated Taxus plants far up the same bank, and later on the opposite side and half a mile farther up stream. In this second station also no plants were found except under Taxus branches. It then became desirable to determine, where possible, the leaves and twigs upon which the fungus had been found. The material was submitted to Mr. F. W. Foxworthy, and it was definitely determined that specimens grew on the leaves and twigs of deciduous trees as well as of Taxus and probably also of Tsuga. It is probable, therefore, that the fungus depends upon the prostrate branches of the yew for the shade and conservation of moisture which enable the delicate fleshy fruit bodies to develop. However, careful examination of the same bank where other plants furnished similarly moist conditions failed to disclose any specimens. It would seem, then, that the association of the fungus with the yew is very intimate, if not essential. It has not yet been possible to extend the search for this form into other localities where similar conditions prevail. No range, therefore, can be given. In this one locality at least one hundred and fifty specimens have been found and studied between October 19 and November 20.

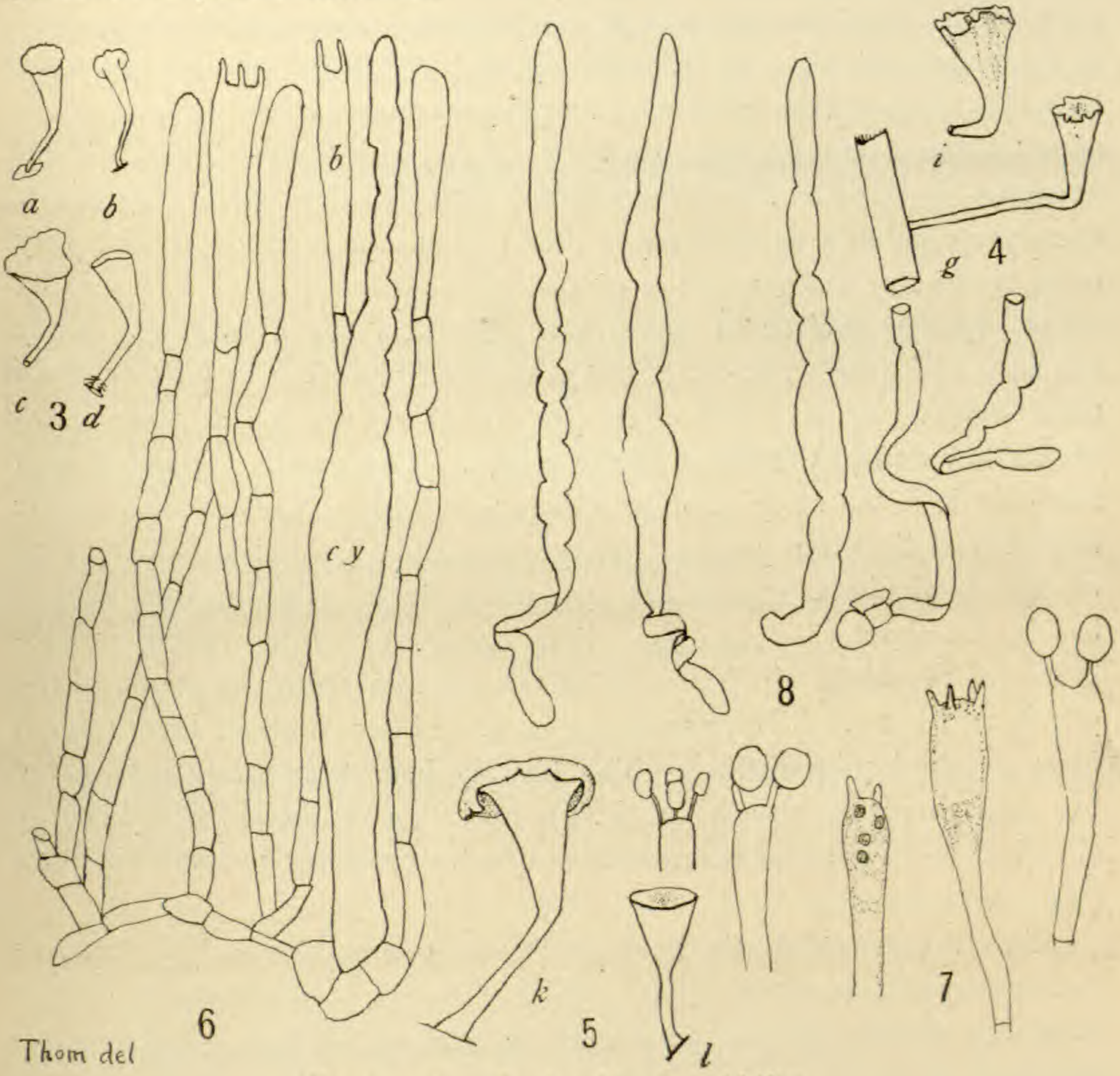
Once seen, there is no great difficulty in finding the plants by close observation of the open places between the branches of yew. The most successful plan, though, is to raise the branches from the ground. The Craterellus, if present, is then conspicuous by its pure white color against the dark background of moldy leaves and twigs.

It is very commonly the only higher fungus present in those places. The plants occur singly, or sometimes in twos or threes, but never cespitose nor scarcely gregarious, since an area of two or three square rods yielded at best only about thirty specimens.

The fruit bodies when young are pure white, but as they become old the upper halves often run through shades of ochraceous, even to orange, which they retain in drying. The plants vary in height from 8 to 30^{mm}, and in diameter at apex, from 4 to 9^{mm}. One specimen was fully developed at 8^{mm} (*fig. 5, l*); the longest one seen (*fig. 4, g*) was 30^{mm} in height. Far the largest number measured between 14 and 18^{mm}. In shape the most usual form is an obconical pileus passing over into a stem of nearly uniform diameter and varying in length from one-half to two-thirds the whole length of the plant. The apex of the pileus is abruptly truncate at times, but is usually furnished with a free margin, which may be upturned so that the center is markedly depressed, or more commonly expanded and wavy, often deflexed in age, and even almost involute in cases (*figs. 1, 5*). The stem in some specimens is straight, but is usually curved, especially near its point of

FIGS. 1 and 2.—*Craterellus taxophilus.* From photographs. 1, natural size; 2, ×2.5.

union with the pileus (*figs. 1, 4*). Another type (*figs. 1, 2*) of general outline often occurs in which the enlargement from base of stem to apex of pileus is gradual and the curvature does not coincide with the junction of pileus and stem.



FIGS. 3–8.—*Craterellus taxophilus.*

FIG. 3.—A group of plants showing the variation in form. Natural size. FIG. 4.—*g*, the largest specimen seen, attached to a twig; and *i*, the same specimen after drying, showing the wrinkled hymenium. FIG. 5.—*k*, showing margin involute; *l*, smallest specimen, 8 mm in height, truncate at apex and without curvature. ×2. FIG. 6.—Cystidium, basidia, and subhymenial filaments shown in a crushed preparation. FIG. 7.—A group of basidia much enlarged. FIG. 8.—Different forms of cystidia.

The plants are hygrophanous when moist, and slightly viscid or glutinous when fresh. The flesh is very soft and almost waxy. The dried plants are extremely light and fragile. The stem is composed of a solid mass of more or less parallel hyphae, and expands directly to form the pileus, which is made up of very loosely woven hyphae in the center, but becomes fairly firm in the subhymenial layers. The stem is white pruinose and bears scattered tufts of white hairs at the base (*fig* 2).

The hymenium surrounds the upper one-third to one-half of the fruit body. It is usually smooth, but in some cases shows a tendency to the formation of longitudinal ridges. When old or dry, there are irregular longitudinal wrinkles, due perhaps to the closer texture of the surface layer compared with the very spongy substance within. These wrinkles are seen in *fig. 4, i* compared with *fig. 4, g*, which represents the same specimen when fresh. The hymenium extends to the very edge of the free margin of the pileus, where it is replaced abruptly by a loose spongy surface of mycelium. Cystidia are numerous. They are long and narrow, 60–70 × 4–6 μ, curiously swollen in part or all of their length (*fig. 8*), with often prominent curvatures at their bases where they end in the trama of the pileus. Their walls are rather thin and colorless, but they contain substances which blacken with osmic acid, especially when young. They extend but little above the surface of the hymenium, sometimes 4 μ, often less. The narrow-clavate basidia are about 18–24 μ × 4 μ. They are borne upon branching subhymenial filaments which arise with the cystidia from the trama of the pileus, and are much interwoven to form a rather compact layer (*fig. 6*, from crushed preparation). The basidia bear four sterigmata (only two and three are shown in *fig. 6*), up to 4 μ in length, with broadly elliptical to subglobose (even almost quadrate) spores 3–4 μ in diameter (*fig. 7*).

This fungus evidently belongs to the genus *Craterellus* Pers., as defined by Engler and Prantl. It is difficult to associate it closely with any of the species described on account of lack of data as to structure in most forms. I propose the name *C. taxophilus* for the species, from the habitat of the plants. The material has been referred to Professor George F. Atkinson, of Cornell University, and to Professor E. A. Burt, of Middlebury College, who agree with me in regarding the species as hitherto undescribed.

Craterellus taxophilus Thom, n. sp.— Plants scattered, rarely 2–3 together, not cespitose, on moist very rotten leaves and twigs under *Taxus canadensis*. Fruit body 8–30^{mm} high, mostly 14–18^{mm}, and 4–9^{mm} in diameter at apex; truncate, clavate, or obconical, tapering gradually into a stem below, or more commonly abruptly narrowed like a funnel, usually curving where hymenophore and stem unite; Apex sterile, truncate, plane, or depressed, with a thin margin upturned or expanded, even deflexed and almost involute at times, and wavy or lobed; entirely white when young, shading in age into ochraceous-buff, ochraceous, and even orange above, remaining more pallid below; hygrophanous when moist, and slightly viscid or glutinous; flesh very soft, almost of waxy consistency, composed of very loosely woven mycelium in the center, becoming denser at the surface. Stem solid, equal or slightly broadened upward, 0.5–1^{mm} in diameter, white pruinose becoming pubescent with scattered white hairs at base. The hymenium surrounds the upper two-fifths to one-half of the length of the fruit body; basidia clavate, 18–24 × 4 μ, 4-spored, sterigmata up to 4 μ in length; spores broadly elliptical to subglobose, smooth, white, 3–4 μ; cystidia white, numerous, often 60–70 × 4–6 μ, usually curved and irregularly swollen toward the base where they arise from the trama, extending beyond the basidia only when young and by 2–4 μ, thin-walled and containing substances which blacken with osmic acid.

Type in Cornell University Herbarium, no. 15,445, collected from very rotten twigs and leaves of deciduous trees and conifers, but only under prostrate branches of *Taxus canadensis*, in Fall Creek gorge, Ithaca, N. Y., between October 19 and November 19, 1903.— CHARLES THOM, *Cornell University*.

NOTES ON SOUTHWESTERN AND MEXICAN PLANTS.

I. THE INDIGENOUS CENTAUREAS OF NORTH AMERICA.

THE first species of the genus Centaurea indigenous to North America was published by Nuttall in 1821, as *C. americana*. The species was originally collected in Arkansas, where it was said by Nuttall to grow "on the banks of streams, and in denudated alluvial situations, throughout the plains or prairies of the upper part of Arkansas territory."

Sprengel in the Supplement of the fourth volume of the *Systema vegetabilium* quite arbitrarily makes a new combination for Nuttall's plant, namely *C. Nuttallii*, having himself previously, in the third volume of the *Systema*, p. 407 (1826), used the combination *C. americana* for a Peruvian plant, which is very different from the North American species. Further, in 1831, D. Don, in Sweet's *British flower garden* 2 : *pl. 51*, characterizes and illustrates the species published by Nuttall under the name *Plectocephalus americanus*. Both of these combinations, *C. Nuttallii* and *Plectocephalus americanus*, are merely altered names for Nuttall's species and are invalidated by all present rules of nomenclature. In 1837 DeCandolle published *C. mexicana*, based upon Berlandier's nos. 430 and 1750, collected between Bexar and the Trinity River, Texas. Later, *C. mexicana* was shown to be identical with *C. americana* Nutt.

A careful study of a large suite of specimens in the Gray Herbarium shows very clearly that we have at least two indigenous species of this genus in the southwest, one of which is new to science, and is readily separated from the older species on the involucral characters alone; its distribution, moreover, is more western and southern, and it grows at a higher altitude. *C. americana* has been so well described and illustrated that it is unnecessary to present here more than the literature and the citation of specimens. Of its congener, however, a description is given below. The two indigenous North American species as here recognized by the writer are as follows:

*Involucral bracts stramineous or the inner ones slightly purplish, pectinate with 3–8 pairs of lateral firm teeth.

C. AMERICANA Nutt. Jour. Acad. Phil. **2**: 117. 1821; Bart. Fl. Am. Sept. **2**: *pl. 50.* 1822; Colla, Hort. Ripul. App. i. 119. *pl. 6.* 1827; Reichb. Ic. Exot. **2**: *pl. 132.* 1828; DC. Prodr. **6**: 575. 1837; Torr. & Gray, Fl. N. Am. **2**: 453. 1843; Engelm. & Gray, Pl. Lindl. 14. 1845; Fl. Serres **4**: *pl. 327.* 1848; Gray, Pl. Wright. **1**: 125. 1852; Young, Fl. Texas 361. 1873; Meehan's Nat. Fls. II. **2**: *pl. 17.* 1880; Hemsl. Biol. Cent. Am. Bot. **2**: 253. 1881 in part, *i. e.*, excl. pl. Rothrock; Gray, Syn. Fl. **1**^{2}: 407. 1886; Coulter, Contrib. U. S. Nat. Herb. **2**: 244. 1891–94; Small, Fl. Southeastern U. S. 1308. 1903.—*C. Nuttallii* Spreng Syst. **4**: (Suppl.) 298. 1827.—*C. mexicana* DC. Prodr. **6**: 575. 1837.—*Plectocephalus americanus* Don in Sweet's Brit. Fl. Gard. **2**: *pl. 51.* 1831; Spach, Hist. Veg. **10**: 63.

UNITED STATES. Arkansas: specimen *ex hb. Durand.* Louisiana: *Dr. Leavenworth.* Texas: *Pope; Lindheimer*, nos. 114, 34; dry prairies, near Dallas, *Hall*, no. 373, *Reverchon; Drummond*, no. 169; between Bexar and the Trinity River, *Berlandier*, nos. 430, 1750; Kerrville, altitude 490 to 615^m, *Heller*, no. 1774; Weatherford, *Tracy*, no. 7896. New Mexico: Jornado del Muesto, *Dr. Wislizenus;* exp. from western Texas to El Paso, *Wright*, no. 405; White Mountains, altitude 1850^m, *Wooton*, no. 195. MEXICO. Coahuila: Saltillo, *Dr. Edward Palmer*, nos. 766 (coll. of 1880), 294 (coll. of 1898) white-flowered form. Chihuahua: Bachimbo Cañon, *Pringle;* Rio Sta Maria, *Thurber*, no. 748.

**Involucral bracts greenish or stramineous below, conspicuously tipped with chestnut-brown, pectinate-fimbriate with 8–12 pairs of lateral rather slender teeth.

C. Rothrockii Greenman, n. sp. Annual or biennial (?), 3–10^{dm} high: stem erect, simple below, sparingly branched above, sulcate-striate, glabrous or slightly hirtellous; leaves lanceolate to oblong-lanceolate, 3–12^{cm} long, 1–3.5^{cm} broad, sessile and often semiamplexicaul, acuminate, acute, sometimes terminated by a conspicuous mucro, entire to slightly sinuate-dentate, hirtellous-puberulent on both surfaces, hispidulous on the margins, resiniferous-dotted; the uppermost leaves much reduced and not infrequently subfimbriate near the tip: peduncles thickened above: heads large, 3–5^{cm} high, including the rays 3–15^{cm} in diameter: involucre subcampanulate, in well-developed specimens about 3^{cm} high and 4^{cm} broad; bracts of the involucre about 9-seriate, rather closely imbricated, lanceolate, pectinate-fimbriate in the upper third, bearing 8–12 pairs of brownish ciliated rather slender teeth: the neutral marginal flowers (rays) elongated, conspicuous, usually purple, much exceeding the lemon-yellow flowers of the disk: mature achenes oblong-obovate, 5^{mm} long, black and smooth.—*C. americana* Rothrock in Wheeler's Report 180. 1878, not Nutt.—*Centaurea* sp. Engelm. in Wislizenus Report 107. 1848, Reprint 23. UNITED STATES. Arizona: Chiricahua, *Rothrock*, no. 527 (type). MEXICO. Chihuahua: near Colonia Garcia, altitude 2300^{m}, August 9, 1899, *Townsend & Barber*, no. 247: August 1–20, 1899, *E. W. Nelson*, no. 6175; southeastern Chihuahua, August–November 1885, *Dr. Edward Palmer*, no. 415; Llanos, *Dr. Wislizenus*. Durango: Sierra Madre, 18.5^{km} north of Guaucevi, altitude 2460–2770^{m}, August 18, 1898, *E. W. Nelson*, no. 4774. Zacatecas: between Bolaños and Guadalajara, September 20, 1897, *Dr. J. N. Rose*, no. 3033. Oaxaca: La Mixteca, Huauclilla, District of Nochixtlan, altitude 2000^{m}, June 26, 1898, *F. Lopez* (*Conzatti & González*, no. 781).

These two species are among the most attractive of the genus; both are well worthy of garden cultivation. *C. Rothrockii* is equal, if not superior, to its sister species *C. americana*, which has already found its way to many American gardens. The writer takes pleasure in dedicating the handsome species here described to Dr. Joseph Trimble Rothrock, now of the State Forestry Commission of Pennsylvania.

II. ON THE GENUS ASPILIOPSIS.

In the "Supplementary leaflet" to the *Contributions from the Gray Herbarium of Harvard University* new series, no. xxv, issued September

25, 1903, the writer proposed the name *Aspiliopsis* for the plant described in the body of the same contribution, p. 106, as *Altamirania*, n. gen. of Verbesineae (Compositae). Professor Theo. D. A. Cockerell, of Colorado Springs, has most courteously called my attention to the fact that no binomial was given under *Aspiliopsis*. This may be formed as follows: **Aspiliopsis pachyphylla**, n. comb. *Altamirania pachyphylla* Greenm. Proc. Am. Acad. 39: 106. 1903.—J. M. GREENMAN, *Gray Herbarium*, *Cambridge*, *Mass.*

VITALITY OF SEEDS.

THE statement in the GAZETTE for February by J. W. T. Duvel concerning the preservation of seeds buried in the soil reminds me of some tests I made years ago, reporting the results in the *Proceedings* of the Society for the Promotion of Agricultural Science for 1894. In September 1882 I gathered and shelled 50 heads of red clover from each of five plants, and kept them in two-ounce bottles, each lot by itself. On June 7, 1894, I tested 50 seeds of each for vitality, and again on June 23, 1894, I tested another set of 50 seeds each. The average of the two lots of all seeds was 35.8 per cent. of living seeds. Of the hundred taken from one of the bottles 66 seeds germinated; while of those from another bottle only 4 seeds out of the hundred germinated. In these cases some of the seeds of each lot retained vitality for nearly twelve years.

In the *Proceedings* of the same society for 1899, I reported the results of tests of the vitality of seeds of weeds buried by me in "clean" dirt in bottles for twenty years. The seeds germinated very unevenly. I name the species of seeds of which some germinated: Amaranthus retroflexus, Brassica nigra, Capsella Bursa-pastoris, Lepidium virginicum, Anthemis cotula, Malva rotundifolia, Oenothera biennis, Polygonum hydropiper, Portulaca oleracea, Rumex crispus, Stellaria media, Verbascum thapsus. None of the following germinated: Ambrosia artemisiaefolia, Erechthites hieracifolia, Euphorbia maculata, Plantago major, Setaria glauca, Trifolium repens, Bromus secalinus, Lychnis githago. I give the names of seeds by which they were known when buried; at the time of their resurrection the names of some of them had been changed!—W. J. BEAL, *Agricultural College*, *Michigan*.

CURRENT LITERATURE.

BOOK REVIEWS.

The culture of plant rusts.

THE ALTERNATION of wholly unlike forms in many Uredineae, the aecidium on the one hand, and the uredo- and teleutospores on the other, and especially the occurrence of these forms upon unrelated hosts in the heterœcismal species, has given to the study of the rusts by the culture method a most absorbing interest. No law has been detected governing the selection of alternate hosts by the different species of rusts, and so each new instance brought to light is an independent discovery, worked out with little or no aid from previous records. As the work progresses, the number of possible combinations between known forms necessarily diminishes, but new forms are found, and known forms are divided up by previously undetected characters

The study of rusts by cultures began in 1865, and has been especially active during the last decade. The results have opened up many intricate problems, none of which has been more discussed and seemed more weighty than that of the relationship of what have been called physiological species or races. The literature of the subject has become abundant and widely scattered, until even a specialist finds it difficult to follow.

The need of a work in which the results thus far attained by culture methods are collected, arranged, and summarized is a real need, and one which has been happily met by Dr. H. Klebahn,[1] of Hamburg, in a treatise on the heteroecismal rust-fungi.

Although it has taken nearly 450 large octavo pages in which to present the subject, the work could not be surpassed for concise and lucid treatment, and for completeness without redundancy. It is an admirable account of the subject.

The author begins his treatise with a short account of other organisms, both animal and plant, that possess heteroecismal adaptations, and then takes up the history of the knowledge of the heteroecismal rusts. In the pages that follow the natural distribution of the aecidiospores, uredospores, and sporidia are discussed, and the methods of natural infection. All available information is presented regarding such questions as: Can the uredo and teleutosporic generation of heteroecismal rusts arise from sporidia, and can aecidia of heteroecismal rusts arise in any other way than from sporidia? These are the questions of much economic interest.

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[1] KLEBAHN, H., Die wirtswechselnden Rostpilze. 8vo. pp. xxxvii + 447. Berlin: Gebrüder Borntraeger. 1904. *M* 20.

Naturally the great problems of the cereal rusts receive considerable attention. Regarding the continuation of the rust through the agency of the seed, and Eriksson's "mycoplasm" theory, the arguments are fully presented, but the author regards these assumptions far from proved.

The chapter upon methods of investigation is especially interesting and helpful. No one has done more or better work in this line of research than the author, and he speaks with long experience and wide knowledge. Sixteen pages are devoted to the study of rust problems from the point of view of plant geography, a subject that will grow more and more important as fuller data become available. In taking up the matter of the association of the host plants selected by the aecidial and teleutosporic generations, the author has developed a number of exceedingly ingenious and helpful charts.

The seventy-five pages remaining of the first half of the book are devoted to the absorbing and intricate problems presented by specialization, the limitations of species and races, the origin of heteroecism, and the questions of sexuality. The numerous theories and facts are clearly and ably presented, but one must confess a feeling of disappointment that, after mastering present knowledge and canvassing the views of other writers, no substantial advance is made in formulating an explanation of the problems. It is evident that these questions must await the writer who is a philosopher as well as a scholar.

The second half of the volume is devoted to a detailed account of the 150 or more species that have been studied by cultural methods. An index of species, one of hosts, and a full bibliography complete one of the most important contributions to the study of plant rusts ever published.—J. C. ARTHUR.

Physical chemistry.

STUDENTS and research workers in plant as well as in animal physiology will find Fischer's translation of Cohen's *Physical Chemistry*[2] an almost indispensable book. This treatise presents those considerations of the general subject which have a close bearing upon physiological phenomena, and presents them in a concise, clear, readable form, with only as much mathematics as is necessary for the establishment of the principles. Besides pure physical chemistry, the book contains a discussion of a number of applications of this science in hygiene, pharmacology, physiology, etc.—discussions which should be eye-openers to many a student of biology. The subject-matter is divided into seventeen lectures, which are numbered serially. A statement of their titles is given here to show the scope of the book: Reaction velocity; Inversion of cane sugar and catalysis in general; The action of ferments; Temperature and reaction velocity; Equilibrium (three lectures); The friction of liquids; Osmotic pressure; The determination of the molecular weight of dissolved substances; The theory of electrolytic dissocia-

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[2] COHEN, ERNST, Physical chemistry for physicians and biologists, translated by Martin H. Fischer. pp. viii + 343. *figs. 49.* New York: Henry Holt & Co. 1903.

tion (two lectures), and its applications (three lectures); and Electromotive force (two lectures). References to important papers are given by footnotes. At the end of the volume is an index both of subjects and of authors' names, but we look in vain for a table of contents to aid the reader in following the scheme of presentation. The translation is excellent throughout, and well worthy of the accuracy of the original.— B. E. LIVINGSTON.

A premedical text-book.

THIS GENERAL TEXT-BOOK of botany[3] is written for premedical and pharmaceutical students in particular and the nonprofessional undergraduate incidentally. Like most German works of its sort, it is divided into three parts: first, a general treatment of the organogeny and cell structure of plants; second, their physiology; third, the general morphology of representatives of the great plant groups. Of these three, the greatest stress is laid upon the first part, which reflects in great measure the views of Goebel as found in his *Organographie* in much detail. The chapters treating of respiration, photosynthesis, and other plant functions are much more elementary, as is the general morphology. There is a wholesome admixture of new illustrations with the time-worn veterans that the author apparently hadn't the heart or the courage to drop by the wayside. In the treatment of what the author calls the "Spezielle Botanik" there is no description nor figure of the sex organs of the liverworts or mosses, and none of the sexual generation of the water ferns, equisetum, selaginella, isoetes, gymnosperms, and angiosperms. The groups of flowering plants described seem to have been selected largely because members of the order afford commercial products. The stamens and pistils are referred to as "geschlechtsorgane." This is an anachronism that does not accord with the views expressed on the alternation of generations, which are quite up to date.—FLORENCE M. LYON.

MINOR NOTICES.

THE FLORA OF PENNSYLVANIA, in preparation many years by the late Professor Thomas C. Porter, has appeared under the editorship of Dr. John K. Small.[4] It consists of a list of gymnosperms and angiosperms with stations, and is the result of personal exploration and extensive cooperation of others for a period of over sixty years. Professor Porter's ambition was to make his list of Pennsylvania plants complete, and this led him to defer printing it from time to time. When death overtook him in his eightieth year, the work seemed to him not yet perfect enough for publication, but a provision in his will for its publication has enabled Dr. Small to present it to the public. The summary shows that it records 2201 species, which have

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[3] GIESENHAGEN, K., Lehrbuch der Botanik. Imp. 8 vo. pp. xii + 475. *figs. 557*. Stuttgart: Fr. Grub. 1903.

[4] PORTER, THOMAS CONRAD, Flora of Pennsylvania. Edited with the addition of analytical keys by John K. Small. 8vo. xv + 362. Boston: Ginn & Co. 1903. $2.15.

been brought together with more painstaking care, probably, than has ever been used in the preparation of a catalogue of plants.— J. M. C.

A SECOND EDITION of Professor Atkinson's book on *Mushrooms* appeared recently from the press of Henry Holt & Company.[5] The new volume contains ten illustrations which did not appear in the first edition. The value and attractiveness of the work are further enhanced by a chapter on the cultivation of mushrooms, illustrated by half-tones of mushroom houses and flash-light photographs of mushroom beds in abandoned mines in New York and Pennsylvania. This chapter gives a good account of the status in the United States of an industry of whose existence probably few are aware. Methods of culture and marketing mushrooms are fully discussed in this chapter.

The typography and half-tone work of this edition are of the same excellent character as in the first edition, making it an exceedingly attractive work. — H. HASSELBRING.

THE SIXTH FASCICLE of Engler's great work on the genera and families of African plants was published in the spring of 1901, and just now, nearly three years later, the seventh fascicle[6] has made its appearance. It is a presentation of the genus Strophanthus (Apocynaceae) by E. Gilg, who recognizes 43 species, only one of which is new, but 8 of which are of recent publication by the author. The 10 lithographic plates, one of them colored, are models of illustrative work.— J. M. C.

NOTES FOR STUDENTS.

DIXON has examined the temperature difference between subterranean organs and the soil by a special thermopile.[7] He finds generally no higher temperatures than those of the soil and no diurnal periodicity other than is induced by periodic fluctuations of external temperatures. The adaptation of apparatus and discussion of errors in thermoelectric measurement of temperatures have a positive value.— C. R. B.

BOUILHAC AND GIUSTINIANI[8] believe that mixtures of bacteria with such algae as Nostoc and Anabaena will prove of great economic value in soils that are poor in nitrogen. Cultures of buckwheat supplied with these forms developed normally in soils deprived of all other organic matter, and subsequent tests showed that large quantities of nitrogen had been fixed. The control cultures of buckwheat developed poorly. — H. C. COWLES.

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[5] ATKINSON, G. F., Studies of American fungi. Imp. 8vo. pp. vii + 323. *figs. 230.* New York: Henry Holt & Co. 1903. $3.

[6] ENGLER, A., Monographieen afrikanischer Pflanzen-Familien und -Gattungen. VII. Strophanthus, bearbeitet von E. Gilg. 4to. pp. 48. *pls. 10.* Leipzig: Wilhelm Engelmann. 1903. *M* 16.

[7] DIXON, H. H., Observations on the temperature of the subterranean organs of plants. Trans. Roy. Irish Acad. **32B**: 145–170. *pls. 5–8.* 1903.

[8] BOUILHAC and GIUSTINIANI, Sur une culture de Sarrasin en présence d'un mélange d'algues et de bactéries. Compt. Rend. **137**: 1274–1276. 1903.

MISS EDITH CHICK[9] has had an opportunity to examine a few seedlings of the Californian species of Torreya, a genus of the Taxaceae of special interest to the morphologist and of peculiar inaccessibility. The meager results confirm the preconceived opinions as to the primitive character of the genus. In the cotyledons there is such a primitive character as the presence of centripetal wood, while the lobing and adhesion of the cotyledons is a feature shared with such genera as Ginkgo and Zamia.— J. M. C.

IN A BULLETIN of the North Carolina Agricultural Experiment Station, Stevens and Sackett[10] describe a new wilt disease of the tobacco which has caused much damage in Granville county. Happily it is yet rather local, but it seems to be spreading. It appears to be due to bacteria which plug the tracheids and blacken the xylem, infection seeming to come through the roots. The disease becomes more and more intense with each crop and will necessitate the abandonment of affected fields unless means of prevention can be found or an immune race can be bred.— C. R. B.

ARBER[11] has presented to the Geological Society of London a paper describing the flora of the Cumberland coal-field. He enumerates twenty species from the Sandstone series and twenty-two from the productive measures. The lower beds of the Sandstone series are held to belong to the middle coal measures and the upper to the Transition coal measures. The productive measures are considered as of middle coal-measures age, the paleobotanical evidence for this conclusion being substantiated by the molluscan remains in the overlying strata. The paper, while describing no new species, is an admirable contribution to local stratigraphy. It is illustrated by two plates of the more interesting species and concludes with a brief bibliography.—E. W. BERRY.

ZELENY[12] has investigated the changes which take place in the position and size of leaflets of palmately compound leaves when one lateral leaflet is removed as early as possible. The remaining leaflets tend to form a new symmetrical system having one less member. This is attained chiefly by the movement of those leaflets which are left in an asymmetrical position with reference to the petiole. In *Lupinus albus* there was a frequent rotation of the leaf which placed the petiole in an interval different from that occupied by it when the operation was performed. Comparison of these leaves with the

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[9] CHICK, EDITH, The seedling of *Torreya myristica*. New Phytologist **2**: 83–91, *pls. 7–8.* 1903.

[10] STEVENS, F. L., and SACKETT, W. G., The Granville tobacco wilt; a preliminary bulletin. Bull. 188, N. C. Agr. Exp. Sta. 1903.

[11] ARBER, E. A. N., Fossil flora of the Cumberland coal-field and the paleobotanical evidence with regard to the age of the beds. Quart. Jour. Geol. Soc. Lond. **59**: 1–24. *pls. 1, 2.* 1903.

[12] ZELENY, CHARLES, The dimensional relations of the members of compound leaves. Bull. N. Y. Bot. Garden **3**: 134–174. *figs. 13.* 1903.

normal showed that presence of the petiole between any two leaflets serves to widen the normal interval by about 37°. The leaflets of the leaves operated on were in each instance shorter than those of the normal leaves.—G. H. SHULL.

REINKE DISCUSSES the available sources of nitrogen for algae, especially marine forms, and concludes that those which he and others have named heretofore, particularly the additions from the offal of cities, are entirely inadequate.[13] In Kiel harbor, nitrogen bacteria (*i. e.*, species capable of fixing free N dissolved from the air) have been found, notably *Clostridium Pasteurianum* and *Azotobacter Chroococcum*, both in the mud at the bottom and in the mucilage covering the fronds of Laminaria, etc. Indeed, the latter are like agar plate-cultures of such species. Reinke suggests, therefore, that this is a sort of symbiosis, inevitably recalling the association of Rhizobia with Leguminosae, in which the bacteria get carbohydrates from the algae and give them nitrogenous compounds produced by the fixation of free N.—C. R. B.

J. ERIKSSON[14] has pointed out that Professor Marshall Ward's attack upon his mycoplasm hypothesis does not distinguish between the two essential points involved. The first is the existence of an internal germ of disease; the second the form in which such an internal germ may be conceived of as existing. The former point Eriksson would regard as proved, the latter as purely hypothetical; and hence he sees no reason why rejection of the latter should involve repudiation of the former. He calls attention to the fact that Professor Ward's work was carried on with artificial infections, when the whole theory rests upon outbreaks of the disease which cannot be explained by external infection; the theory having to do with that may be called the first stage of the disease, and Professor Ward's experiments with the second stage.—J. M. C.

N. BERNARD has discovered some interesting peculiarities about the germination of orchids.[15] Seeds of Cattleya and Laelia germinate readily in about fifteen days, soon developing into minute green spherules. The plants rest here for some time and later slowly develop into a top-shaped body, which is always infested at the suspensor end by an endophytic fungus. In aseptic cultures the seedling does not go beyond the spherule stage, whence Bernard concludes that fungi are necessary even in the early stages of the orchid plant. By introducing the proper fungi, the ordinary slow growth may be much accelerated, and the resting period after the spherule stage may be much

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[13] REINKE, J., Zur Ernährung der Meeres-Organismen disponiblen Quellen an Stickstoff. Ber. Deutsch. Bot. Gesells. **21**: 371–380. 1903.

[14] ERIKSSON, J., The researches of Professor H. Marshall Ward on the brown rust on the bromes and the mycoplasm hypothesis. Arkiv för Botanik **1**: 139–146. 1903.

[15] BERNARD, N., La germination des Orchidées. Compt. Rend. **137**: 483–485. 1903.

abbreviated. The author concludes by stating that we have here an embryo which cannot develop without fungal symbiosis, just as an egg commonly has to be fertilized before it can develop.— H. C. COWLES.

A PAPER BY HELLER[16] on the influence of ethereal oils and the like upon plants comes from the Leipzig laboratory. Plants were subjected to the influence of such substances as the oils of Eucalyptus, Citrus, Salvia, Thymus, Origanum, Mentha, Pinus, etc., and of gum camphor, thymol, etc., as well as of petroleum ether, petroleum, benzine, benzene, xylene, anilin, phenol, etc. These substances are more poisonous in vapor form than as liquids or in aqueous solution. Plants which produce an oil are somewhat immune to its action. Volatile hydrocarbons act like ethereal oils. As would be expected, all these substances enter the cell by going into solution in the water of imbibition of the cell walls and then diffusing as solutes. But, as would not be expected, a dry membrane appears to be a poorer protection to the plant than a moist one. Resin and paraffin failed to gain an entrance into the cells.— B. E. LIVINGSTON.

DIXON has replied to criticisms of the cohesion theory of the ascent of water[17] by Steinbrinck and by Copeland. To Steinbrinck's contention that the permeability of lignified walls to air renders the Dixon-Joly theory untenable, he replies briefly that the gas is chiefly in solution, in which state, as had already been shown, it does not interfere with the transmission of tensions in water columns. Furthermore, even if the gas is free it only interrupts the function of the vessel in which it develops. Chief attention is given to Copeland,[18] whose methods and interpretations are criticized. Dixon holds that the manometers as arranged in Copeland's apparatus indicate only local differences of gas pressure and of water pressure, the latter produced by long continued absorption of water after the plaster has set. This peculiarity of plaster may be a source of error in Copeland's work; the other criticisms do not appear valid to one familiar with his experimentation.—C. R. B.

THE POLLEN TUBE structures of *Cupressus Goveniana*, as recently described by Juel,[19] are extremely interesting. Up to the division of the body cell, the sequence is as in other members of the Cupresseae, there being a stalk nucleus, a tube nucleus, and a body cell. The body cell, however, instead of giving rise to two sperm cells, gives rise to a cell complex consisting of a variable number of cells, sometimes four, oftener eight or ten,

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[16] HELLER, A. Ueber die Wirkung ätherischer Öle und einiger verwandter Körper auf die Pflanzen. Flora **93**: 1–31. 1903.

[17] DIXON, H. H., The cohesion theory of the ascent of sap. Sci. Proc. Roy. Dublin Soc. **10**^{1}: 48–61. 1903.

[18] COPELAND, E. B., The rise of the transpiration stream: A historical and critical discussion. BOT. GAZ. **34**: 161–193, 260–283. 1902.

[19] JUEL, H. O., Ueber den Pollenschlauch von Cupressus. Flora **93**: 56–62. *pl. 3.* 1904.

and in a few very vigorous tubes about twenty. All other living gymnosperms yet described have but two sperm cells. The pollen grains of Cordaites contain a cell complex which has been interpreted as an antheridium. The cell complex in Cupressus seems to be similar, although in Cordaites it is formed in the pollen grain, while in Cupressus is formed later in the pollen tube. *Callitris quadrivalvis* was also examined, but the pollen tube structures are practically the same as described by Belajeff for Juniperus and by Land for Thuja.—C. J. CHAMBERLAIN.

ZEILLER AND FLICHE[20] have discovered fossil remains of Sequoia in Portlandian beds near Boulogne-sur-Mer. This is a discovery of great importance, since Sequoia has not previously been reported from Jurassic strata. Even at this early date the generic characters were well marked, and some of the specific characters of *Sequoia gigantea* were present. Of no less importance is the finding of Pinus in the same beds, one of the Strobus type, and one more like *P. Laricio*. Pinus is thus surely established as a Jurassic genus, and largely differentiated as now. Although Jurassic pines have been reported at least three times in as many places, not till now has there been such undoubted evidence. Perhaps most remarkable of all is the fact that this oldest of known pines is in no sense generalized or archaic, but belongs to the most highly specialized group of pines as they exist today. Thus in the pines, as in so many plants and animals, are the first known forms as highly specialized as any which come later.—H. C. COWLES.

MATHEWS[21] has hit upon what seems to be a generalization of rather broad significance in his work upon the toxic action of ions upon eggs of Fundulus. Since this may well apply to plant protoplasm as well as to that of animals, it would be well for plant physiologists who are working with poisons to be familiar with it. The hypothesis is briefly this: The physiological action of both kations and anions is an inverse function of their solution tension, *i. e.*, their affinity for their electric charge. Thus "mercury, silver, and copper are poisonous because they part with their charges to the protoplasmic particles easily, thereby bringing about changes in the state of aggregation of the colloidal particles, and decomposition of the molecules." The physiological action of a salt is, therefore, an inverse function of the sum of the solution tension of its resulting ions. There seems also to be an inverse relationship between atomic volume and toxicity, and a direct relation between this and equivalent weight. Poisonous action of metals would thus appear to be a "periodic function of their atomic weights." While the evidence is fairly in unison, the hypothesis must needs be tested much further before it is fully established.—B. E. LIVINGSTON.

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[20] ZEILLER, R., and FLICHE, P., Découverte de strobiles de Sequoia et de Pin dans le Portlandien des environs de Boulogne-sur-Mer. Compt. Rend. **137**:1020–1022. 1903.

[21] MATHEWS, A. P., The relation between solution tension, atomic volume, and the physiological action of the elements. Am. Jour. Physiol. **10**:290–323. 1904.

ACCORDING TO Molliard and Coupin[22] the sterigmata and basidia of *Sterigmatocystis nigra*, when grown in a medium without potassium, have a remarkable tendency to grow out into mycelial filaments instead of producing conidia in the normal way. These filaments sometimes enlarge to form secondary conidial heads, which in turn may proliferate again. Finally some conidia are produced, but of smaller size and with thinner walls than normally occurs. Often these conidia appear on the ends of simple radiating branches without a central head, somewhat after the manner of Penicillium; or the swollen head may be produced with its basidia, which bear conidia directly without the intervention of sterigmata at all, somewhat as in Aspergillus. Conidia which germinate in absence of potassium are apt to produce chlamydospores very soon, sometimes immediately upon germination. The control cultures, wherein the fungus grows normally, differ from those which exhibit the above phenomena only in the presence of 0.6^{gm} of K_2CO_3 in 1500^{cc} of medium. Both control and experiment cultures contain 0.4^{gm} of $MgCO_3$, so it is hardly possible that the response is due to the anion CO_3. The difference in osmotic pressure between the two is so slight as to be negligible. The last two points are not considered by the authors.—B. E. LIVINGSTON.

IN A SERIES of digestion experiments upon the mannans and galactans of certain leguminous and other seeds and of the tubers of several orchids, Hérissey has demonstrated a new enzyme, or group of such bodies, which he terms seminase.[23] Seminase is a soluble ferment, best obtainable from alfalfa (lucerne), but it has been found in *Aspergillus niger* and to some extent in the tubers of certain Orchidaceae. It has the power to render soluble both mannans and galactans, producing mannose and galactose, respectively. Alfalfa seeds which have been germinated at a temperature of 27–30° C. for from 36 to 48 hours yield the maximum amount of the ferment. The body obtained from these seeds acts upon the carbohydrates of other seeds, upon those of orchid tubers, etc., but fails to have any effect upon those of palm seeds, although the latter yield mannose when hydrolyzed with weak mineral acid. Although the seeds of alfalfa, etc., even in the resting state, contain seminase, yet at no stage of their germination has the author found mannose or galactose present in quantity sufficient for identification. Cane sugar is generally present, however, and the author believes that mannose and galactose are only a transition state, and that these bodies pass as soon as formed into some other carbohydrate, perhaps cane sugar.—B. E. LIVINGSTON.

[22] MOLLIARD, M., and COUPIN, H., Influence du potassium sur la morphologie du *Sterigmatocystis nigra*. Rev. Gén. Bot. 15:401–405. *pl. 17*. 1903.

[23] HÉRISSEY, H., Recherches chimiques et physiologiques sur la digestion des mannanes et des galactanes, par seminase, chez les végétaux. Rev. Gén. Bot. 15:345–368, 406–417, 446–463. 1903.

DOUGLAS H. CAMPBELL[24] has published a second paper upon the Araceae, dealing chiefly with *Aglaonema commutatum* and *Spathicarpa sagittaefolia.* In the former species the embryo-sacs vary in number from one to three, and where two or three are formed they may be derived from a single archesporial cell or may possibly originate independently from hypodermal cells. The most interesting feature, however, is the variation in the number of nuclei in the embryo-sac, this ranging from four to twelve and with slight indication of polarity. Multiple nuclear-fusions are of common occurrence, and it is often impossible to be certain which of the structures represent the egg-apparatus and which the antipodal cells. The embryo of this species also conforms to what seems to be an aroid type, namely a large mass of cells with little differentiation of external parts and with tissues almost completely homogeneous.

In Spathicarpa the embryo-sac is of the ordinary angiospermous type, but after fertilization the antipodals become greatly enlarged and one of them may divide. The embryo remains small and the external organs are evident, but the tissues are only slightly developed.

In both species the development of endosperm proceeds gradually from the base of the embryo-sac until it is completely filled.—J. M. C.

DEANE B. SWINGLE[25] in his study of the formation of spores in Rhizopus and Phycomyces has summarized the essential features of the process as follows: (1) streaming of the cytoplasm, nuclei, and vacuoles up the sporangiophore and out toward the periphery, forming a dense layer next the sporangium wall and a less dense region in the interior, both containing nuclei; (2) formation of a layer of comparatively large, round vacuoles in the denser plasm parallel to its inner surface; (3) extension of these vacuoles by flattening so that they fuse to form a curved cleft in the denser plasm; and, in the case of Rhizopus, the cutting upward of a circular surface furrow from the base of the sporangium to meet the cleft formed by these vacuoles, thus cleaving out the columella; (4) division of the spore-plasm into spores; in Rhizopus, by furrows pushing progressively inward from the surface, and outward from the columella cleft, both systems branching, curving, and intersecting to form multinucleated bits of protoplasm, surrounded only by plasma-membranes and separated by spaces filled with cell sap only; in Phycomyces, by angles forming in certain vacuoles containing a stainable substance and continuing outward into the spore-plasm as furrows, aided by other furrows from the columella cleft, and dividing the protoplasm into bits homologous with and similar to those in Rhizopus, and separated by furrows

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[24] CAMPBELL, DOUGLAS H. Studies on the Araceae. The embryo-sac and embryo of Aglaonema and Spathicarpa. Ann. Botany **17**: 665–687. *pls. 30–32.* 1903.

[25] SWINGLE, DEANE B., Formation of the spores in the sporangia of *Rhizopus nigricans* and of *Phycomyces nitens.* pp. 40. *pls. 6.* Bulletin 37, Bureau of Plant Industry. 1903.

partly filled with the contents of the vacuoles that assist in the cleavage; (5) formation of walls about the spores and columella, and, in the case of Rhizopus, the secretion of an intersporal slime; (6) partial disintegration of the nuclei in the columella.—J. M. C.

WHAT SEEMS a careful study of the effect of certain external conditions upon the evolution of oxygen by some green water plants has been made by Pantanelli.[26] He finds that the curve of oxygen production with varying light intensity shows a distinct optimum (at about one-fourth the intensity of direct sunlight), beyond which it falls as light increases, unless the supply of CO_2 is varied at the same time, in which case the optimum would be displaced in the direction of weaker light with less CO_2, and toward the stronger light with more CO_2. The regulation of the activity of the chloroplasts is not instantaneous, five to ten minutes passing before a change in their activity can be ascertained. Ultra-optimal light stops protoplasmic streaming, and, if excessive, produces aggregation and diminishes the evolution of O_2. Furthermore, and independently of these changes, it produces in the chloroplasts phenomena of fatigue like those of an isolated muscle, which pass away gradually after the return of normal conditions, the slower the more complete the fatigue. By light intense enough to diminish the decomposition of CO_2 the chlorophyll pigment is attacked. After such injury it is never reformed. The evolution of O_2 increases with the increased content of CO_2 in the water to an optimum, and then decreases, unless the light varies correspondingly. The bubbles of gas given off, however, continue to increase beyond the CO_2-optimum, but contain more and more CO_2, which merely diffuses through the plant unchanged.

Pantanelli also finds that various solutes exercise a marked influence upon photosynthesis, for which details the original must be consulted. He holds the chief result of his work to be the demonstration that the plasmatic portion of the chloroplasts works, tires, and recuperates, the chlorophyll remaining primarily wholly indifferent; but if the plasmatic stroma becomes injured, the chlorophyll immediately suffers photochemical oxidation. Normally, however, its lability does not appear, because it is constantly protected by the plasma. Nothing, he thinks, indicates that in strong light chlorophyll is continually decomposed and regenerated—an assumption of those who look upon chlorophyll as a sensitizer.—C. R. B.

ITEMS OF TAXONOMIC INTEREST are as follows: G. F. ATKINSON (Ann. Mycol. 1: 479–502. *pl. 10.* 1903) has discussed the genus Harpochytrium in the United States.—F. v. HÖHNEL (*idem* 522–534) has described the following new genera of fungi: *Bresadolella* (Nectriaceae), *Myxolibertella* (Melanconieae), *Sporodiniopsis* (Hyphomycete), *Cirrhomyces* (Dematieae), *Aegeritopsis* (Tubercularieae).—R. PILGER (Engler's Pflanzenreich IV. 5. p. 117.

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[26] PANTANELLI, ENRICO, Abhängigheit der Sauerstoffausscheidung belichteter Pflanzen von äusseren Bedingungen. Jahrb. Wiss. Bot. **39**: 167–228. 1903.

1903) has described a new genus (*Acmopyle*) of Taxaceae. — C. S. SARGENT (Proc. Rochester Acad. Sci. **4**: 93–106. 1903), in a presentation of the genus Crataegus as displayed in and about Rochester, N. Y., has described 27 new species. — W. R. MAXON (Contrib. U. S. Nat. Herb. **8**: 271–276. *pls. 61–62.* 1903), in studying certain Mexican and Guatemalan species of Polypodium, has described 5 new species. — A. W. EVANS (Ottawa Nat. **17**: 13–24. *pls. 1–2.* 1903), in a paper on Yukon Hepaticae, embracing 38 numbers, has raised to generic rank Mesoptychia, one of Lindberg's sections of Jungermannia, and more recently a subgenus of Lophosia.—E. L. GREENE (Leaflets **1**: 1–32. 1903) has published, as segregates from Aster, *Oclemena* (*A. acuminatus* and *A. nemoralis*), *Lasallea* (*A. sericeus* as type), and *Unamia* (*A. ptarmicoides*); has recognized *Kyrstenia* Necker (Eupatorium § Ageratina) as entitled to generic rank, transferring the numerous species involved and describing 9 new ones; has described as a new genus *Uncasia* (to include *Eupatorium perfoliatum* and its numerous allies); in discussing certain genera of Polygonaceae, has recognized the generic rank of *Bistorta*, transferring the species and describing 6 new ones, and of *Duravia* and *Persicaria*, describing 11 new species under the latter. — J. R. JOHNSTON (Proc. Amer. Acad. **39**: 279–292. 1903). has published a revision of the genus Flaveria, recognizing 15 species, 4 of which are described as new. — N. L. BRITTON and J. N. ROSE (Bull. N. Y. Bot. Gard. **3**: (no. 9), 1–45. 1903), in publishing "new or noteworthy North American Crassulaceae," have described as new genera *Oliverella*, *Clementsia*, *Villadia*, *Urbinia*, *Gormania*, *Dudleya*, *Altamiranoa*, *Stylophyllum*, *Hasseanthus*, and *Sedella*, besides 101 new species. — R. S. WILLIAMS (*idem* 104–134), in reporting on a collection of Bolivian mosses, has described 3 new genera (*Chrysoblastella*, *Teretidens*, *Aligrimmia*) and 29 new species. — W. B. HEMSLEY (Jour. Linn. Soc. London **35**: 517. 1903) has published a new genus of Cyrtandraceae (*Rhabdothamnopsis*) from China. — C. S. SARGENT (Trees and Shrubs, part III) has published new species Crataegus (6), Euonymus, Viburnum, Pinus (W. Indies), and a new Mexican genus (*Gryphocarpa*) of Compositae by Greenman. — A. A. HELLER (Muhlenbergia **1**: 31–46. 1904) has described new species of Scutellaria (2), Agastache, Stachys, Monardella (5), Veratrum, Holodiscus, Boisduvalia, Gilia, Pentstemon, and Orthocarpus. — P. HENNINGS (Hedwigia **42**: 307. 1903) has described a new genus (*Biatorellina*) of Patellariaceae, and one (*Squamotubera*) of Xylariaceae. — Three new species of Opuntia left in manuscript by the late DR. WEBER have just been published (Gard. Chronicle III. **35**: 34. 1904). — W. SUKSDORF (West Am. Scientist **14**: 31–33. 1903) has published three new species of Nemophila. — J. M. C.

A. A. LAWSON[27] has obtained some most interesting results from a study of *Sequoia sempervirens*, whose essential morphology has long been a desideratum.

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[27] LAWSON, A. A., The gametophyte, archegonia, fertilization, and embryo of *Sequoia sempervirens*. Ann. Botany **18**: 1–28. *pls. 1–4.* 1904.

The reduction division preceding the formation of pollen mother-cells occurs during the first week in December. Pollination occurs during the first week of January, each microspore containing tube and generative nuclei, with no trace of prothallial cells. The microspores remain in the micropyle three or four weeks before further germination, when tubes are put forth and pass in various directions, some between the integument and nucellus, others directly into the nucellus. No branching of tubes was found, as reported by Shaw. At this time the division of the generative nucleus into stalk and body nuclei was observed, the latter becoming surrounded by a dense mass of cytoplasm invested by a membrane. The maturity of the body cell was obtained at various times between early in May to the middle of June. The spindle organized for the formation of the male cells was found, but no trace of an organ suggesting a blepharoplast could be observed.

Five or six megaspore mother-cells become differentiated rather deep in the nucellus, and each one divides twice (about March 1), but develops only two megaspores. The ten or twelve megaspores begin to germinate, but only two or three get beyond the first division and continue to elongate toward the chalaza, and one of these soon becomes dominant. Free nuclear division occurs in the two extremities of the embryo sac, and at the last division neighboring nuclei become connected by radiating fibrils, and cell plates are formed. The development of the endosperm takes about three months, archegonium initials appearing during the first week in June.

Numerous archegonium initials become differentiated deep in the micropylar region of the prothallium, the neck cells being forced toward the periphery of the endosperm by the elongation of the central cells. Two neck cells were observed, confirming Arnoldi, though occasionally four were formed. The nucleus representing the ventral canal cell was also observed, which, in the absence of a cell plate and on account of its ephemeral existence, may well have escaped the earlier observers. A remarkable feature in connection with the archegonia is that their necks are directed toward the nearest lying pollen tubes, which have taken up various positions before the archegonia are formed.

Fertilization is unique in the fact that only the male nucleus, with a very small amount of cytoplasm, leaves the tube and enters the archegonium, the denucleated male cell retaining its form in the pollen tube. In fusion the two chromatin masses form a common network, and the male and female constituents become indistinguishable. As a rule, the two male cells fertilize two neighboring archegonia. The development of the embryo is also a decided departure from the ordinary early stages observed in conifers, in that there is no free nuclear division. The first division of the egg nucleus results in two walled cells, so large that they almost fill the egg. Subsequent divisions result in a row of five large cells, the lowest of which gives rise to the embryo, and the next above to the suspensor. In the first spindle of the embryo the chromosomes were estimated to be thirty-two in number, and in the endosperm enough was observed to indicate that the number was approximately sixteen.—J. M. C.

ORIGIN OF THE OVULE.—Paleobotanical evidence for the origin of the ovule is accumulating with remarkable rapidity. In discussing the ovules of the older gymnosperms, F. W. Oliver[28] has described some most significant structures. The two ordinary types of unassigned paleozoic seeds are called for convenience Radiospermae and Platyspermae, the former including radially symmetrical seeds, the latter flattened ones. The simplest form is known as Stephanospermum (a radiosperm), in which the nucellus stands up freely within the integument: the apex of the nucellus is occupied by an extensive pollen-chamber; and "the chalazal strand of tracheids expands at the base of the nucellus into a tracheal plate, the margins of which are continued in the wall of the nucellus right up to the pollen chamber, the floor of which is paved with tracheids." The pollen grains are multicellular, and apparently liberated free-swimming sperms. The tracheal mantle of the nucellus is thought to be a mechanism for bringing water to the pollen-chamber, to be of use to the swimming sperms. This promiscuous liberation of swimming sperms is thought to be reminiscent of a heterosporous pteridophyte.

Among the platysperms (Cardiocarpus as type) there is the same tracheal plate at the base of the nucellus, from which tracheal strands extend into the walls of the nucellus at least as far as the separation of integument and nucellus. In this case the tracheal mantle, so far as known, is not so complete as in Stephanospermum. Moreover, the pollen grains are multicellular, but the cell-group by no means fills the entire grain. It is evident that the platysperms approach the cycads much more nearly in these particulars than do the radiosperms.

One of the most striking seeds, however, is that of Lagenostoma, from the lower Coal Measures. The integument and nucellus are free from one another only in the region of the pollen chamber, from the floor of which a conical mass of nucellar tissue rises, plugging up the micropyle (a structure, by the way, resembling that described by Hirase in Ginkgo), leaving the cavity of the pollen chamber a circular crevice. Surrounding the pollen chamber is the very complicated integument, consisting of an outer zone of heavy tissue, and an inner zone of large chambers separated by strong radiating plates. The internal angle of each chamber is convex, the inner wall of the integument thus forming a fluted membrane known as the "canopy." It seems that each of the large, vertical chambers of the integument was occupied by soft parenchyma, through which there ran longitudinally a single tracheal strand. In this case, also, the pollen grains were filled with tissue, indicating free-swimming sperms, and the more or less complete tracheal mantle would

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[28] OLIVER, F. W., The ovules of the older gymnosperms. Ann. Botany **17**: 451–476. *pl. 24.* 1903.

represent the essentials of a contrivance for supplying the pollen chamber with water. The unique thing in Lagenostoma, however, is the peculiarly chambered integument.

Professor Oliver also calls attention to the general resemblance of modern cycads in the features described for radiosperms and platysperms, the main difference being found in the fact that only at the apex are nucellus and integument free from one another. Moreover, he describes the distribution of the vascular system in the cycadean ovule as probably derived from the vascular mantle found in the paleozoic seeds. He accounts for these differences, and also for the fact that among the cycads the integument and nucellus are distinct only at apex, while among the paleozoic seeds they are distinct to the base of the ovule or nearly so, by assuming that between the original ovule and its insertion a new region has been intercalated, resulting in a retreat of the nucellar bundles from the pollen chamber.

The remarkable case of Torreya is also introduced, whose anatomy suggests that it is the most archaic of living conifers, fuller details of which we are promised in a forthcoming memoir. Strong tracheal branches extend upwards from the tracheal plate at the base of the nucellus, and ultimately send branches into the nucellus which connect with a peculiar mucilage layer that may be a modification of the palaezoic tracheal mantle. It will be remembered that the other conifers have lost their nucellar vascular systems.

About the time the preceding paper was going through the press, Mr. Oliver and D. H. Scott[29] made preliminary announcement that the peculiar seeds of Lagenostoma, described above, belong to the genus Lyginodendron, one of the Cycadofilices of Potonié. The evidence for the intermediate position of this group has been drawn entirely from anatomical vegetative characters, and the discovery of fructifications was looked forward to with peculiar interest. An undescribed species of Lagenostoma showed young seeds inclosed in a husk or cupule, whose peculiar glands and whose internal anatomical structure were only duplicated in the vegetative organs of Lyginodendron. This genus, therefore, in its vegetative structure retains the intermediate position already assigned to it, but had fully attained the seed-habit.

On January 21, 1904, the same authors[30] presented their full paper to the Royal Society, and in connection with a discussion of the systematic position of Lyginodendron proposed the establishment of a distinct class, under the name *Pteridospermae,* to "embrace those paleozoic plants with the habit and much of the internal organization of ferns, which were reproduced by means of seeds." The opinion was ventured that not only Lyginodendrae but

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[29] OLIVER, F. W., and SCOTT, D. H., On *Lagenostoma Lomaxi,* the seed of Lyginodendron. Ann. Botany 17: 625–629. 1903.

[30] OLIVER, F. W., and SCOTT, D. H., On the structure of the paleozoic seed *Lagenostoma Lomaxi,* with a statement of the evidence upon which it is referred to Lyginodendron. Abstract preprint.

also Medullosae would be removed from Cycadofilices and included among Pteridospermae.

And now, in a note issued January 27, Professor Oliver[31] announces the discovery of three specimens of fragments of fronds of *Neuropteris heterophylla*, each bearing a large seed. As this Neuropteris is without doubt the foliage of a Medullosa, the two families Lyginodendrae and Medullosae, as prophesied, at present represent the known forms of Pteridospermae. While the new group is distinctly intermediate between Filicales and Gymnospermae, the undoubted seeds would include it among gymnosperms as at present constituted, although the form of the name would indicate the intention of proposing it as a third group of seed-plants.

Associated with the above results is a recent contribution by Miss Margaret Benson[32], who supports the theory of the soral origin of the ovule, and proposes an entirely new theory of the phylogeny of the inner integument. She finds that certain digitate clusters found among paleozoic plant remains are synangia that have dehisced septicidally and then opened along the ventral sutures for the liberation of spores. Telangium is a form-genus proposed to include such forms as were studied, and proofs are advanced to show that it is the microsporangial sorus of Lyginodendron. If this be true, the information concerning Lyginodendron has developed rapidly, and its intermediate character would be still further emphasized by the possession of a distinct ovule (Lagenostoma) and a microsporangial synangium (Telangium). In our own observation this is exactly paralleled by the case of Cycadoidea in which ovules are associated with synangia.[33] The most far-reaching suggestions of the paper, however, have to do with the origin of the ovule and the nature of the inner integument. The conclusion that the microsporangium of Lyginodendron is a synangium suggested that the megasporangium (Lagenostoma) of the same form might be derived from a synangium whose sterile sporangia are still represented by the anomalous cavities of the integument surrounding the functional sporangium, as described above. This interpretation of the "canopy" of Lagenostoma is supported by a number of arguments, including such analogies as may be obtained from the megasporangial sorus of Azolla, and the sterilized sporangia in the tufted sori of Botryopteris. This means that the ovule is a synangium in which the peripheral sporangia are sterilized and specialized as an inner integument! — J. M. C.

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[31] OLIVER, F. W., A new pteridosperm. New Phytologist 4: 32. 1904.

[32] BENSON, MARGARET, *Telangium Scotti*, a new species of Telangium (Calymmatotheca) showing structure. Ann. Botany 18: 161–177. *pl. 11*. 1904.

[33] See COULTER and CHAMBERLAIN, Morphology of Spermatophytes. Part I. Gymnosperms. pp. 145–148.

NEWS.

A STATE forestry association has been formed in Vermont.

THE DEATH of Professor Wilhelm Behrens, of Göttingen, has just been announced.

PROFESSOR GASTON BONNIER has been elected president of the Botanical Society of France.

W. ARNOLD has been appointed professor in the University of Charkow and director of the botanic garden.

PROFESSOR H. DE VRIES and R. von Wettstein have been elected honorary members of the Berlin Botanical Society.

SCIENCE announces the death of M. Jean Dufour, professor of plant physiology at Lausanne, at the age of forty-three years.

THE UNIVERSITY OF MICHIGAN has received from Mr. J. B. Whittier, of Saginaw, $4,000 for the endowment of a fellowship in botany, named in honor of his mother.

DR. WILLIAM C. STURGIS, formerly mycologist of the Connecticut Agricultural Experiment Station, has been appointed lecturer in botany at Colorado College, Colorado Springs.

THE VERMONT BOTANICAL CLUB held its ninth annual winter meeting on Thursday and Friday, January 21 and 22, at the Williams Science Building of the University of Vermont.

PROFESSOR FRANCIS RAMALEY, of the University of Colorado, reached Tokyo, Japan, about the middle of January. He will visit Java, Penang, and Peradeniya, and will return *via* Europe.

DR. HARRY N. WHITFORD left the University of Chicago February 20 for the Philippine Islands, under appointment for two years as botanical collector in the government laboratory at Manila.

MR. R. H. YAPP, of Cambridge, England, known for his studies of myrmecophilous ferns, has been appointed professor of botany in the University College of Aberystwyth in succession to Professor J. H. Salter.

DR. H. C. COWLES, of the University of Chicago, has been sent by the department of botany to investigate the everglade region of Florida, using the U. S. Subtropical Laboratory at Miami as a base of operations.

DR. BRADLEY M. DAVIS, of the University of Chicago, sailed for Europe about January 1, to be absent from the university nine months. During the spring he will occupy a Carnegie table at the Zoological Station, Naples.

DR. CHARLES J. CHAMBERLAIN, of the University of Chicago, will visit Mexico in March under a grant from the Botanical Society of America to procure living and morphological material of certain endemic Mexican cycads.

PROFESSOR FRANCIS E. LLOYD, of Teachers College, New York city, has received a grant from the Botanical Society of America to study certain problems regarding the transpiration of xerophytes at the Desert Botanical Laboratory at the Carnegie Institution.

DR. E. W. OLIVE, who has been working on nuclear division in Cyanophyceae during the last year under a Carnegie grant at Bonn, is to continue his work under a new grant at the University of Wisconsin in the laboratory of Professor R. A. Harper.

THE STATION for Experimental Evolution, established by the Carnegie Institution at Cold Spring Harbor under the directorship of Professor C. B. Davenport, has secured the services of Mr. George H. Shull, of the University of Chicago, to conduct the work in plant-breeding and the study of mutations in nature.

THE FORESTRY department of the University of Michigan has been provided with an eighty-acre tract just outside Ann Arbor which is to be used for an arboretum of forest trees suitable for the state, model plantations of forest trees, and for demonstration and experiment plats. The land is the gift of Mr. Arthur Hill, of Saginaw.

THE RECENT DEATH of M. Émile Bescherelle interrupted the preparation of a useful work, a *Sylloge* of all the species of mosses described by him. M. Jules Cardot, to whom its completion was entrusted, writes that it will contain 450 to 500 pages, and that it will need to be published by subscription. It will be possible to print the work at $3 a copy, provided at least fifty of the minimum of 140 subscribers necessary to begin the printing can be found in the United States. Professor John M. Holzinger, of Winona, Minn., will receive names of subscribers.

A SOCIETY of more than usual promise has been founded in Germany, on the initiative of Dr. Engler, the "Vereinigung der systematischen Botaniker und Pflanzengeographer." Their first report, containing an account of the Berlin meeting last autumn is at hand. The purpose of the new organization is largely the systematic and unified exploitation of German taxonomy and phytogeography. The social factor also is concerned in the large response to Dr. Engler's call. Among the schemes which the society hopes to further is the preservation of typical natural plant formations. The next meeting is to be at Stuttgart, August 4-7, 1904.

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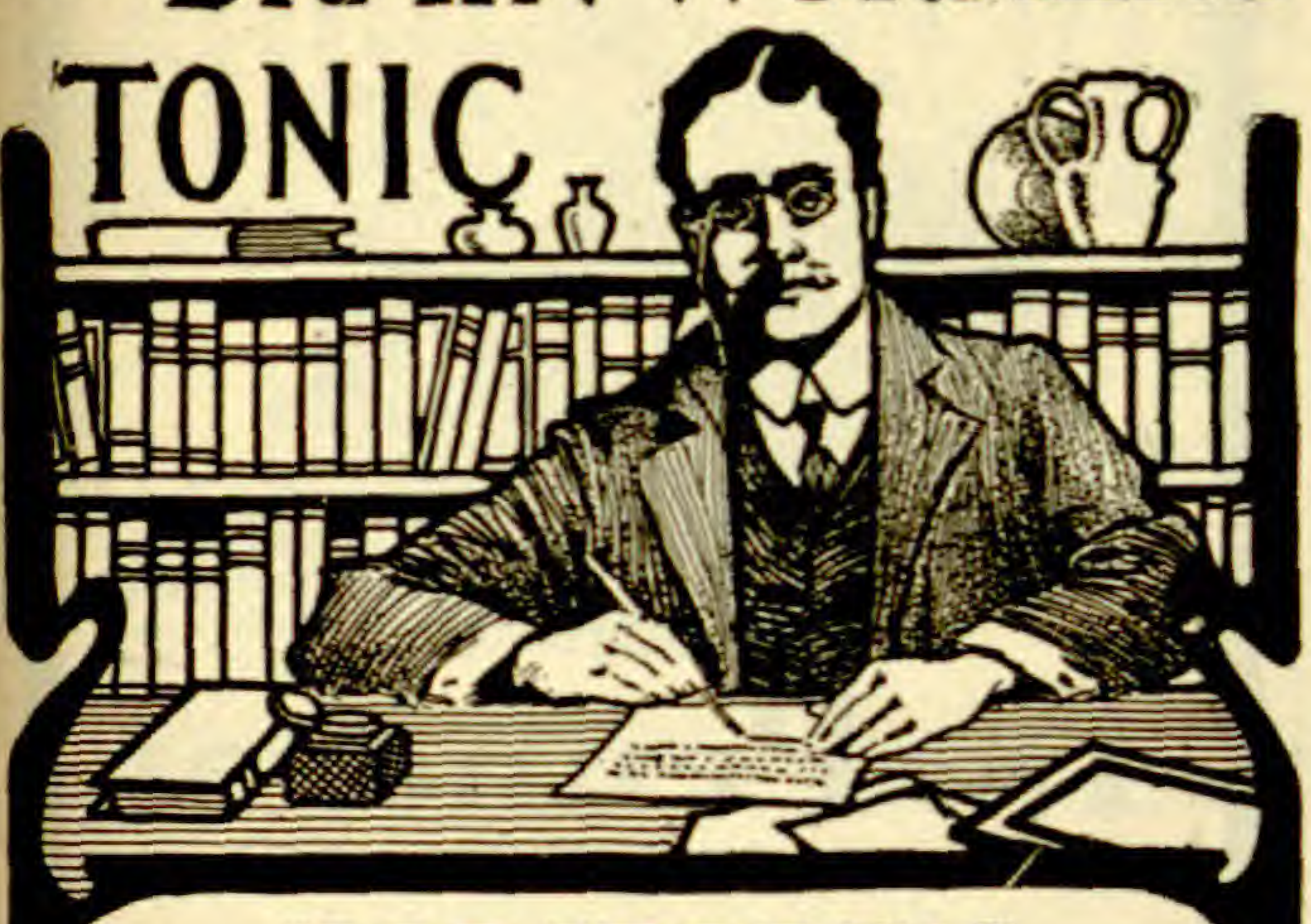

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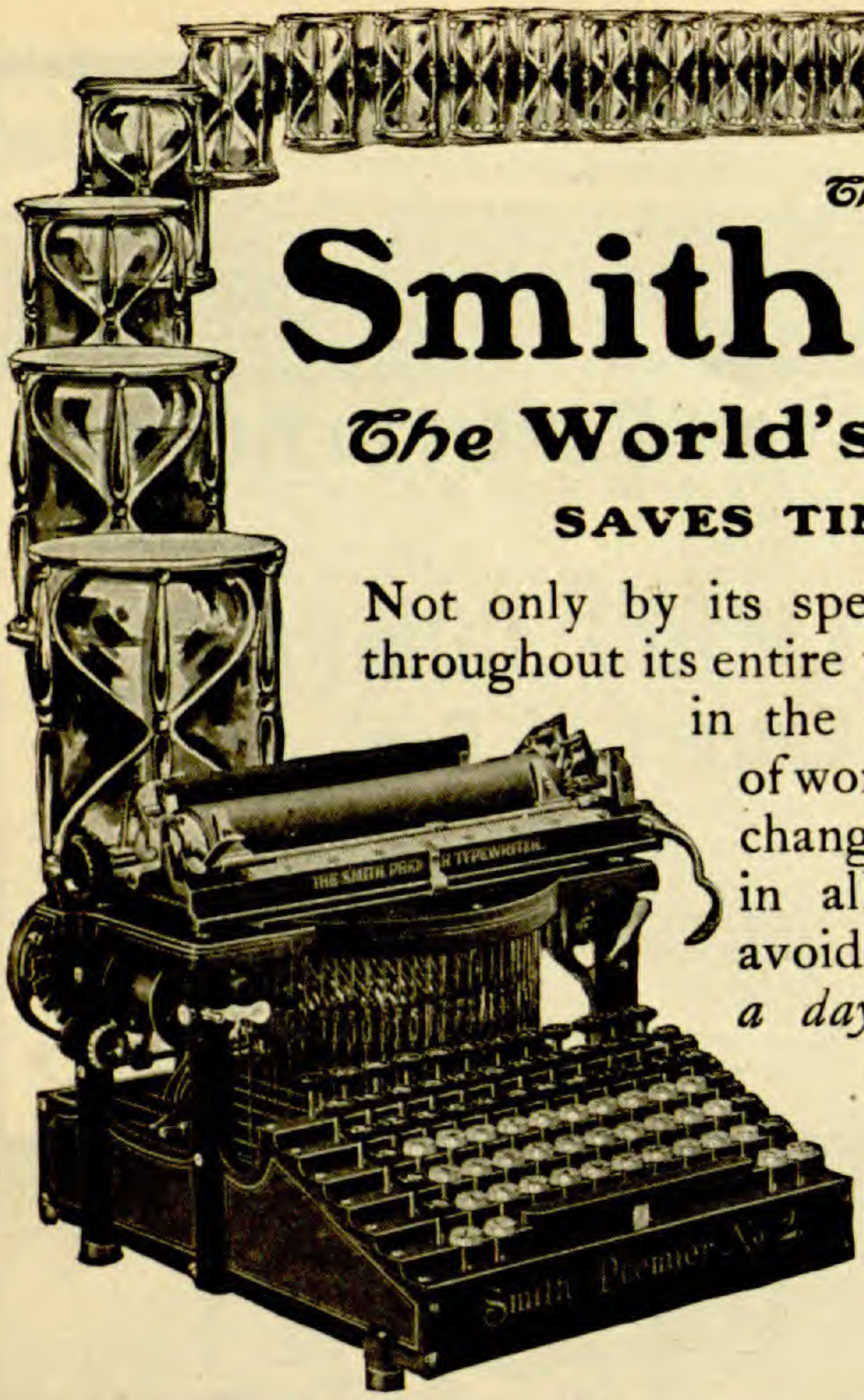
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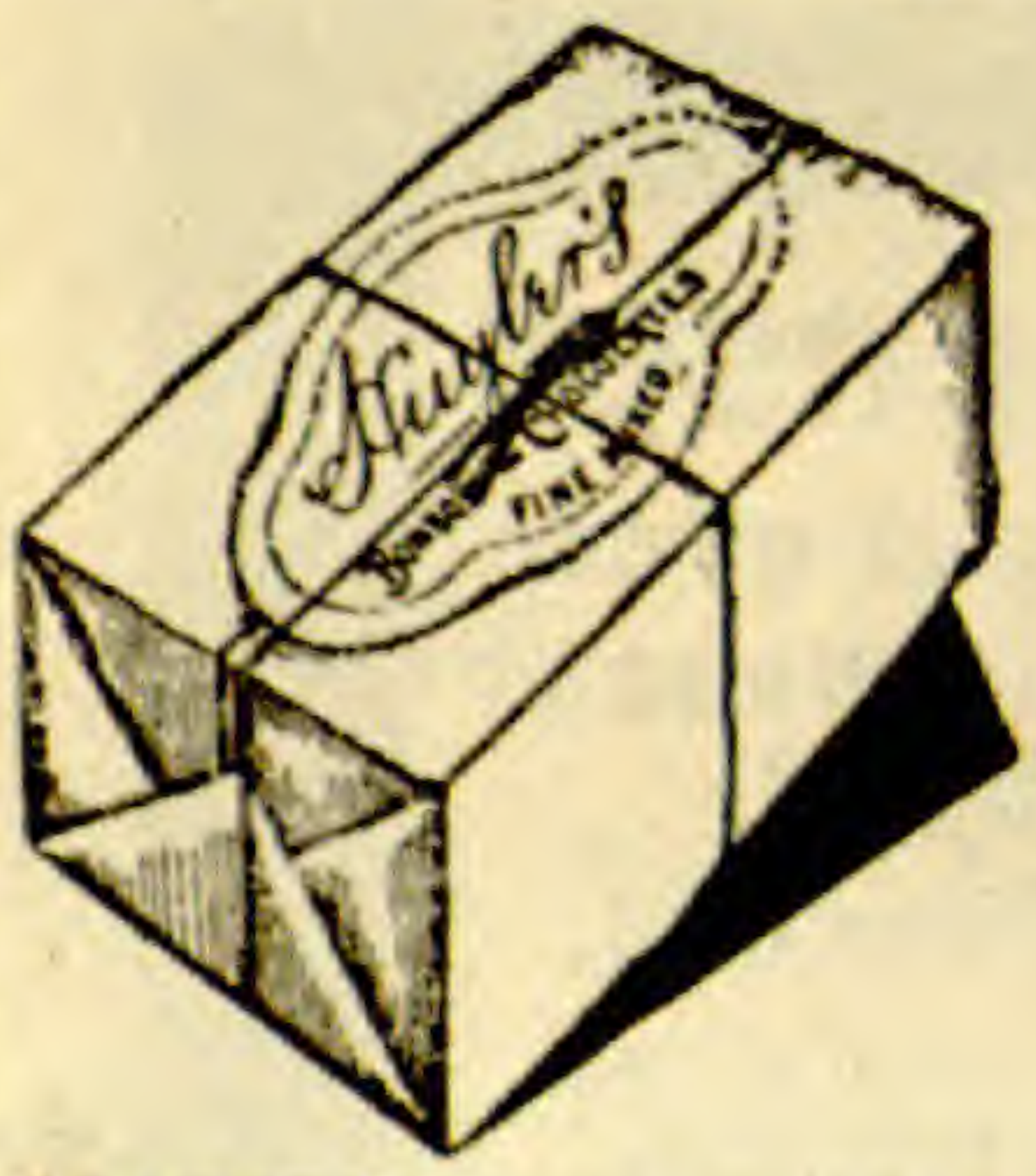
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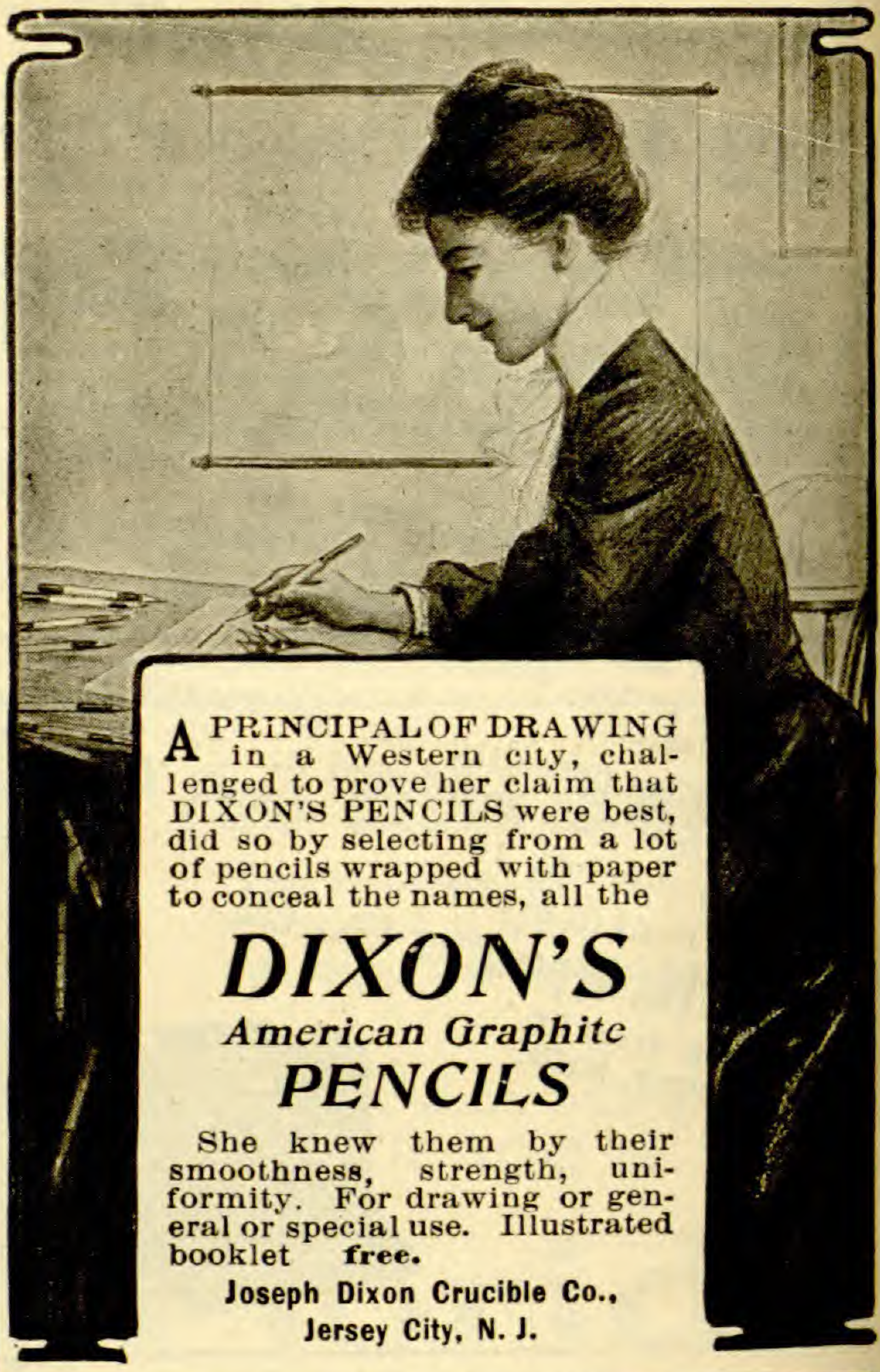

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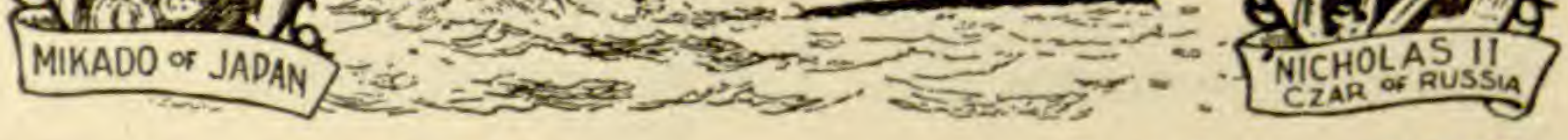

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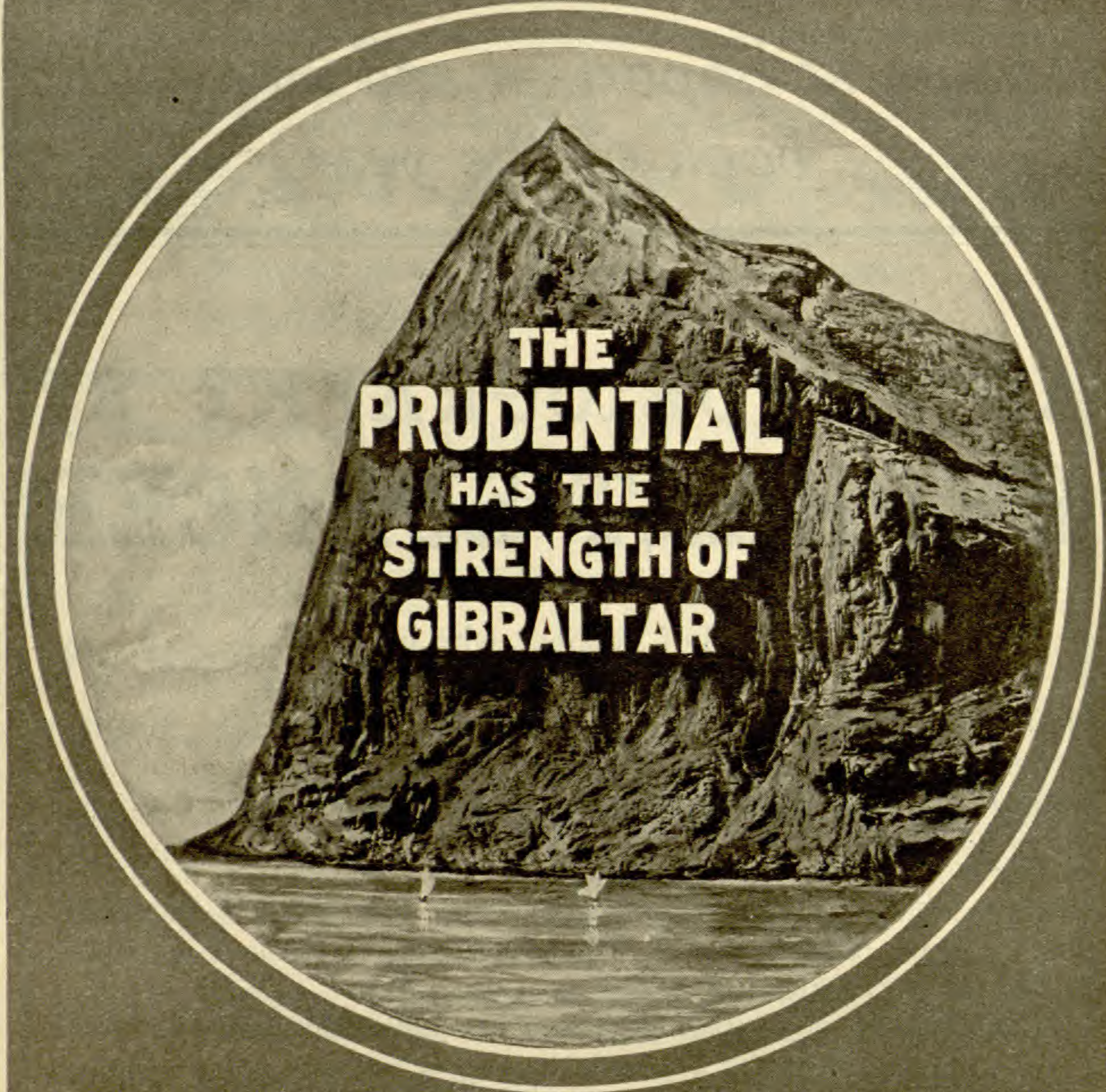
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VOLUME XXXVII NUMBER 4

BOTANICAL GAZETTE

APRIL, 1904

ARE ROOTS AEROTROPIC?[1]

MARY ELLA BENNETT.

(WITH FIVE FIGURES)

I. HISTORICAL REVIEW.

AFTER noting the peculiar curvings and contortions that roots of *Zea Mays* exhibited when growing in water, especially when their tips were just touching the surface of the water or were slightly immersed, Molisch[2] formulated the hypothesis that these roots were affected by a poverty of oxygen in their immediate vicinity, and through their curvings were brought into a richer supply of that gas. In pursuance of that thought, he sought to determine whether roots of other seedlings would not also show definite responses to the influence of various gases. In determining this point, Molisch employed only one form of apparatus, which is here described.

The chamber containing the gas to be used was a wide-necked bottle, closed with a plate of hard rubber in which were cut one or two slits 2^{cm} high by 1.5 to 2^{mm} wide. A strip of cork was fastened to the neck of the bottle in such a position that the seedlings, when pinned to it, were supported in front of and very close to the slits. The bottle was laid, with the slits in a vertical position, on a glazed dish, and was covered with a large bell jar lined with moist filter paper. Light was excluded.

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[1] LXVIII Contribution from the Botanical Laboratory of the University of Michigan.

[2] MOLISCH: Ueber die Ablenkung der Wurzeln von ihrer normalen Wachsthumsrichtung durch Gase (Aerotropismus). Sitzungsber. Akad. Wiss. Wien 90: 111. 1885.

The roots of *Pisum sativum* and *Zea Mays* were subjected to the application of various gases diffusing or streaming in mass from the slits, and the reactions of the roots were termed aerotropic. Only those responses to the application of oxygen, hydrogen, carbon dioxid, and nitrogen are considered in my paper, as the other gases used by Molisch were poisonous, and might produce chemotropic or traumatropic reactions.

The striking similarity in the results of Molisch's experiments —namely, that regardless of the species of seedling or the gas used, whether it were a stream of pure oxygen, of oxygen of a lower pressure than the normal, of nitrogen, or of carbon dioxid, the majority of the roots in every case made an initial curve toward the source of the gas and later turned away—looks suspicious. His own explanation of these phenomena is that the curves both toward and away from the gas chamber were due to the presence of an optimum pressure of the gas for longitudinal growth. If this were true, it would seem to make the response simply a mechanical one.

Several features of Molisch's work are subject to criticism. To thrust needles through the cotyledons, as he did, is objectionable for several reasons. To take seedlings directly from the sawdust and support them before the slits is objectionable, since injurious substances often occurring in sawdust effect curvatures in roots, which do not show until some time after the seedlings have been set up. The gases which streamed out of the slits were not moist, except in the experiments with CO_2 and possibly pure oxygen. This condition would tend to bring about hydrotropic curves. Too few seedlings were used to establish certain conclusions. The data of the experiments lack details as to growth of seedlings, degree of curvature, and other minor points. Lastly, the position of the root at the conclusion of the experiment is accepted for record, regardless of the numerous curves, positive and negative, which this root made during the continuance of the experiment. Since the paper by Molisch nothing on this subject has appeared.

The present investigation of the supposed aerotropism of roots was conducted in the Botanical Laboratory of the University of Michigan during the years 1900–1902, under the supervision of Professor Frederick C. Newcombe, to whose valuable suggestions and constant assistance is largely due whatever of merit this paper may possess. It is with pleasure that I here acknowledge my indebtedness to him.

II. EXPERIMENTAL INVESTIGATION.

It has been my purpose to determine the following points as definitely as possible: whether roots are aerotropic under natural conditions; and whether they are aerotropic under any conditions. Observations have been made of the effect of oxygen, hydrogen, carbon dioxid, and, as a test, illuminating gas, these being allowed to flow against one side of roots in gaseous form or dissolved in gelatin blocks. This is the same as the effect of a less and a greater pressure of oxygen than the normal atmospheric pressure.

1. *With roots in water.*

In the series of experiments under this head, the seedlings were grown in filtered tap-water and placed parallel to one chamber, or between two chambers of gas, which usually had a parchment membrane closure.

At the outset several methods of experimentation were employed to determine whether roots of *Zea Mays* grow straight in water if supplied with a larger proportion of oxygen than usual. In one series, seedlings having roots from 10 to 15^{cm} in length were secured to the sides of inverted air chambers, without membranes, immersed in the water, the kernels of corn being above water, and the root tips just below the lower edge of the chamber. The root tips were thus from 5 to 10^{mm} from the air in the immersed chamber, but 9^{cm} or more from the air above the water in the larger chamber. Observations showed that of 20 seedlings used, 7 turned toward the air in the immersed chamber, 4 away, 3 in other directions, and 6 remained straight.

In another series, seedlings supported, as in all the following experiments when necessary, between two strips of moist blotting paper held firmly to small pine rods by rubber bands between the seedlings, were suspended over a chamber which was connected with a gasometer of oxygen, and had a finely perforated membrane closing the upper end through which the oxygen was allowed to bubble slowly up toward the roots. The root tips were kept not more than 5 mm from the membrane. Of 87 seedlings thus supported, only 14 grew even approximately straight.

In a third method, seedlings were supported in a Novy jar containing filtered water saturated with oxygen under an atmosphere of pure oxygen. After the water had been saturated, the cover was slightly lifted to avoid confining the stems in an atmosphere of pure oxygen. Every four hours the seedlings were transferred to another Novy jar of water saturated with the same gas. A control experiment was prepared with the same number of seedlings in ordinary filtered tap-water. There was no apparent difference in the behavior of the roots in two preparations. Of 25 seedlings used in the first preparation, 7 only were growing straight at the close of the thirteenth hour.

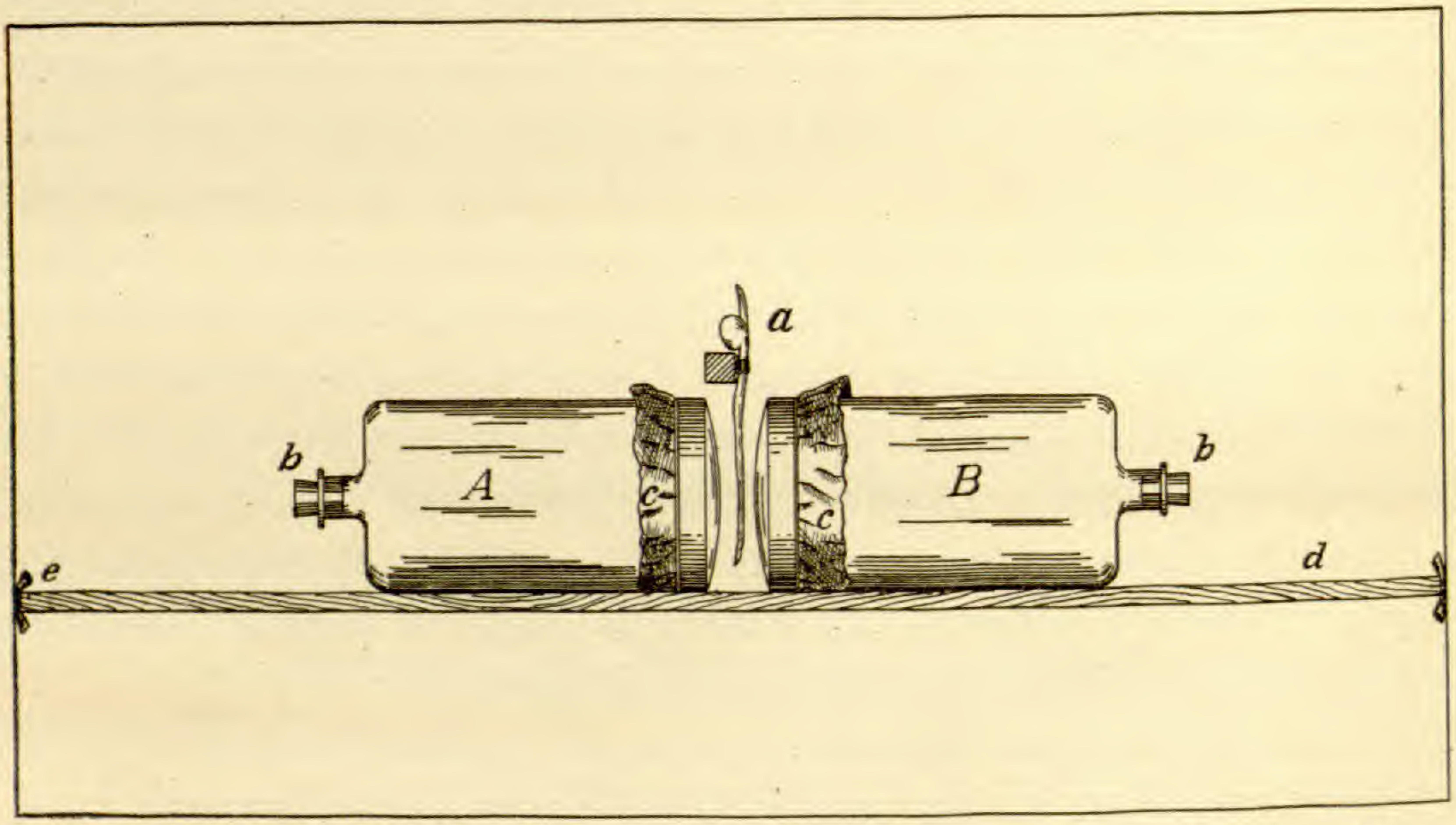

FIG. 1.—*A*, chamber containing air; *B*, chamber containing CO_2; *a*, seedling supported on wooden bar; *b*, rubber stopper; *c*, parchment membrane; *d*, strip of pine; *e*, small piece of rubber tubing.

Evidently, from these experiments no proofs have been found to justify Molisch's hypothesis that roots of *Zea Mays* in their curving in water are turning from a position in which the water is poor in oxygen to a position in which it is richer in that gas.

We must seek farther for the cause of the curving of these roots when growing in a water medium.

Other seedlings were grown in water, and placed parallel to membranes of immersed gas chambers, as shown in *fig. 1.* In the first series of experiments only one gas chamber was used, and this contained air. An explanation of the following table, in which are recorded the results, will suffice for most of the other tables found in this paper. The plus sign (+) indicates a curvature toward the supply of oxygen, and the minus sign (–) a curvature away. Only those roots which turned and continued thereafter growing toward the air chamber are counted as positive. The reverse of this rule is used in determining the negative curves. Under the zero sign (o) are classified all other curves and roots growing straight. It is noted that of 362 seedlings, including those of corn, radish, popcorn, and pumpkin, nearly as many turned away from the supply of oxygen, or the air chamber, as toward it, and more than half (206) were neutral. The angles of curvature were slight.

TABLE I.

(Plus sign indicates curve toward higher proportion of oxygen.)

Species	No. of individuals	Period: hours	Temperature of water	+	–	o	Angle
Zea Mays (field corn)	86	22–24	22–29°	24	12	50	10–45°
Raphanus sativus...	104	24–96	....	33	15	56	10–45°
Zea Mays (popcorn)	120	20–24	20–30°	18	36	66	5–90°
Cucurbita Pepo	52	20–24	16–29°	9	9	34	5–60°
Totals	362			84	72	206	

In the second series of experiments the pressure of carbon dioxid was increased above the normal on one side of the root by saturating the water frequently with that gas or by passing a slow stream of CO_2 continuously through the water, other conditions being the same as in the preceding experiment. It might be expected that the roots would turn from the CO_2 toward the supply of oxygen in the air chamber. The following table seems to indicate faintly such a response, where 39 radish seedlings were positive, as opposed to 24 that were negative or indefinite.

TABLE II.

(Plus sign indicates curve toward higher proportion of oxygen.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Saturation with carbon dioxid	+	—	o
Raphanus sativus	10	48–120	20°	3–4	Once	6	1	3
Raphanus sativus	19	72	20°	3–4	Several times	11	7	1
Raphanus sativus	34	14–20	20°	3–4	Continuous stream	22	5	7
Totals	63					39	13	11

These seemingly aerotropic curvatures are invalidated, however, by those of another experiment, tabulated below, in which 166 seedlings of *Cucurbita Pepo*, *Raphanus sativus*, and *Zea Mays*, placed parallel to gas chambers containing CO_2, and a mixture of CO_2 and air (as in *fig. 1*), gave only 37 curves away from the source of CO_2 as opposed to 129 that were either turned toward that gas or were neutral. That the majority of the curves in the two experiments were in opposite directions relative to the position of similar gases indicates that the curves were not aerotropic.

TABLE III.

(Plus sign indicates curve away from gas chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	In chambers		+	—	o	Angle
					% CO_2	% air				
Cucurbita Pepo ..	29	24–48	25°	2–7	100	..	4	2	23	5–45°
Raphanus sativus.	40	20–30	....	1–6	100	..	5	6	29	5–45°
Zea Mays........	44	9–22	24–31°	1–6	100	..	9	8	27	5–45°
Zea Mays........	45	18–23	21–25°	1–7	75	25	17	6	22	5–60°
Zea Mays........	8	5.5	25°	2–5	50	50	2	..	6	5–45°
Totals........	166						37	22	107	

In a series of experiments following these, similarly prepared, with the root tips not more than 2 to 5^{mm} from each membrane, the results could not be interpreted as showing aerotropism, since of 135 seedlings of lupine and radish, 46 turned toward the supply of oxygen, 39 away, and 50 were neither positive nor negative.

Finally, to increase the difference in the oxygen pressure on opposite sides of the roots as much as possible, the water in which the roots were supported opposite a chamber of air was prevented, by the device illustrated in *fig. 2*, from replenishing its supply of oxygen which was exhausted through respiration. A small aquarium was chosen which was hermetically sealed by weighting down a glass cover (*F*) on a cushion of rubber (*E*) cemented securely to the upper edges of the aquarium. The chamber (*B*) containing air was a rectanglar glass dish, 14^{cm} by 8^{cm} by 4^{cm}, supported, at angles between 20 and 45° to the horizontal, by pressing in small pieces of rubber tubing (*a*) between the ends of the dish and the sides of the aquarium. No membrane was used to inclose the gas. When the required seedlings (*C*), which had been growing in a vertical position in a damp chamber from 12 to 24 hours, were supported before the air chamber so that their tips extended 1 to 3^{mm} below the upper edge of the chamber and 1 to 5^{mm} away from it, the aquarium, already partly filled, was now completely filled with water, the cover pressed down, and the water above the roots replaced through tube *L* by gas

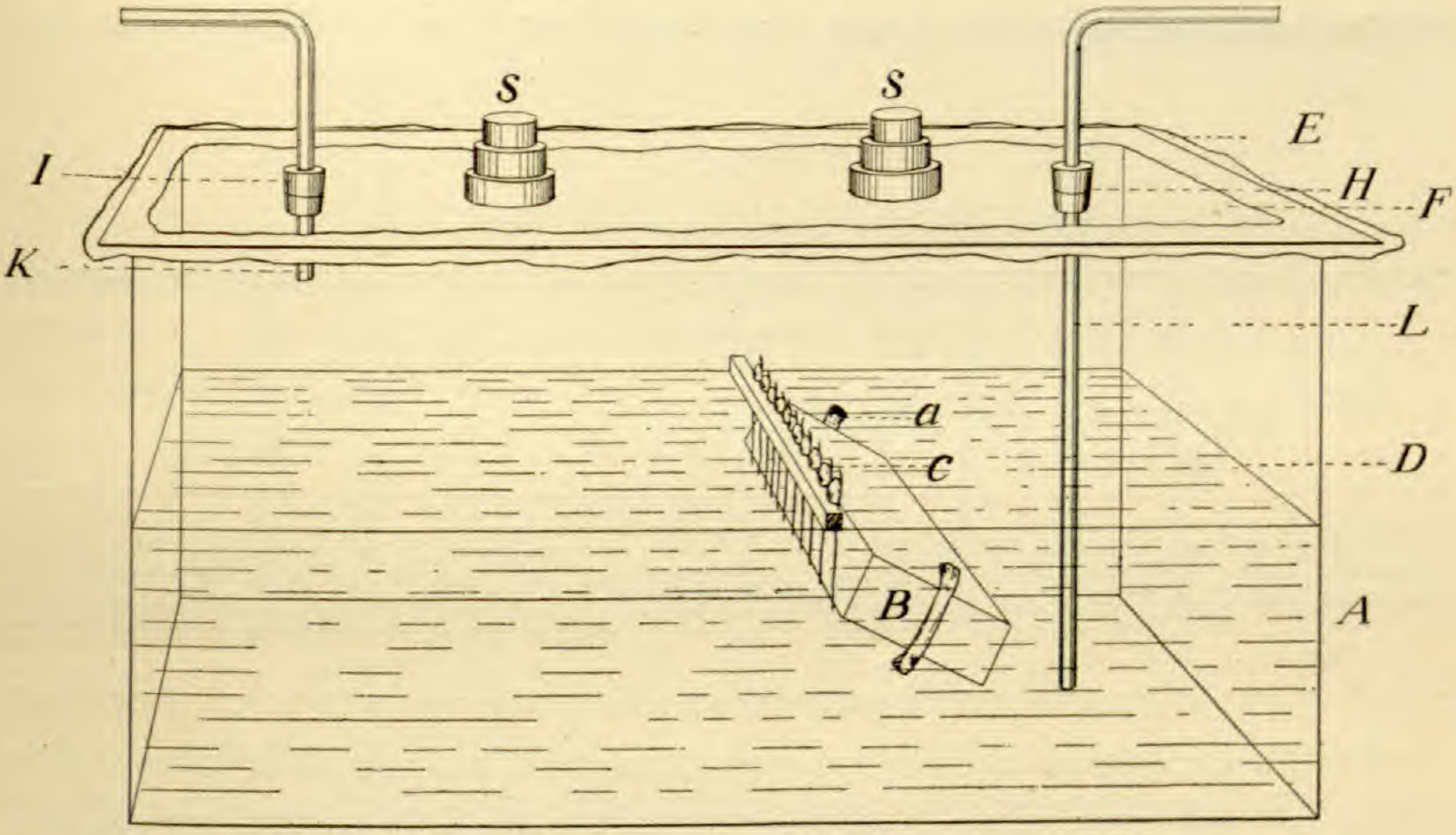

FIG. 2.—*A*, aquarium; *B*, chamber containing gas; *C*, seedlings; *D*, height of water; *E*, rubber cushion; *F*, glass cover; *H*, aperture in cover; *I*, rubber stopper; *K*, glass tube through which gas enters; *L*, glass tube for escape of water; *S*, weights; *a*, rubber tubing.

brought in through tube *K*. In such a contrivance the oxygen pressure in the water, which was reduced through respiration, would be continually renewed on the side facing the air chamber.

Table IV shows no aerotropic curves with the 54 seedlings of *Cucurbita Pepo*, 40 of which were neutral, while the remaining 14 were divided equally between positive and negative. The angles of curvature were not large and the growth was slight at first, due to insufficient pressure of oxygen. However, as more and more oxygen diffused from the chamber the roots grew more rapidly.

TABLE IV.

(Plus sign indicates curve toward air chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Gas above water		+	—	o	Angle	Growth
					% CO_2	% air					
Cucurbita Pepo.	16	10	27°	3-9	10	90	2	4	10	5-45°	Little first 6 hrs.
Cucurbita Pepo.	18	10	28	3-9	30	70	3	2	13	5-45°	Little first 6 hrs.
Cucurbita Pepo.	20	22	27	1-3	60	40	2	1	17	5-20°	Little first 4 hrs.
Totals......	54						7	7	40		

When the water above the gas chambers was replaced by mixtures of hydrogen and air in varying percentages, approximately the same results were obtained both in curvature and growth, as shown in Table V.

TABLE V.

(Plus sign indicates curve toward air chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Gas above water		+	—	o	Angle	Growth
					% H	% air					
Zea Mays (popcorn) ..	18	7	25°	3-9	10	90	..	2	16	5-30°	Good growth
Cucurbita Pepo	18	12	30	2-4	25	75	2	1	15	5-90°	Considerably retard'd
Cucurbita Pepo	18	10	25	2-4	33⅓	66⅔	..	4	14	5-20°	Slight during first 6 or 7 hrs.
Zea Mays (popcorn) ..	19	21	25	3-5	50	50	3	2	14	10-60°	Not apparently retarded
Zea Mays (popcorn) ..	16	22	..	...	75	25	4	2	10	......	Slight during first 5 hrs.
Totals......	89						9	11	69		

The duration of the experiments was necessarily short, since the roots could not be readjusted to the air chamber without altering the conditions. It is noticeable that of the 143 seedlings thus tested, 16 turned toward the air chamber, 18 away, and 109 were not responsive. The angles were generally very slight.

In the foregoing series of experiments, in which the roots were immersed in water with the oxygen pressure so reduced as to retard growth beyond the usual retardation in water, the presence of air within a few millimeters of the root tips induced no aerotropic curves.

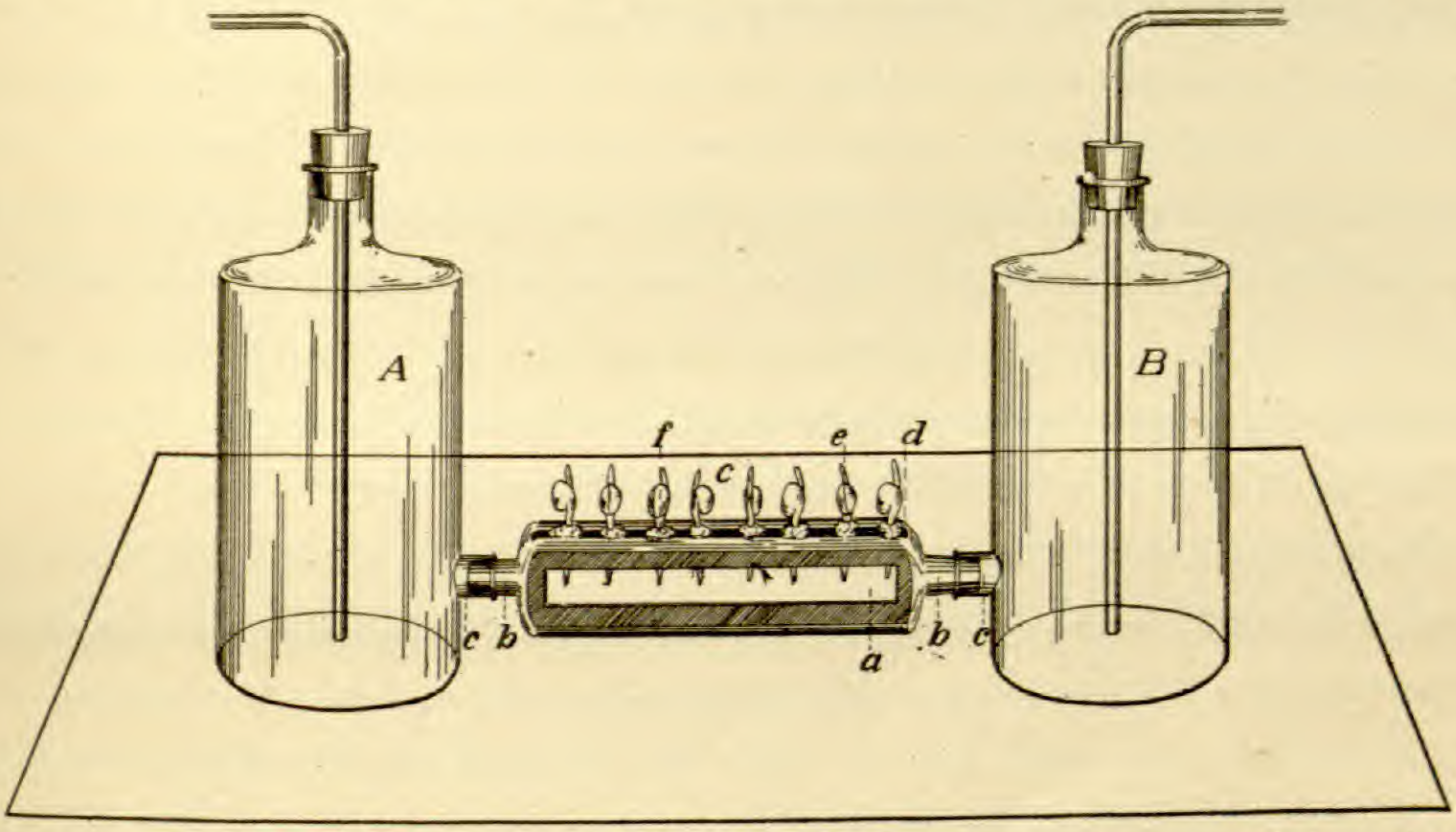

FIG. 3.—*A*, chamber filled with various gases; *B*, chamber containing air; *C*, chamber connecting *A* and *B*; *a*, glass side-wall of chamber *C*; *b*, cork sealed in end of chamber *C*; *c*, opening into bottle; *d*, position of groove; *e*, seedlings; *f*, cotton around seedlings.

2. *With roots in damp chambers.*

Because of the slow diffusion of gases in water, other results were anticipated on growing seedlings in damp chambers. To this end an apparatus (*fig. 3*) was constructed consisting of two eight-liter bottles (*A* and *B*) which were connected near their bases by a rectangular chamber (*C*) whose inner dimensions were 15^{cm} by 3^{cm} by 1^{cm}. This chamber was covered entirely with plaster of Paris, except along the sides, where the plaster was removed to expose the inner side walls of glass (*a*). A large cork (*b*) was sealed into each end of the chamber, through which openings were made of the same cross-section as the chamber. The distal end of each cork was fitted tightly into the opening of the bottles (*A* and *B*). On the upper side of the plaster case was hollowed out a groove (*d*), and perforations were made through the floor of this groove in such a way that the roots of the seedlings (*e*) projecting through these holes would be suspended in a chamber of gas when *A* and *B* were filled with gas. The groove made a good support for the cotyledons and for the cotton which was wrapped around them to keep them moist. The plaster was entirely covered with a thin layer of paraffin. In this way an air-tight passage was made from one bottle to another. To insure a moist condition of the gases which filled chambers *A* and *B*, several sheets of damp filter paper were placed in the bottles, and the cotton around the seedlings was moistened frequently. Besides this, the connecting chamber was soaked in water to infiltrate the plaster before inserting the seedlings.

In such a contrivance, judging from a preliminary experiment, it was thought that the gases diffused too rapidly through the chamber to be effective. However, by testing with a mixture of illuminating gas and air in one bottle and air in the other, and observing the contortions in the roots produced by the illuminating gas, it seemed evident that the gases must diffuse slowly enough to allow a considerable difference in the gases on the opposite sides of the roots.

Seedlings of *Zea Mays*, *Lupinus albus*, *Vicia sativa*, and *Pisum sativum* were now supported in the chamber, and bottle *A*, filled with 100 per cent. CO_2 or with mixtures of air and CO_2 in varying percentages, and bottle *B* filled with air. It was found that when a mixture of 20 per cent. CO_2 and 80 per cent. air on one side was opposed to air on the other, of 18 seedlings used only 1 was positive toward the air, the remaining being indefinite; while when 100 per cent. CO_2 was opposed to air, of 18 seedlings only 2 were positive and 16 indefinite. In the former case the roots grew 5 to 10^{mm} during the experiment, while in the latter case only 0.5 to 1.5^{mm}.

Although probably there was not a very great difference in the composition of the gases on the opposite sides of the roots, there was unquestionably some difference; and, notwithstanding this, it may be seen that the roots, although influenced in growth, did not make any definite curves with references to these gases, even when 100 per cent. CO_2 was used. In nature one can hardly conceive of conditions which would give a greater difference in the composition of gases on opposite sides of the roots.

3. With roots in earth.

In the lower half of a battery jar was fastened securely with sealing wax a glass plate in a vertical position so that gas could not pass the septum. Water was placed in the bottom to the depth of 2 or 3^{cm}, and pieces of broken plant crock were thrown in loosely. A glass tube was brought down to the bottom of each chamber, with its lower end curved upward under a piece of broken crock. The whole jar was now filled with moist earth. The seedlings were planted in a line directly above the upper edge of the glass partition. A different gas was led into each chamber, having passed on its way from the gasometer through liter bottles of water, that the rate of flow might be known and kept the same for each gas.

In this experiment the roots were in practically natural conditions, except for the gases used. If they were sensitive to the gases, and responded by curving toward one or the other, then aerotropism would be demonstrated.

At first, very short seedlings were used and the gases allowed to diffuse slowly through the earth; but later, longer roots were used and the gases passed in more rapidly. In every case CO_2 was passed into one side of the chamber and air into the other, the volume of each varying from 18 to 40 liters during the experiment of 24 hours' duration. Of the 165 seedlings of *Raphanus sativus*, 31 were positive toward the air, 34 negative, and 100 were neither positive nor negative, 98 of the last being straight. In the last two sets, when the 60 seedlings were planted twelve hours before the gases were led into the chambers, the majority of the roots were straight at the close of the experiment.

In a modified form of this experiment the seedlings were planted in a vertical layer of earth or sawdust 18^{cm} long by 12^{cm}

wide by 1^{cm} thick, inclosed in an iron wire gauze cage which was fitted in as a partition so closely between the sides of a glass jar that gases brought into the two chambers thus formed could pass over only through the earth or sawdust. This chamber was carefully covered; the seedlings were kept constantly moist; and the CO_2, or mixture of CO_2 and air, on one side, and air on the other, were forced in from a gasometer or water stream air-pump at the same rate and equally moist. By such a method there was certain to be an access to different gases on opposite sides of the roots.

Regardless of the percentages of CO_2 used, the results were not indicative of aerotropism; 14 roots bent toward the earth through which air was flowing, 14 away, and 28 grew in the vertical plane. *Pisum sativum*, *Lupinus albus*, and *Zea Mays* (popcorn) were used in this experiment.

From these two methods of experimentation it is seen that, while 221 representative seedlings were exposed to the one-sided application of a normal pressure of oxygen as opposed to some mixture of gases having a less pressure of oxygen or none at all, and while they were otherwise in almost natural conditions, still only 45 turned toward the source of oxygen, while 48 turned away, and 128 remained neutral. Certainly no one would contend that such results indicate that the roots are aerotropic, though they do show some disturbance in the direction of growth.

4. *With roots in gelatin.*

In the use of gelatin a medium was found that would permit of growth of the root, while preventing a rapid diffusion of gases. Solutions of 6 or 7 per cent. of gelatin in distilled water were thoroughly saturated, when cold but before solidifying, with air, hydrogen, or CO_2, either by forcing the gas through the solution, or with the solution in an air-tight chamber by exhausting and refilling the chamber with the gas which passed through the gelatin as it entered. These solutions were allowed to harden for twelve hours, standing in chambers of air, or hydrogen, or CO_2, as the case might be, in paper-lined, rectangular dishes, 20^{cm} by 12^{cm} by 4^{cm}, into which they had been poured when saturated, the gelatin containing the hydrogen, or CO_2, remaining in the air-tight chamber of that gas from which it had not been removed at any time during the operation.

Two of these blocks of hardened gelatin (*fig. 4*, *e* and *e*), removed from the rectangular molds and freed of all unnecessary paper, were transferred quickly to a damp chamber (*A*), lined with moist filter paper dipping into several centimeters of water (*D*) in the bottom of the jar. The gelatin blocks were placed on their narrow sides on a raised platform of glass (*C*) supported in the bottom of the jar, so that their broad sides were vertical and facing each other. Seedlings, supported in the usual manner on the bar of wood, were now quickly placed between the blocks of gelatin, the latter were pressed together and held firmly in the vertical position by means of glass plates (*a* and *a*) and wooden bars (*d* and *d*), at their backs, the latter pressing at both ends against the sides of the damp chamber.

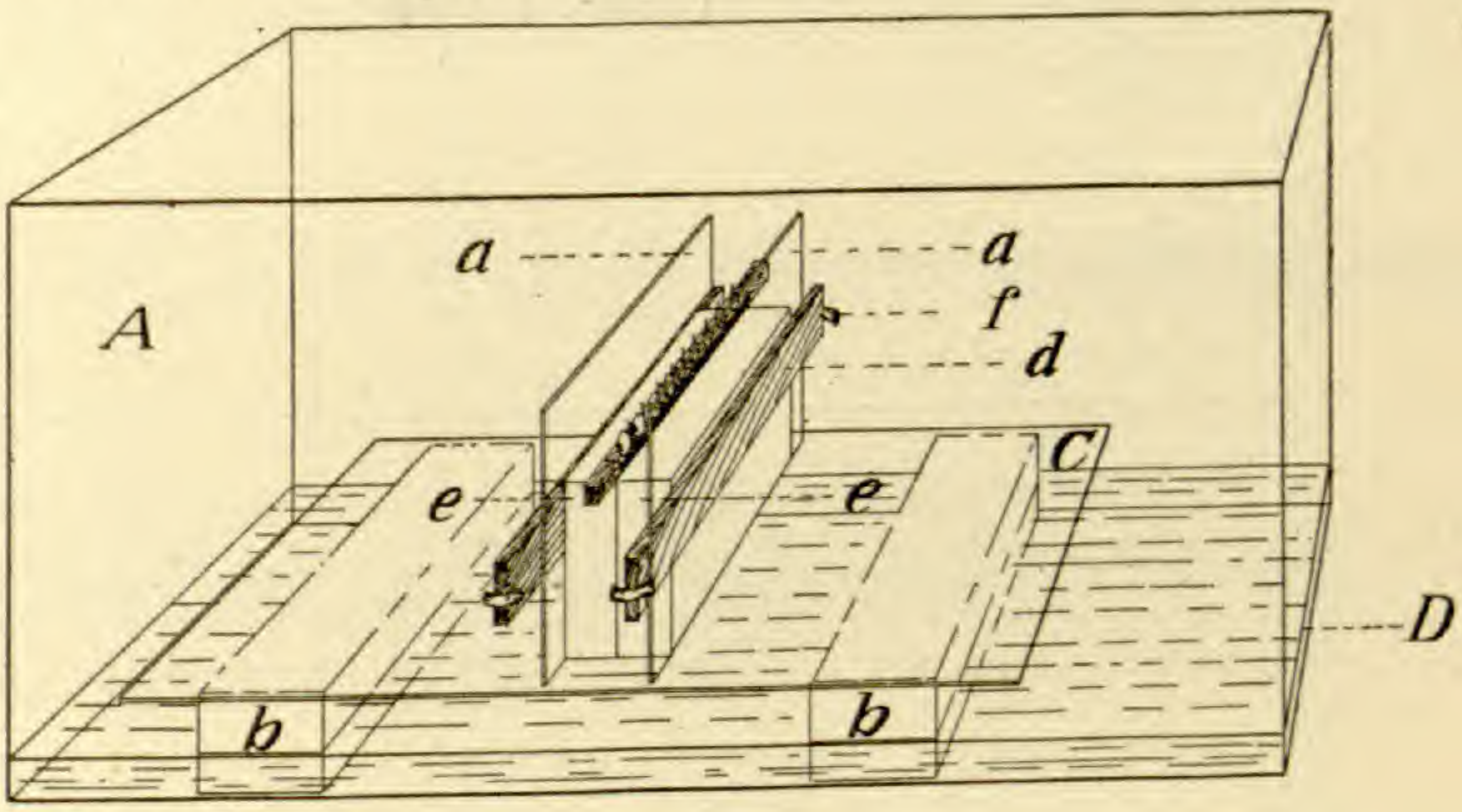

FIG. 4.—*A*, damp chamber; *D*, height of water; *C*, glass plate resting on *b*; *b*, glass jar; *e*, block of gelatin; *a*, supporting glass plate; *d*, supporting wooden bar; *f*, rubber tubing.

It may be seen from Table VI that in the first two sets of seedlings the gelatin was not thoroughly saturated with CO_2. Under such circumstances the difference in oxygen pressure on opposite sides was not great, and the seedlings had ready access to a sufficient oxygen pressure for good growth, but made no definite curves. In the other sets, in which the gelatin was thoroughly saturated with CO_2 or hydrogen, the oxygen pressure was not sufficient for good growth. Here again none of these roots showed curvatures of any definite character.

A still further trial, however, was made by supporting the roots in a very thin septum of gelatin and allowing gases to diffuse through the gelatin from the opposite sides.

TABLE VI.

(Plus sign indicates growth into gelatin containing air.)

Species	No. of ind'vs	Period: hours	Gases		+	−	o	Growth in mm.	Remarks
Lupinus albus..	15	24	CO_2	Air	5	3	7	....	Gelatin not thoroughly saturated with CO_2.
Lupinus albus..	18	30	CO_2	Air	2	11	5	....	Gelatin not thoroughly saturated with CO_2.
Lupinus albus..	16	24	CO_2	Air	6	7	3		
Lupinus albus..	13	30	CO_2	Air	5	7	1		
Lupinus albus..	7	30	CO_2	Air	..	..	7	20	
Zea Mays...... (popcorn)	11	30	CO_2	Air	2	3	6	8–28 12–27	Growth retarded during first 30 hrs.
Pisum sativum .	5	48	H	Air	1	..	8	4–20	Growth much retarded.
Lupinus albus..	4	60		Air				8–17	

A frame (*fig. 5*) was made of strips of glass cemented together along the edges and fastened at the ends in grooves in wooden bars (*a* and *e*). These strips were of two sizes. The wider ones (*b*) were so secured in the wood that narrow spaces were left between them (*c*), which were covered by the narrower strips (*d*), except in the lower 1.5^{cm}. Thus a series of little chambers was formed not more than 3^{mm} in diameter, open at the top and closed at the bottom except for the opening (*f*) between the strips of glass. By temporarily closing these openings with strips of glass the chambers could be filled with gelatin, after the hardening of which the two strips of glass could be removed. This frame with the little chambers filled with gelatin was now pressed down into a battery jar containing enough water to cover the lower bars of wood (*h*). By inserting rubber tubing between the edges of the frame and the sides of the battery jar two almost air-tight chambers were formed.

Down the middle of each column of gelatin a needle was thrust to make easy the passage of roots which were pushed down into the gelatin till the tips came below the glass covers, as shown in *fig. 5*. The chambers on the two sides of the partition were then filled with gas as desired.

In one series of experiments, in which CO_2 was passed slowly into one chamber and air more rapidly into the other, of 3 lupine, 5 pea, and 4 popcorn seedlings used, all grew nearly straight, though 2 took a somewhat slanting course toward the air chamber.

In another series, in order to reduce the surface for the cross-diffusion of the gases, the gelatin was smeared over with olive oil and the surface opposite the roots melted off with a hot needle. Thus, just as far as possible, the cross-diffusion of gases was confined to the vicinity of the root-tips, and the tips were exposed to the gases, except for the very thin covering. Air and CO_2 were introduced on opposite sides of the seedlings, and at the close of 42 hours it was found that, while there had been very little growth, there had been no curves.

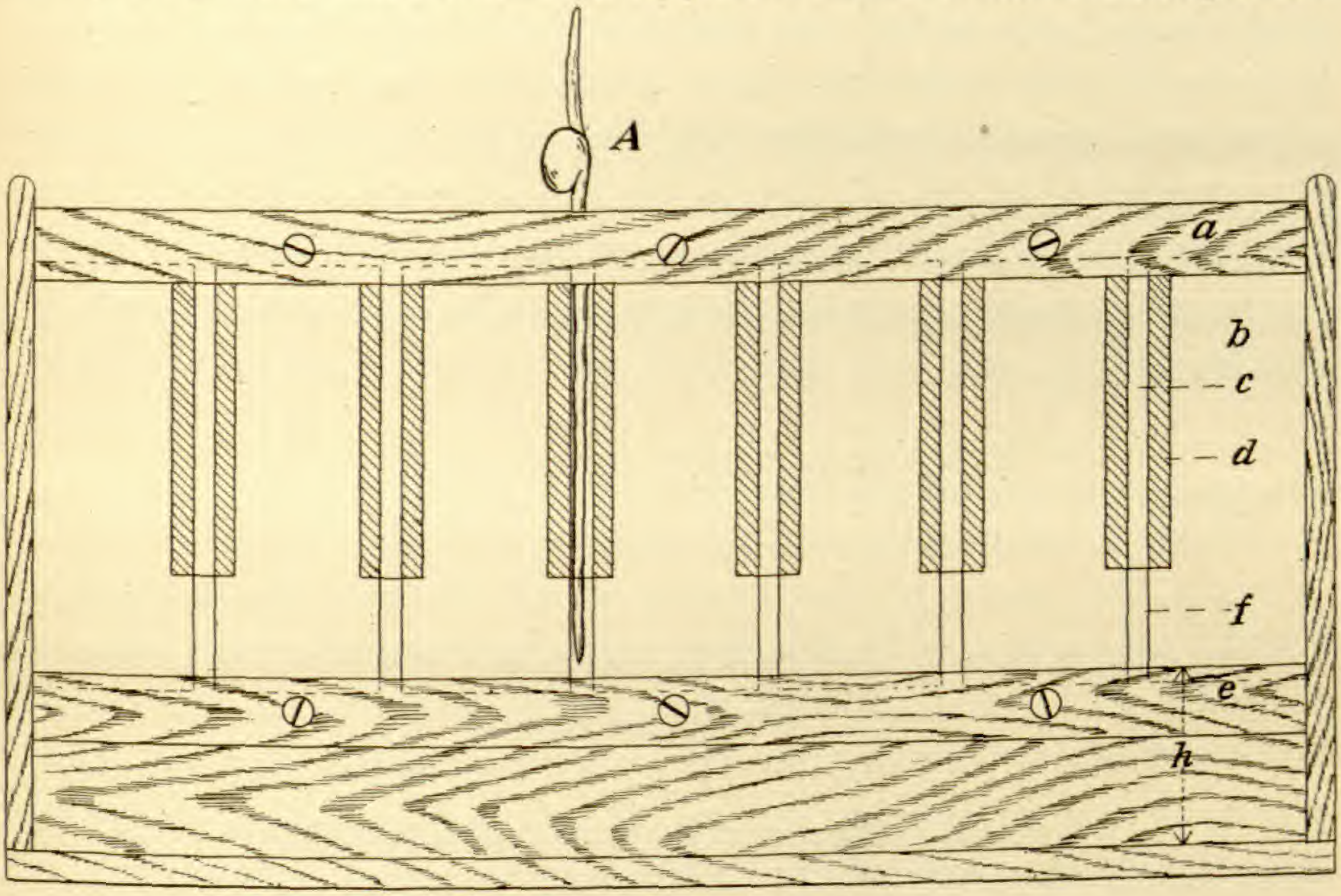

FIG. 5.—*A*, seedling; *a* and *e*, bars of wood; *b*, wide strips of glass; *c*, narrow spaces; *d*, narrow strips of glass sealed on; *h*, height of water; *f*, spaces filled with gelatin.

Thinking to determine roughly the rapidity of diffusion of gases in such contrivances as have been described above, one block of gelatin, made alkaline and colored with phenophthalein, was opposed to one saturated with CO_2, and the septum of gelatin in *fig. 5* was made pale red and the CO_2 and air brought on opposite sides as in the experiment. In the former case, within 4 hours the gelatin was decolorized to a depth of 10^{mm} and in 24 hours the entire block had lost the red color; while in the preparation shown in *fig. 5* the gelatin was entirely decolorized in 1¾ hours. Judging from these two tests, the CO_2 must have diffused rapidly enough through the gelatin to cause curves had the roots been aerotropic; and if CO_2 diffuses rapidly, hydrogen and air would diffuse even more rapidly.

Beyond doubt, in these experiments with the gelatin cultures, and especially in the last-described series, the roots have been met on opposite sides by different gases, and if they were aerotropic have been given the opportunity to show such reaction. In spite of this, under all these conditions the majority of the roots have remained straight, and the main result has been simply retardation of growth due to the diminished oxygen pressure. It is certainly difficult to conceive of any more favorable conditions under which the roots might have been placed to exhibit aerotropism.

5. *Experiments similar to those of Molisch.*

There remains only one more task, namely to determine if possible the cause of the curves which Molisch observed and termed aerotropic. To this end an apparatus was made similar to that used by him and described in the first part of this paper. It consisted of a rectangular jar containing folds of moist filter paper, having an opening on one side through which moist gases were led from a gasometer; and having a plate of cork infiltrated with paraffin sealed into the open end. In the plate were cut six vertical slits 2^{cm} long by 1 to 2^{mm} in width, and fastened to the upper edge of the closure was a ledge of cork in which was cut a longitudinal slit 5^{mm} wide. Small corks, through which projected the roots held firmly in their support with moist cotton, rested upon this ledge so that the roots passing through the slit in the ledge hung directly before, and within 2 to 4^{mm} of the slits in the cork plate closing the gas chamber.

An apparatus prepared in this way was placed in a large covered aquarium lined with and also containing many folds of moist filter paper supported on wooden bars, so as to add to the evaporating surface. The aquarium was covered with opaque black paper and the whole wrapped in black cloth. The gas, led in through an opening in the cover of the aquarium from the gasometer, was passed through a wash bottle containing water to insure a moist condition of the gas as well as to aid in determining the rate of flow.

In these experiments, pea, radish, and popcorn seedlings were used, and in the gas chamber were CO_2, hydrogen, or air. When CO_2 was diffusing from the gas chamber during 6 to 12 hours, and 17 seedlings were used, it was found that 4 were curved away from the source of CO_2, 5 toward it, and 8 were neutral; 4 of those which turned toward the gas chamber grew into the chamber through the slits.

When hydrogen was diffusing from the chamber, 7 of the 12 seedlings used curved toward the source of that gas. At the close of 12 hours it was found that there had been good growth, and that 4 roots had grown through the slits into the hydrogen chamber.

When air was diffusing through the slits in the cork plate, 10 of the 18 seedlings turned toward the air chamber, 1 away, and 7 were neutral.

The gas chamber was thoroughly aerated after each series of experiments, so that no remnant of the gas previously used could influence the results.

The most interesting results were obtained, however, when no special gas was used, but only air at rest both inside and outside the small chamber. It was found that under these conditions also curvatures were made, 4 of the six seedlings turning toward the small chamber containing air.

Altogether in this series of experiments, in which 53 seedlings were used, regardless of the gases diffusing from the chamber, 26 turned toward the gas chamber and 11 away, while 16 remained neutral. Even more striking was the observation that curves appeared in the roots whether or not a gas was passed through the slits. It must be very evident from these observations that such curvatures are not aerotropic, but are to be accounted for in some other way. It seemed not unreasonable to conclude that they were hydrotropic curves, and that, as the large chamber was probably not thoroughly saturated with moisture, the roots were turning toward the moisture emanating from the surface of the cork plate.

To verify this conclusion, a preparation was made in which the roots were placed between two cork plates set in the same damp-chamber, with the same evaporating surface as before.

Six pea seedlings were set up in the ordinary manner, the roots being 2 to 3^{mm} from each cork plate. After 2 hours, 1 root was touching one plate of cork; after 3 hours, 4 were touching this plate; and at the end of 24 hours, 2 roots were touching one cork, 2 the other, 1 was straight, and 1 had grown out beyond the two plates.

The evidence was absolutely convincing that here were purely hydrotropic curves. The cork surfaces had acted as evaporating surfaces in a chamber of the kind ordinarily said to be saturated with moisture. Accordingly it is highly probable that Molisch's damp-chamber, which had relatively less evaporating surface than mine, was not saturated with moisture and that the curves he obtained were hydrotropic rather than aerotropic.

III. DEDUCTIONS FROM EXPERIMENTS.

In my experiments, roots of *Zea Mays*, *Pisum sativum*, *Raphanus sativus*, *Cucurbita Pepo*, and *Lupinus albus* have been subjected to the one-sided access of oxygen, hydrogen, and carbon dioxid, to determine whether these roots do really curve toward or away from these gases in natural or artificial conditions.

Incidentally I have offered my solution for the curvatures of roots recorded by Molisch and by him termed aerotropic.

1. When the roots of the various seedlings mentioned in this paper were grown in water between submerged chambers, the one containing air and the other CO_2 or H, no constant and regular curvatures were observed. Under these conditions the majority of the roots were indifferent to the influence of any of these gases. The same results followed when the roots were not submerged in water, but placed between the gas chambers in a larger damp-chamber.

2. When the seedlings were grown in a thin, vertical layer of earth, forming a septum between air and CO_2, or air and hydrogen, or in earth permeated on one side with air and on the other with CO_2 or hydrogen, very few curves were formed, the large

majority of roots growing straight or, if curved, the curves were not directed by the presence of the gases.

3. When the roots of seedlings were grown in a thin layer of gelatin, between different gases, as air and CO_2 or air and hydrogen, or when grown between and enclosed by blocks of gelatin, one saturated with air and the other with CO_2 or hydrogen, no curves of constant direction were shown.

4. The preparation of experiments similar to those of Molisch, where roots were supported close to narrow slits opening into gas chambers from which gases were constantly diffusing, brought to light the important truth that curves were produced, generally toward the gas chambers, no matter whether gases (oxygen, hydrogen, or CO_2) were diffusing from the chambers, or no gases whatever were diffusing and a like pressure of air surrounded the roots on all sides. The observations led to the discovery that these curves were purely hydrotropic.

5. Finally, from a careful consideration of the results of experiments set forth in this paper, with the large number of individuals of representative species, and the variety of methods of experimentation employed, both under nearly natural and under artificial conditions, one is driven to the conclusion that, at least so far as the representative land plants here used are concerned, definite direction curvatures are not induced in roots by the one-sided access of such gases as oxygen, hydrogen, or carbon dioxid, and their roots are therefore not aerotropic.

Thus far the evidence is decidedly against a belief in the aerotropism of roots.

UNIVERSITY OF MICHIGAN.

CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. V.

AVEN NELSON.

To THOSE who have known them in the field and who have studied them carefully in the herbarium, desert plants are of peculiar interest. No other plants show so many adaptations to their environment and, as a consequence, so many variant characters that have become fixed. During the spring of 1902 Mr. Leslie N. Goodding, a student in the University of Wyoming, was sent into the field in the interest of the Rocky Mountain Herbarium. He made collections in southern Nevada, southern Utah, the Wasatch Mountains, and in the Uintah Mountains, especially on their southern desert slopes. He secured many rare species of great interest, as well as some novelties. This paper is based, in a large measure, upon his field work.

NEW GENERA AMONG THE APLOPAPPUS SEGREGATES.

Notwithstanding the attention that the genus *Aplopappus* Cass. has had in recent years, it seems that further division would tend to simplicity. The genus Stenotus as now constituted is nearly homogeneous. Before the recent separation of two of the species and their erection into the genus Stenotopsis by Rydberg (Bull. Torr. Bot. Club **27**: 617), a concise generic description was unthinkable. My attention was called to this fact recently when some material of *Stenotus interior* (Coville) Greene came into my hands for determination. To one perfectly familiar with the normal species, the possibility that this plant also was listed as a Stenotus did not for some time occur to me. Several other genera come to mind more readily than this, among them Macronema, when one has in hand only the leafy floriferous twigs that constitute the usual herbarium specimens.

The difficulties encountered in generically placing the original species of the group (*Aplopappus linearifolius* DC.) has been recognized from DeCandolle down. Greene has stated the whole matter very fully in the fifth of that series of papers entitled "Observations on the Compositae" (Erythea **2**: 71). In his discussion of the asteroid genera (Erythea **2**: 53) it seems to me that he was at his best, and gave us a bit of botanical philosophy that must stand for all time. But the criterion there laid down, and now generally accepted, as marking the limits of genera, confirms Stenotopsis as a valid genus. Into this genus another species must therefore find its way as follows:

Stenotopsis McLeanii, n. n.—*Aplopappus McLeanii* T. S. Brandegee, Bot. Gaz. **27**: 448. 1899; *Stenotus McLeanii* Heller, Muhlenbergia **1**: 7. 1900.

There are three other plants that seem to me to form an equally good and homogeneous group. One of these, starting as *Stenotus pygmaeus* (T. & G. Fl.), passed into Aplopappus (Gray Syn. Fl.) and was there associated with a near relative, *Aplopappus Lyallii* Gray. Greene in his discussion of the segregates of Aplopappus (Erythea **2**:) considers the status of the former of these two and decides that it has enough Macronema characters to justify its transfer to that genus. Recently, however, it has been distributed on Greene's determination as Stenotus (Pl. Baker, 1899), though this may have been a clerical error. The second of these species Greene either overlooked or ignored entirely. But now Rydberg (Mem. N. Y. Bot. Gard. **1**: 382. 1900) after due consideration very reluctantly makes the second *Pyrrocoma Lyalli.* Henderson, apparently not accepting the segregates of Aplopappus, describes (Bull. Torr. Bot. Club **27**: 347. 1900) a third species which he pronounces "close to *A. Lyallii* as well as to *A. pygmaeus.*" With these doubts and these differences of opinion staring us in the face, why not again accept the criterion laid down by Greene (that is, if I interpret him aright, a genus may be founded on characters of habit, along with characters of the vegetative organs and morphological characters of the flower, but not upon morphological characters of the flowers alone in the face of differences in habit and of the vegetative organs) for the limitation of genera, and thus bring together under one name these species which are allied by habit and morphological characters to each other and are aberrant in any recognized genus or genera in which they can be placed.

Tonestus, n. gen.—Low herbaceous perennials from woody roots, having a short more or less branched subligneous caudex. Stems simple, a few to several centimeters high, leafy throughout, monocephalous. Leaves herbaceous, obscurely 3-nerved, spatulately tapering to a short margined petiole. Heads relatively large (15–25^{mm} broad); the involucral bracts herbaceous, in about two loosely imbricated rows, usually with one to several outer foliaceous ones. Rays conspicuous, ten or more; the disk flowers more numerous. Pappus soft and white, equaling the corolla. Style tips slender, subulate-elongated. Akenes glabrous or pubescent. Anagram of Stenotus.

1. **Tonestus Lyallii**, n. n.—*Aplopappus Lyallii* Gray, Proc. Acad. Philad. **1863**: 64; Syn. Fl. **1**: 131; *Pyrrocoma Lyallii* Rydb. Mem. N. Y. Bot. Gard. **1**: 382. 1900.

2. **Tonestus laceratus**, n. n.—*Aplopappus laceratus* Henderson, Bull. Torr. Bot. Club **27**: 347. 1900; *Stenotus laceratus* Heller, Muhlenbergia **1**: 7. 1900.

3. **Tonestus pygmaeus**, n. n.—*Stenotus pygmaeus* T. & G. Fl. **2**: 237. 1842; *Aplopappus pygmaeus* Gray, Am. Jour. Sci. II. **33**: 239. 1862; *Macronema pygmaeum* Greene, Erythea **2**: 73. 1894.

STUDIES IN THE COMPOSITAE.

Coleosanthus venulosus, n. sp.—A low shrub 3^{dm} or less high, freely branched, the stems whitened with irregularly furrowed bark: leaves glabrous, sprinkled with microscopic (waxy?) particles, subsessile, triangular-deltoid, rather thin, with narrow prominent reticulate veins, the base truncate or subcordate, sharply acute or even acuminate at apex, cuspidately few-toothed on the margins, often subcrenate, generally less than 2^{cm} long, mostly on the herbaceous branchlets which terminate in slender monocephalous peduncles: heads about 14^{mm} high and fully as broad: involucral bracts minutely granular-puberulent as are also the peduncles, sub-equal, acuminate; the inner linear-lanceolate, few-nerved; the outer ovate-lanceolate, 6–10-nerved, usually with a subtending bract: flowers numerous: akenes linear, with 10 minutely hispidulous nerves: pappus strictly capillary, scarcely scabrous.

I know of no near ally of this species. It is based on Mr. Goodding's no. 678, from southern Nevada, " The Pockets," April 30, 1902; "in the crevices of the rock."

Hofmeisteria viscosa, n. sp.—Allied to *H. pleuriseta:* stems decumbent at base; lignescent below, grayish-white with glabrous bark; the upper herbaceous part granular-viscid: leaves slightly viscid, greatly reduced as to the blade; the lamina often reduced to a broadly linear-subulate point, frequently with 1 or 2 teeth near the base, from one-third to one-sixth as long as the slender petiole which is often 3^{cm} or more long: heads about 25-flowered, at the ends of the slender naked peduncles in 2–7 capitate clusters, the pedicels very short: involucral bracts oblong-linear, abruptly short-acuminate, scarious with three parallel green nerves: pappus of a few slender bristles (8–12); the squamellae wanting or if present represented by a few (1–6) variable bristles; corolla shorter than the pappus, its tube with minute scattered stipitate glands: the club-shaped styles included or at least not noticeably exserted: akene very short, ovate-oblong.

This species is somewhat at variance with the genus in the congested heads. It differs from all the species in its leaves and from its nearest ally as well as the others in floral characters.

Secured in southern Nevada, at " The Pockets," April 30, 1902, on dry stony bottom lands; no. 671.

Chrysopsis imbricata, n. sp.—Stems few to many from the crown of the root, quite simple, decumbent-ascending, $3–4^{dm}$ long, subcinerous, the pubescence short and close with some longer hirsute hairs: leaves very numerous, broadly oblong or narrowly elliptic, sessile, often broadly obtuse, abruptly apiculate, sometimes lanceolately narrowed, grayish-hirsute; usually crowded till they appear imbricated, with smaller fascicled ones in the axils, the lower wanting at anthesis; the floral leaves reduced and often ciliate: heads several, closely glomerate at the summit of the stems, $10–14^{mm}$ high: involucre cinereous-hirsute: rays several, conspicuous, distinctly nerved: pappus fuscous: akenes silky.

The writer's no. 8618, from Pike's Peak, September 1, 1901, is taken as the type. Dr. Clements's no. 39, from the same region, is this species, but not typical in habit, having been browsed off (my set). It was distributed as *C. hispida* (Hook.) Nutt.

Chrysopsis scabrifolia, n. sp.—Stems several from a woody root, ascending or erect, dark green and subpruinose, simple, or branched above, $12–20^{\mathrm{cm}}$ high: leaves small ($1–2^{\mathrm{cm}}$), nearly linear, at anthesis wanting below but crowded above, greenish in aspect, but distinctly scabrous with short upturned hairs from a pustulate base: heads few, solitary at the ends of the resinous-glandular branches, about 1^{cm} high: involucral bracts in 4–5 rows, merely puberulent: rays 20 or fewer: pappus somewhat sordid, equaling the disk corollas.

The specimen upon which this species is based was secured by Mr. Paul J. White, in Woods co., Okla., June 29, 1900. It was distributed as *C. hispida*, to which it bears little resemblance and less yet to any other species known to the writer.

The Natural History Survey of Oklahoma, so energetically conducted by by Dr. Van Vleet, of the State University, has suffered the loss, by fire, of many very valuable collections, among them the plants of which these specimens were a part. Dr. Van Vleet is again in the field, and it is to be hoped that he may once more secure some of the rare species found on his first expedition.

Guttierrezia myriocephala, n. sp.—Branching freely from the shrubby base, becoming $3–5^{\mathrm{dm}}$ high, the grayish branches dissolving into myriads of filiform, green, subresinous branchlets: leafless below, trichophyllous above: cymes small, supernumerous: heads many, small, nearly cylindrical, somewhat glutinous: bracts of the involucre linear, acute, in about 3 rows: rays minute, 3–4; the disk flowers as many or fewer: pappus paleae 6–8, broadly linear and subacute.

The type is no. 8645, secured near Badger, Laramie co., Wyo., in the sandy draws of the Platte Cañon, September 3, 1901.

Solidago scopulorum, n. comb.—*S. multiradiata scopulorum* Gray, Proc. Am. Acad. **17**: 187; Syn. Fl. 1^2: 148.

There seems to be no reason for supposing that true *S. multiradiata* Ait. comes within the limits of the United States. The original high northern form is said to occur from Labrador and Hudson's Bay to Behring Strait and Unalaska. It is characterized by villous-pubescent stems, few and closely glomerate heads with very narrow rays. To carry the Rocky Mountain form along as a variety of this arctic species can serve no useful purpose.

Pyrrocoma brachycephala, n. sp.—*Aplopappus lanceolatus brachycephalus* Piper, n. var. in herb.—Stems several from the crown of a thickened root, slender, erect, 4–6^{dm} high, glabrous, rather leafy, clothed at the base with the shreds of former petioles: leaves glabrous or nearly so; the basal few, linear-oblanceolate, entire or minutely denticulate, acute at apex, 1–2^{dm} long, tapering to a margined petiole nearly as long; the cauline sessile, noticeably denticulate: inflorescence a long crowded or glomerate spike-like raceme, with foliar bracts: heads about 1^{cm} high: the bracts unequal, in about 4 rows, oblong, abruptly acute.

The above description is taken from Mr. William C. Cusick's no. 2778 (in the Rocky Mountain Herbarium), the label of which bears the legend already given. The plant is so different from *Pyrrocoma lanceolata* in its habit, in the spicate, foliar-bracted inflorescence, and in the character of its leaves that it seems best in transferring it to Pyrrocoma to give it specific rank at the same time.

Pyrrocoma Kennedyi, n. sp.—Stems several from the root, ascending, 2–4^{dm} high, light-green, somewhat villous-pubescent, paniculately branched upward and bearing numerous heads: leaves permanently and rather softly and densely lanate-pubescent, mostly basal, oblong or oblanceolate, acute at apex and conspicuously dentate with narrow spinulose teeth, 5–10^{cm} long, tapering into a petiole usually much shorter; cauline leaves smaller and narrowed to a sessile base: heads medium sized (1^{cm} or more broad and high), several to many (often 30 or more on each of the several stems) on the slender linear-bracted branches of the panicle: involucral bracts in 3 or 4 rows, unequal, herbaceous-tipped, but not noticeably broadened or squamose: rays mostly fewer than 20.

The nearest ally of this species is *P. lanceolata.* In fact, it bears much the same relation to this that *P. inuloides* bears to *P. uniflora.* The distinctly paniculate arrangement of the numerous heads, together with the permanent woolliness of the plant as a whole, seems to justify its separation from *P. lanceolata.*

The type is no. 630 secured by Professor P. B. Kennedy on Maggie Creek, Elko county, Nev., August 13, 1902. Similar but smaller is his no. 615, Tuscarora flats, same county. Mr. William C. Cusick's no. 2744, Oregon, 1901, distributed as *Aplopappus hirtus* Gray, var., is the same, as is also probably no. 1137 by Merrill and Wilcox, from Buffalo River, northwestern Wyoming.

Stenotus latifolius, n. sp.—Caudex woody, with numerous slender naked branches rising some centimeters above the ground; herbaceous stems numerous, slender, leafy, monocephalous, 10–15^{cm} high, striate, glabrous but obscurely glutinous: leaves glabrous, slightly glutinous, acute or apiculate, 3-nerved and more obscurely reticulate-veined; the crown leaves not persistent, small, spatulate and cuneately tapered to a petioled or subsessile base, usually not more than 7–12^{mm} long; stem leaves longer, several (5–7), the lowest broadly spatulate-cuneate, the upper from broadly oblong to lanceolate, usually with tapering base, 2–3^{cm} long; the upper one-third of the stem naked-pedunculate, often with a linear bract: heads 10–12^{mm} high: the bracts in 3–4 series, oblong, abruptly acute, light green with narrow scarious margin: rays several, rather short: pappus bristles slender, white, about as long as the somewhat angled canescent akene.

This species has no near relative, but is most nearly approached by *S. falcatus* Rydb. From this and all the other species it is at once separated by the open naked slender branches of the caudex which wholly lack the enlarged indurated and petiole-sheathed crowns of the other species. This also is the only species with decidedly foliose stems, the leaves of which are relatively much broader and more herbaceous than in the other species.

Type no. 1111, by Mr. Goodding, "rock crevices," mountain slopes, near Provo, Utah, June 16, 1902.

Sideranthus Gooddingi, n. sp.—Caudex woody, branched, several centimeters high: herbaceous stems slender, 2–3^{dm} high, numerous, fascicled, nearly simple, monocephalous or with 2–3 monocephalous branches, minutely glandular-puberulent throughout: leaves linear, spinulose-tipped, 1–3^{cm} long, 1–2^{mm} broad, with a few slender flagellate-spinulose teeth upon the margins, rarely with a few short linear lateral lobes: heads about 1^{cm} high, the disk hemispherical: involucral bracts in 5–6 series, very narrowly linear, somewhat greenish and minutely glandular, flagellate-spinulose tipped: rays orange-yellow, many, linear: disk flowers numerous: pappus bristles scabrous, of several lengths, the longest not equaling the disk corollas: akenes softly pubescent, broadly linear, not more than half as long as the disk corollas.

Allied to both *S. gracilis* (Gray) and *S. australe* (Greene) Rydb. It is distinguished from both by the nearly simple branches, the glandulosity of the whole plant, and the narrowly linear leaves. From the former also by the greener stems which lack the canescent harsh pubescence of that species; from the latter also by a very different involucre.

I dedicate this species to Mr. L. N. Goodding, who secured a most valuable collection of plants in southern Nevada and Utah, in fact, as will be noticed, most of the species of this paper. No. 667, from "rock crevices," "The Pockets," southern Nevada, April 30, 1902.

Townsendia dejecta, n. sp.—Depressed-acaulescent, the caudex bearing a few heads in a small rosulate semisubterranean tuft: leaves linear-spatulate or oblanceolate, somewhat petioled, $1–2^{cm}$ long (including the petiole), surpassing the heads, somewhat fleshy, green and apparently glabrous but under a lens appressed strigose on both faces: heads sessile at the base of the leaves, about 1^{cm} high; involucral bracts in 2–3 series, oblong ovate, mostly subacute, purple or some with green centers, ciliate margined, otherwise nearly glabrous: rays white or possibly purple: disk flowers numerous, the corolla lobes purple: pappus white, similar in disk and ray flowers as are also the akenes: akenes brown, flattened, spatulate-cuneate, about 4^{mm} long, wholly glabrous except for some obscure puberulence at the very base, as long as the pappus and disk corolla.

Most nearly allied to *T. alpigena* Piper, from which it may be distinguished by its absolute stemlessness, the strigose pubescence, the purple of the involucre, of the disk, and probably of the ray, and by the glabrous akenes wholly devoid of bidentate hairs. Townsendias with glabrous akenes are rather rare.

Collected by Mr. Goodding in the Uintah Mountains, near Dyer's Mine, at an altitude of about $3,000^{m}$. Type no. 1238, July 3, 1902.

Machaeranthera verna, n. sp.—Perennial from thickened woody roots: stems several from the ligneous crown, erect, branched above, $4–6^{dm}$ high, striate, nearly or quite glabrous except above: leaves from linear to lanceolate, glabrous or sparsely crisped or ciliate-pubescent especially on the margins, spinously few-toothed on the margins; the uppermost reduced and bract-like, lanately-puberulent as are also the branchlets: heads corymbose-paniculate: involucre $12–14^{mm}$ high and broad; its bracts imbricated in 5–6 rows, scarcely viscidulous, lightly sublanate, linear acuminate, the slender tip green and at length reflexed: rays purple, rather numerous: pappus slightly dingy, equaling the slender corollas: akenes linear, pale, sparsely and minutely soft pubescent.

This tall handsome species differs from the species known to the writer in its early development. It comes into blossom in April, whereas most of the species are autumnal or at least of late summer. But apart from that its morphological characters readily distinguish it.

Collected by Mr. Leslie N. Goodding, Big Bend, Virgin River, Arizona, May 10, 1902, no. 757.

Machaeranthera coronopifolia, n. n.—*Dieteria coronopifolia* Nutt. Trans. Am. Phil. Soc. **7**: 300. Annual, or probably often biennial, divaricate-branched from the base upward (rarely two or more stems from the base), 1–2^{dm} high, green but puberulent and minutely glandular: leaves from moderately to very deeply pinnatifid, oblanceolate in outline, from 1–4^{cm} long; the segments very variable, from linear to oblong or merely with broad teeth upon the margins of the blade, setulose-mucronate: heads large: the involucre in about 5 series, the slender green reflexed portion of the bract about as long as the scarious imbricated base: rays often nearly 2^{cm} long, bluish-purple: akenes sparingly appressed pubescent.

This is in part the *Aster tanacetifolius* of Gray, Syn. Fl. 206; not *Machaeranthera tanacetifolia* Nees, nor the *M. tanacetifolia* of Greene in Pitt. 3:59.

This northern species may at once be distinguished from that southern and earlier named one by its greener aspect, lower stouter and more spreading habit, simply pinnate leaves, broader and more numerous involucral bracts, and by the sparse appressed pubescence of the akenes. Of the southern species I have seen only a few plants, but Wooton's no. 22, Mesilla, N. M., seems to be quite typical. The northern species is frequently collected in Wyoming, northern Colorado, and western Nebraska.

My numbers are 443, Platte River, July 13, 1894; 2581, Chug Creek, August 1, 1896; and 8205, Colorado-Wyoming line, August 28, 1900.

Aster meritus, n. sp.—Stems one to several from each of the many crowns of the woody roots and rootstocks that make up the dense perennial base, the tufted stems suberect or more usually widely spreading and forming a mat 5–10^{dm} across, 2–4^{dm} long, green but under a lens sparsely pubescent, simple or branched, leafy throughout: leaves oblong or sometimes elliptic, 3–7^{cm} long, subacute, entire or obscurely crenulate-serrate, glabrous above, often sparingly and minutely ciliolate-scabrous below and on the margins: heads several to numerous, usually in a crowded corymbose leafy cyme, turbinate-campanulate: involucral bracts broadly linear, in 3–4 rows, subacute or obtuse, erect, purple-tipped and margined, delicately ciliate, sometimes puberulent (as are the peduncles and pedicels): rays mostly fewer than 15, purple or violet, pappus brownish: akene linear, half as long as the pappus, minutely ciliate and obscurely few-nerved (about 5).

The literature of the subject seems to indicate the distinctness of the Aster occurring in the middle Rocky Mountains, which has been called *A. Sibiricus* or *A. Richardsonii.* There can be no doubt that the true *A. Sibiricus* L. is foreign to North America and that it belongs where its name would indicate.

It is equally clear that *A. Richardsonii* is the name given to the *A. montanus* of Nuttall. Hooker (Fl. Bor. Am. 2:7) seems to have satisfied himself that *A. salsuginosus* (?) Less. equals *A. Espenbergensis* Nees, and that the latter is undoubtedly the *A. montanus* of Rich. It follows, therefore, that the more southern form, if distinct from *A. Richardsonii* Spreng. (re-characterized by Hooker, *l. c.*), has so far remained unnamed. The original *A. Richardsonii* is a plant of the "barren country from lat. 64° to the Arctic Seas." The Torrey and Gray *Flora*, which took into consideration these arctic forms only, emphasizes the characters which separate them from the species now proposed, viz., the tomentum, the serrate leaves, the squarrose involucre, many-ribbed achenia, etc. In the *Syn. Fl.* Dr. Gray modifies this description so as to include all the European as well as the North American forms.

Typical of the species now proposed are the writer's collections as follows: Yellowstone Park, 1899, nos. 6754 and 6610 (distr. as *A. Sibiricus*); Big Horn Mountains, nos. 2334 and 7924, secured in 1896 and 1901 respectively.

Aster incertus, n. sp.—Low, more or less cespitose-tufted, from small woody root-crowns and slender rhizomes: stems leafy, usually decumbent at base, rarely more than 1^{dm} high (occasionally nearly 2^{dm}), sparingly cinereous-pubescent: leaves oblong to oblanceolate, $2–5^{cm}$ long, most of them tapering to a short petiole, glabrous or nearly so; the uppermost sessile by a clasping base: heads solitary at the ends of the stems which are usually simple, rather large and showy ($2–3^{cm}$ broad): involucral bracts spatulate, subacute, minutely soft-pubescent on the margin, otherwise glabrous and green or sometimes purple margined: rays purple, rather numerous (25–50): pappus brownish, twice as long as the brownish nearly glabrous akene.

The species here proposed seems to belong in the *A. adscendens* group. In habitat and aspect, however, it reminds one more of *Erigeron glacialis.* After trying for some time to find in the recognized Rocky Mountain species a near ally, I now offer it, with some hesitancy as a new species. The type is no. 7924, from alpine summits in the Medicine Bow Mountains, Albany co., Wyo., August 2, 1900.

Xylorrhiza scopulorum, n. sp.—A low shrub 3–4^{dm} high, the woody base branched and naked: branches with a glistening white bark, glabrous except for a tuft of wool at the old leaf-scars: young branches herbaceous, greenish, leafy throughout, sparsely lanate and above viscid-glandular, monocephalous: leaves oblong-lanceolate, green and herbaceous, lightly lanate-pubescent and glandular-dotted, spinulose-dentate, the lower short-petioled, the uppermost reduced to lanceolate bracts: heads with the expanded rays about 4^{cm} broad: involucral bracts many, linear-acuminate, about 1^{cm} long, minutely viscid-pubescent: rays numerous, white or light-blue, 3-toothed: disk flowers very numerous, slender-tubular, about 5^{mm} long, and four times as long as the short-cylindrical merely canescent akenes; pappus as long as the disk corollas.

This species is to be distinguished from *X. tortifolia* (T. & G.) Greene, its nearest ally, by its less rigid, wholly herbaceous, not at all contorted leaves, which are not in the least incised (only bordered with small spinulose teeth); by the presence of some viscid-glandulosity upon leaves, young stems, and involucre; by the leafiness of the peduncles; and by the color of the rays. Type specimens from rocky cliffs at "The Pockets," southern Nevada, April 30, 1902, by Mr. Goodding, no. 669.

Erigeron glacialis, n. comb.—*Aster glacialis* Nutt. Trans. Am. Phil. Soc. **7**: 291; T. & G. Fl. **2**: 155; *Erigeron salsuginosus glacialis* Gray, Syn. Fl. **1**^{2}: 209.

I think we shall do well to allow Nuttall's conception of the rank of this plant to stand.

Erigeron nauseosus, n. comb.—*E. caespitosus nauseosus* Jones, Proc. Cal. Acad. Sci. II. **5**: 696.

The specimens distributed by Mr. Jones (no. 5586) bear out nicely the fairly complete description cited.

Hymenoclea fasciculata, n. sp.—Stems shrubby, several to many, spreading, simple, leafless, striate, with light yellowish-green resiniferous bark, 2–4^{dm} high; branches fasciculate or brush-like at the top of the stems, 5–15^{cm} long, glabrous or subresinous, sometimes leafless and having a spinescent appearance: leaves narrowly linear, 1–4^{cm} long, entire or with a few widely divaricate linear lobes, slightly involute, leaving exposed a median line of canescent pubescence: sterile heads small, 3–4^{mm} in diameter, about 20-flowered, mostly spicate on the ends of the branches, or more scattered and intra-axillary: their involucre green, glabrate, its lobes 7, ovate, obtuse or subacute, often ciliate-laciniate; the corollas tubular-funnelform, 2–2.5^{mm} long, distinctly surpassed by the stamens and protruded penicillate stigma, its five tooth-like lobes with a long delicate pubescence partly concealing the numerous minute glands: anthers linear, shorter than the slender filament; chaff spatulate with a long narrow claw: fertile involucre oval, 5–6^{mm} long, its scales consisting of 3 or 4 cordate-deltoid green ciliate-margined bracts and about 12 spirally arranged scales which are broadly reniform, delicately nerved, thin, and petaloid in appearance, closely enwrapping the gland-dotted coriaceous body of the involucre: akene (immature) light yellow or greenish, closely dotted with brown.

The nearest ally is *H. salsola* T. & G. Pl. Fendl. 79; Pl. Frem. 14, *pl. 8;* but the fertile involucre is only the size of the involucre in *H. monogyra* Gray Pl. Fend. *l. c.*, and its scales, like the scales of that species, are reniform and not contracted at base. Besides the many other minor differences, the two species differ markedly in habitat and time of flowering. *H. salsola* is a plant of the saline basins of desert regions of California and comes into blossom in August, while *H. fasciculata* occurs on rocky ledges and comes into blossom in April.

The type is no. 662, by Leslie N. Goodding, Kernan, southern Nevada, April 29, 1902.

Gymnolomia nevadensis, n. sp.—Perennial from slender subvertical rootstocks, from the crown or crowns of which spring few to several slender stems: stems 3–5^{dm} high, somewhat striate, sparsely pubescent with minute appressed or sometimes spreading hairs, simple or more rarely branched; the branches very slender, alternate or opposite: leaves mostly opposite, narrowly linear, tapering at both ends, 3–7^{cm} long, 1–3^{mm} wide (rarely nearly 5), appressed minutely hispid-pubescent, the margins revolute; often a fascicle of small leaves in the axils representing the suppressed branches: heads mostly solitary at the ends of the peduncle-like branches, the main axis usually with 3; the peduncles naked or bracteate: involucre canescent, about 1^{cm} broad, its bracts in two series: rays 8–12, oblong to elliptic: disk corollas tubular, noticeably dilated just above the very short glandular pubescent tube: pappus wholly wanting.

Notwithstanding the morphological similarity of the floral characters of this and *G. multiflora* Benth. & Hook., the distinctness of the two can scarcely be questioned. In the excellent revision of the genus by Robinson and Greenman (Proc. Bost. Soc. Nat. Hist. **29**: 87–104. 1899) mention is made of narrow-leaved forms of *G. multiflora* which occur to the southwest of the range of the species, but judging from the specimens cited nothing like the plant now described was at hand. In any case, the species now proposed is strongly marked by its slender, rhizome-like roots, its very narrow revolute leaves, and its slender fascicled stems; in contrast with the woody taproot, the relatively stout branched stems, the lanceolate leaves, and the somewhat larger heads and broader rays of *G. multiflora.*

The type is no. 968, Leslie N. Goodding, Meadow Valley Wash, southern Nevada, May 17, 1902; in blossom and with mature akenes; growing among the rocks on dry steep mountain slopes.

Encelia virginensis, n. sp.— Perennial, the base shrubby and freely branched, 3–5^{dm} high including the herbaceous part of the plant: the ligneous stems white, rather slender; the herbaceous branches leafy below, terminating in a long slender monocephalous peduncle, light green, roughish-puberulent as are also the ligneous stems for a time: leaves opposite below but alternate upward, short-petioled, broadly rhomboid- or deltoid-ovate, rarely sub-cordate, generally 3-nerved from the base, 12–20^{mm} long, some nearly as broad: the pubescence of two kinds, some short white strigose-hispid hairs, and a fine close puberulence: peduncles 1–2^{dm} long, naked or 1- or 2-bracted near the head: involucre strigose-canescent; its bracts acute, in about 2 series, linear-lanceolate, rather coriaceous, some of them abruptly narrowed to a slender somewhat recurved tip: rays 12–20, minutely pubescent below, cuneate-oblong, deeply 3- or 4-toothed at the truncate apex, neutral, 15–20^{mm} long: disk-flowers numerous; the tube proper narrow, half as long as the cylindrical throat: style branches acute, linear: akene flattened, broadly linear-spatulate, slightly depressed at summit, glabrous on the sides, densely long ciliate-villous on margins and summit, about 4^{mm} long, as long as the corolla; pappus wholly wanting: receptacle flat; the chaffy bracts broadly linear, membranous with herbaceous tips and midrib which are finely pubescent and viscid-glandular, as are also the involucral bracts and to some extent the peduncles.

Related to *Encelia frutescens* Gray, but wholly distinct from that as originally defined in Bot. Mex. Bound. 89 (*Simsia* [*Geraea*] *frutescens*). We must consider Colonel Emory's plants from the Gila country as the type of that species. The species now defined may be represented in some herbaria under the name *E. frutescens* by specimens from southwestern United States. The type is Mr. Goodding's no. 666, secured at "The Pockets," on the Virgin River, in southern Nevada, April 30, 1902.

Helianthella Covillei, n. n.—*H. argophylla* Coville, Contrib. U. S. Nat. Herb. **4**: 132; *Encelia grandiflora* Jones, Proc. Cal. Acad. Sci. II. **5**: 702.

While working out the preceding species I naturally looked up all of the species of Encelia. As a result of this study I gained, with much difficulty, a conception of some of the species as understood by M. E. Jones. I feel satisfied that he is right in asserting the distinctness of the plant described by Dr. Coville (*l. c.*) from the *Tithonia argophylla* of Eaton, Bot. King. Exp. 423. On the other hand, he does not seem to be right in taking Coville's plant out of Helianthella, and in either genus Jones' specific name is untenable. I refer it back to Helianthella, therefore, naming it for Dr. Coville, who has furnished us with a clear and full diagnosis of it.

Bebbia aspera (Greene), n. sp.—Stems slender, the woody basal portion with gray fibrous bark, the herbaceous stems subcinerous with scattering abruptly upturned white scabrous often deciduous hairs from a papillate base: leaves nearly linear; the lower opposite, $2–4^{cm}$ long; the upper alternate, small and finally reduced to subulate bracts; pubescence similar to that of the stems: heads in an open corymbose panicle, $10–15^{mm}$ high, canescently pubescent: corollas yellow: style-tips slender-subulate, exserted, recurved: receptacle flat, chaffy throughout; the bracts linear-lanceolate, scarious, with base inflexed and partly enclosing the akene: akene broadly linear-clavate, with an evident epigynous disk: pappus of 20–30 plumose bristles as long as the corolla.

Never has a plant come into my hands that was so difficult to place. Superficially it has one or two eupatoriaceous characters, but the real characters unite it to the Helianthoideae. Inadvertently overlooking Greene's genus Bebbia, I applied to Dr. B. L. Robinson for assistance, writing him as follows: "This plant may get into the Helianthoideae. Here by a little amplification of characters it might be included in the Verbesineae or in the Madiae. If in the former, near Varilla; if in the latter, near Layia." I mention this to show that to one to whom the plant was wholly unknown it appeared in such a way as to confirm exactly the views expressed by Greene in the diagnosis of the genus (Bull. Calif. Acad. 1:179).

In regard to the elevation of *Bebbia juncea aspera* Greene (*l. c.*) to specific rank, I believe that no one who will take the trouble to compare the description of the *B. juncea* from Cedros Island, which furnished the type, with the full description of the inland forms will question their distinctness.

The foregoing description was drawn from plants collected by Mr. Gooding at Rioville, Nevada, May 6, 1902, no. 720. It is a low shrub 3–7^{dm} high, occurring on dry sandy hillsides.

Hymenopappus eriopoda, n. sp.—Perennial; the caudex decidedly woody, multicipitous, forming a large dense tuft; stems single from each crown, simple, 0.5–1^{m} high, leafy for more than one-half the height, more or less lanate-pubescent, glabrate upward: leaves numerous, glabrate, some lanate pubescence on the petiole and rachis, bipinnately divided into filiform lobes rarely more than 0.5^{mm} broad; petiole and rachis flattened-semiterete; the primary divisions 2–5^{cm} long; the secondary 1–2^{cm}; root-leaves numerous, crowded on the crowns, their bases involved with the stem in a dense white pannose tomentum, including the petiole 15–20^{cm} long; stem leaves 5–7, the uppermost merely pinnate: peduncles axillary, from the two or three uppermost leaves and from as many minute bracts, very slender, monocephalous, or developing 1 or 2 accessory heads on filiform pedicels, 1–3^{dm} long, the lowest usually much elongated: heads about 12^{mm} high: involucre rusty-tomentose, shorter than the disk; its scales in 2 series, mostly oblong, or oblong-elliptic, obtuse, with scarious margin and tips, rarely purplish: corolla tube obscurely glandular-pubescent, very slender, about 3^{mm} long, expanding into an equally long broadly tubular throat, which is three times as long as its lobes; akene 5^{mm} long, somewhat enlarged upward, pubescent especially on the angles; pappus of numerous linear-oblong obtuse scales half as long as the corolla-tube.

The two related species are *H. lugens* Greene and *H. macroglottis* Rydb., the species now described making the third in the series of long-throated forms (see Rydberg, Bull. Torr. Club 27:636).

Type no. 880, by Mr. Goodding, who reports it as abundant in "rocky volcanic draws" near Diamond Valley, Utah; May 19, 1902.

Tetraneuris epunctata, n. sp.—Caudex simple or with 2-several crowns: leaves crowded on the crowns, glabrate and bright green, with a few long whitish scattered hairs, wholly free from the punctate glands so usual in the genus, some microscopic resin particles present, narrowly spatulate or oblanceolate, 2–4^{cm} long, the margined petiolar bases imbricated on the crowns but not involved in the usual wool of the other species: scapes simple, ebracteate, 1^{dm} or less high, sparsely silky-canescent and obscurely granulate: heads large, 25–30^{mm} broad when fully expanded: involucre silky-lanate; the green tips of its oblong acute bracts mostly free from the wool: the bright-yellow rays about 12^{mm} long: disk corollas penicillate glandular-pubescent on the lobes: pappus scales nearly as long as the disk corollas, obovate, abruptly long-acuminate.

The type of this excellent species is no. 1236, collected by Mr. L. N. Goodding near the Dyer Mine in the Uintah Mountains, Utah, July 3, 1902. Most of the species in this genus are xerophilous plants and strictly vernal, occurring on broken ridges of the plains or on denudated foothills. In the species before us we have an inhabitant of moist subalpine slopes, occupying a belt from 9,000–12,000 feet in altitude. No. 1374 by the same collector was obtained above timber line.

Tetraneuris eradiata, n. sp.—Densely silky throughout: caudex short, of one or more crowns, slightly lanate and covered with the expanded bases of the petioles: leaves crowded on the crowns, linear or narrowly oblanceolate, 5–8^{cm} long, the short petiole margined and expanding at its scarious base: scapes slender, 12–25^{cm} high: heads wholly eradiate, 1^{cm} or more high, the disk almost orange or tinged with brown: pappus-scales obovate, glistening-white, tipped with a slender awn, including the awn almost as long as the silvery akene and scarcely shorter than the corolla.

Collected on steep mountain side at the head of the Middle Fork of Powder River, Big Horn Mountains, by Leslie N. Goodding, July 18, 1901, no. 276.

Gaillardia gracilis, n. sp.—Perennial from a woody root: stems usually several, simple or sparingly branched, slender and somewhat virgate, 5–7^{dm} high, the upper half naked-pedunculate, straw-colored, striate and nearly glabrous: leaves softly and sparsely short-pubescent, oblanceolate in outline, 4–8^{cm} long including the margined petiole, from entire to deeply pinnatifid with linear or broader lobes: the bracts of the involucre moderately canescent, narrowly lanceolate-acuminate, green and the tips somewht reflexed: rays yellow, cuneate, deeply cleft (nearly divided) into broadly linear obtuse lobes: disk purplish-brown: the corolla-teeth short-triangular, without tip of any kind, the penicillate pubescence short: akenes short-turbinate, densely long-villous, about equaling the numerous aristiform fimbrillae of the receptacle: pappus of 10 narrowly lanceolate paleae, as long as the rather broadly tubular corolla.

This will have to be looked upon as segregated from *G. pinnatifida* Torr. I take as typical of *G. pinnatifida* the plant of southern Colorado, southward and eastward. This is known by its almost scapose stems (the leaves being crowded on the crowns or at least well towards the base), by its canescent pubescence, and the fine purple of the disk which extends at least to the veins and the lower half of the ray. *G. gracilis* is twice as tall, with indurated base, leafy to the middle or above, rays wholly yellow and cleft almost to the disk.

The type is no. 894. Mr. Leslie N. Goodding, Diamond Valley, Utah, in deep hot cañons.

Arnica arcana, n. sp.—Tufted or cespitose in rock crevices, about 3^{dm} high: stems slender, minutely granular-glandular especially upward: leaves dark-green, denticulate, somewhat granular-glutinous; root-leaves oblong-oblanceolate, 2–4^{cm} long, on very slender petioles longer than the blade; lower stem leaves small, broadly oblong, sub-acute at apex, abruptly narrowed at base to short margined connate-sheathing petioles; middle stem leaves lanceolate, sessile or nearly so, 3–5^{cm} long; the foliar bracts similar but smaller: heads usually three, on subequal peduncles 5–10^{cm} long; more rarely 1 or 2 smaller additional heads on short slender peduncles proliferous from the base of the central head: involucre turbinate-campanulate, about 1 cm high, shorter than the disk; its bracts in two series, the outer broadly linear, short-acuminate, minutely glandular, the inner narrower, subscarious: rays orange-yellow, obscurely 3-toothed: disk corollas with narrow minutely pubescent tube as long as the gradually dilated throat: akenes linear, dark, sparsely hispidulous.

After deliberating on this for a long time and failing to decide upon even its nearest ally, I submitted it to Dr. Greene, who replied as follows: "This I can refer to no known species; yet it is a feeble thing as to any character." Nevertheless, it seems well to place it on record and to distribute to the herbaria specimens which will enable our students to judge for themselves whether it is a species with "feeble" characters or not.

The type is no. 377, from Doyle Creek, Big Horn Mountains, Wyo., July 26, 1902; collected by Mr. Goodding.

Tetradymia axillaris, n. sp.—A shrub mostly less than 1 m high: stems several from the base, these freely and somewhat fastigiately branched at summit, all very white with a close fine permanent pannose tomentum: spines widely divaricate but not reflexed, very straight, slender, rigid and pungently acute, 2–4 cm long, tomentum somewhat floccose and rather early deciduous: leaves fascicled in axils of the spines, green and glabrous, somewhat fleshy, linear subulate, very unequal, 5–12 mm long: heads solitary, axillary, 5-flowered, on glabrous peduncles as long as the oblong-cylindrical head: bracts of the involucre 5, about 1 cm long, somewhat carinate and rigid, glabrous: pappus bristles much surpassing the copious hairs of the akene.

This relative of *T. spinosa* Hook. & Arn. I was at first inclined to refer to Jones's var. *longispina* of that species. With that variety it has some points in common, but because of the relatively long internodes of the stems, the straight rigid spines which are 3–5 times as long as the fascicled leaves, the glabrous heads, and peduncles which are solitary in the axils, it seems as impossible to unite it with that variety as with the species.

The type no. 917 is from Meadow Valley, Wash., southern Nevada, collected by Mr. Goodding, May 22, 1902.

MISCELLANEOUS SPECIES.

Cuscuta Anthemi, n. sp.—Stems delicately slender-filamentous, only 2 or 3 dm long: flowers sessile in capitate few-flowered clusters about 5 mm in diameter: calyx-lobes broadly ovate, acute, united below the middle, somewhat imbricate, equaling or at first surpassing the corolla: corolla less than 2^{mm} long; its lobes ovate, acute, equaling or longer than the broadly campanulate tube: scales oval, fringed around the summit with short processes: filaments about as long as the anthers: capsule globose, about 1^{mm} in diameter: stigmas linear, purple, as long as the distinct equal styles; stigma and style together 1^{mm} long: ovules 4, usually but 1 maturing.—On *Artemisia gnaphalodes.* Wyoming.

When Dr. Rydberg published his *Cuscuta gracilis* (Bull. Torr. Bot. Club **28**: 501), founding it in part upon material that had passed for *C. epilinum,* I was at first inclined to doubt the presence of indigenous species in this country possessing the characters that Gray and Engelmann had considered as possessed only by old world species. I am satisfied now, however, that both types occur here. Species undoubtedly indigenous and having characters clearly separating them from the European forms, with which we have been wont to ally them, leave no room for doubt.

The species now proposed was collected in the Seminole Mountains, Wyo., by Mr. Elias Nelson in 1898, no. 4936. It was found on *Artemisia gnaphalodes,* but I have no doubt it will be secured on other species of the Anthemideae.

Pectocarya miser, n. sp.—Minutely appressed-strigose, branched from the base, the several stems filiform, spreading, $5–20^{cm}$ long: leaves linear, imperfectly opposite, mostly less than 1^{cm} long, the floral one of the pair reduced or wanting: flowers singly at the nodes: nutlets geminate, very flat, irregularly and narrowly winged on the sides, sides and apex bordered with hooked bristles, the dorsal disk slightly keeled and glandular-hairy.

Known only from the type locality, Point of Rocks, Wyo., where it was collected by the writer, June 15, 1898, and distributed under no. 4741 as *P. penicillata* H. & A.

Orobanche xanthochroa Nels. & Ckll.,[1] n. sp.—Glabrous, $20–25^{cm}$ high: stem bracteate: the bracts large (20^{mm} long and 7^{mm} broad at the base), the upper of these covering rudimentary flowers: spike $10–12^{cm}$ long, about 38^{mm} broad, densely flowered: floral bracts single, acuminate-lanceolate, 17^{mm} long: flowers entirely pale yellow: upper lip large (9^{mm} broad, surpassing the calyx by 7^{mm}), rounded, entire or with two slight notches:

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[1] The characters of this plant were worked out by Professor Cockerell from the living plant. It has had further study in the herbarium.—A. N.

anthers with a fringe of long hairs on each side, but not otherwise hairy; anther cells caudate basally: calyx with five short triangular lobes about 2^{mm} long: discoid stigma about 3^{mm} broad: capsule oval, somewhat pointed apically, $10–11^{mm}$ long, about 7^{mm} in diameter; style persistent, nearly 9^{mm} long, strongly curved: seeds very numerous, irregularly angular, light-brown, obscurely pitted.

The affinity of this species is with *Orobanche Ludoviciana* Nutt. It turns ferruginous on fading or after bruising. First collected, June 7, 1903, by Dr. M. Grabham, at Pecos, N. M., where it occurs as a parasite on the roots of Quercus.

THE ROCKY MOUNTAIN HERBARIUM,
Laramie, Wyoming.

THE EVOLUTION OF THE SEX ORGANS OF PLANTS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY.

LV.

FLORENCE LYON.

(WITH SIXTEEN FIGURES)

WITHIN the last twenty-five years there have been repeated attempts to bridge the chasm between the bryophytes and algae, but no transitional stages have been found between the unicellular sex organs of the green algae and the multicellular archegonium and antheridium of the bryophytes.

Morphologists have persistently fixed their attention upon the Chlorophyceae in their search for ancestral conditions, and have regarded the brown and red sea-forms as aberrant. Perhaps this is because no bryophytes, so far as is known, occur in salt or brackish water, and but few forms of brown algae exist in fresh. More likely, the attention focused on the alternation of generations, and the suggestion of an antithetic sporophyte and gametophyte in Coleochaete, Oedogonium, and Ulothrix, have been so dominant that the other groups have been set aside as unfruitful fields for investigation. All morphologists of note have laid stress upon the development of the sex cells and the sex organs as of the greatest importance in determining any theory of evolution. While the vegetative part of the gametophytes of bryophytes and pteridophytes is most changeable, appearing in many bizarre forms in the leafy jungermannias and the mosses, and varying from thin sheets of cells of the most primitive sort to tuberous bodies with highly differentiated tissues in the club mosses, simulating those of the higher plants, the sex organs of a group retain, as a rule, a constant monotonous type, varying from one another in related genera only in unimportant details, such as the length of the neck, the presence or absence of a stalk, the total emergence, or the whole or partial submergence of the archegonium in the vegetative tissues.

In the course of conducting university classes in general morphology for the past few years, I have had occasion to examine many preparations of representative plants of the chief groups, and have become impressed by the comparative frequency of certain irregularities in the development of the sex organs, particularly in pteridophytes, that show their plasticity and are suggestive from the evolutionary standpoint. I am inclined to look upon the "monstrosities," as biologists are fond of calling organisms which do not conform to a morphological rule of thumb, as presenting hints of ancestral conditions which afford at least a logical theory of the origin of the sex organs.

In a recent paper on the "Origin of the archegonium," Davis (1) has given a series of diagrams of hypothetical transitional forms to illustrate his view of the evolution of the sex organs from a plurilocular sporangium similar to that of *Ectocarpus virescens.* His theory would be far more convincing had he cited actual rather than hypothetical transitional forms, and such evidence is not difficult to obtain.

In an article on the development of the archegonium of mosses, Hy (2) describes an organ of mixed sexual character which has the egg apparatus at its base, and is distinctly spermatogenous at the summit. This phenomenon, he says, is not uncommon, occurring in several species— notably in *Atrichum undulatum.* Unfortunately he gives no figures of this interesting variation. Many instances of a similar nature in *Mnium cuspidatum* were observed by students in the Hull Botanical Laboratory two years ago, and figures of bisexual organs from this material appeared in Holferty's (3) paper in the February number of the BOTANICAL GAZETTE. None of the plants in that collection was mature enough to determine the future of the gametes, or whether the sperms were actually formed.[1] That the tissue appearing in a single organ consisted of immature cells of two kinds there can be no doubt. That antheridium and archegonium are homologous organs is a logical conclusion from the fact that cells at the apex of a moss shoot may indifferently develop into male,

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[1] Since the above was written, specimens have been secured with perfectly typical moss sperms which were discharged from the antheridial region above the egg.

female, or bisexual organs. Further evidence to support this view of the homology of the sex organs, and that the simple axial row of an archegonium is reduced from forms which had two or more, is furnished by several groups of pteridophytes.

In three species of Equisetum (*E. hiemale*, *E. arvense*, *E. limosum*), the archegonium frequently consists of an egg, a shallow ventral canal and two neck canal cells pyriform in shape and lying side by side (*fig. 1*). Jeffrey (4) regards an archegonium of this form as typical. In his monograph he figures *E. arvense* and *E. hiemale* with two neck canal cells in this position, and the text calls attention to this characteristic.

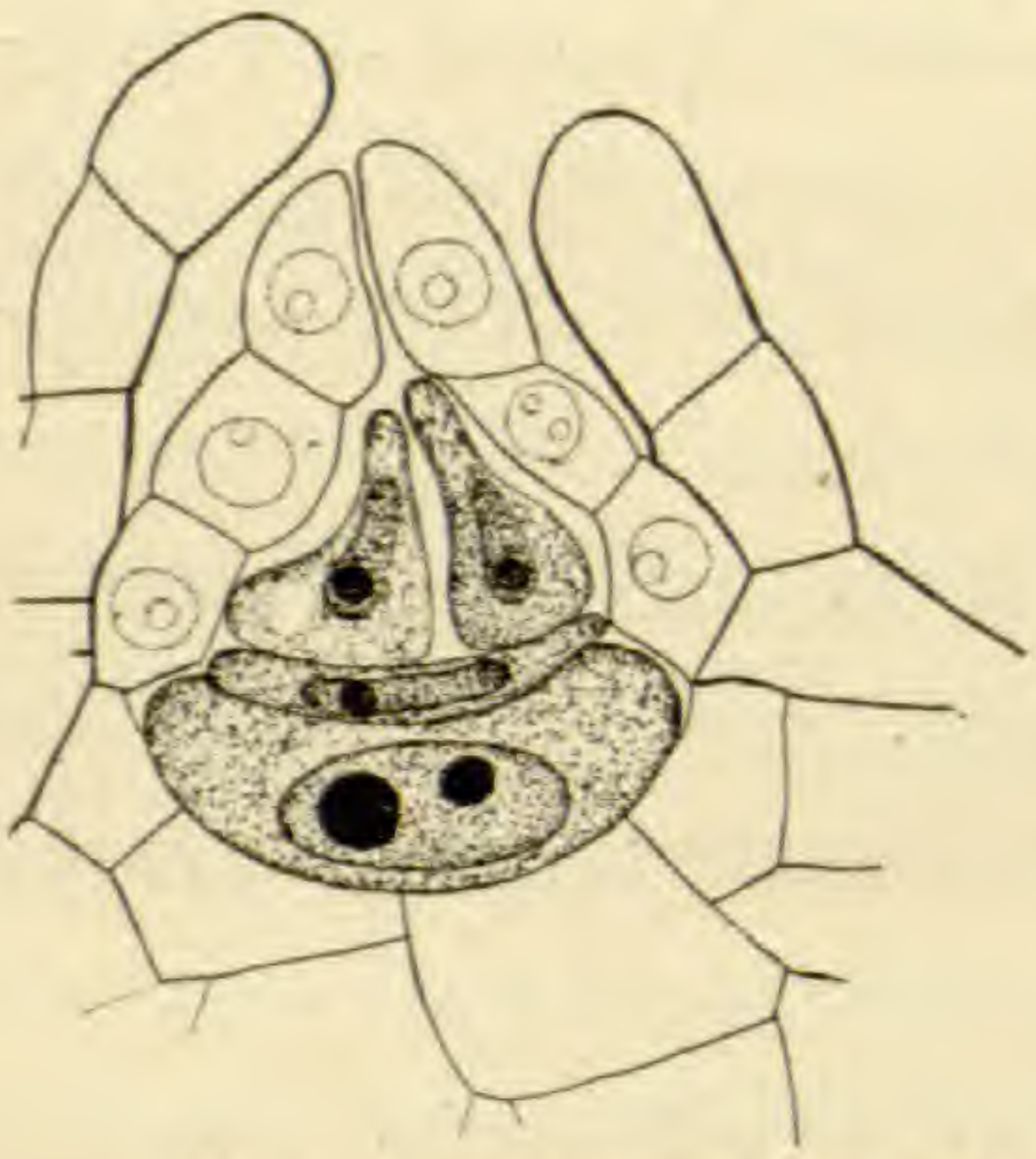

FIG. 1.—Longitudinal median section of archegonium of *Equisetum limosum*, showing the lateral position of the neck canal cells.

I have a few specimens showing the same conditions in *Isoetes lacustris* (*fig. 2*). Campbell (5) found two laterally placed nuclei in the single neck canal cell of *Isoetes echinospora* with no intervening wall.

Occasionally a division of the lowermost cell of the axial row, probably the "central" cell, occurs in *Selaginella apus*. This possibly may be interpreted as an egg and a ventral canal cell laterally placed (*fig. 3*). That they may both function as eggs seems evident from the case of polyembryony shown in *fig. 4*.

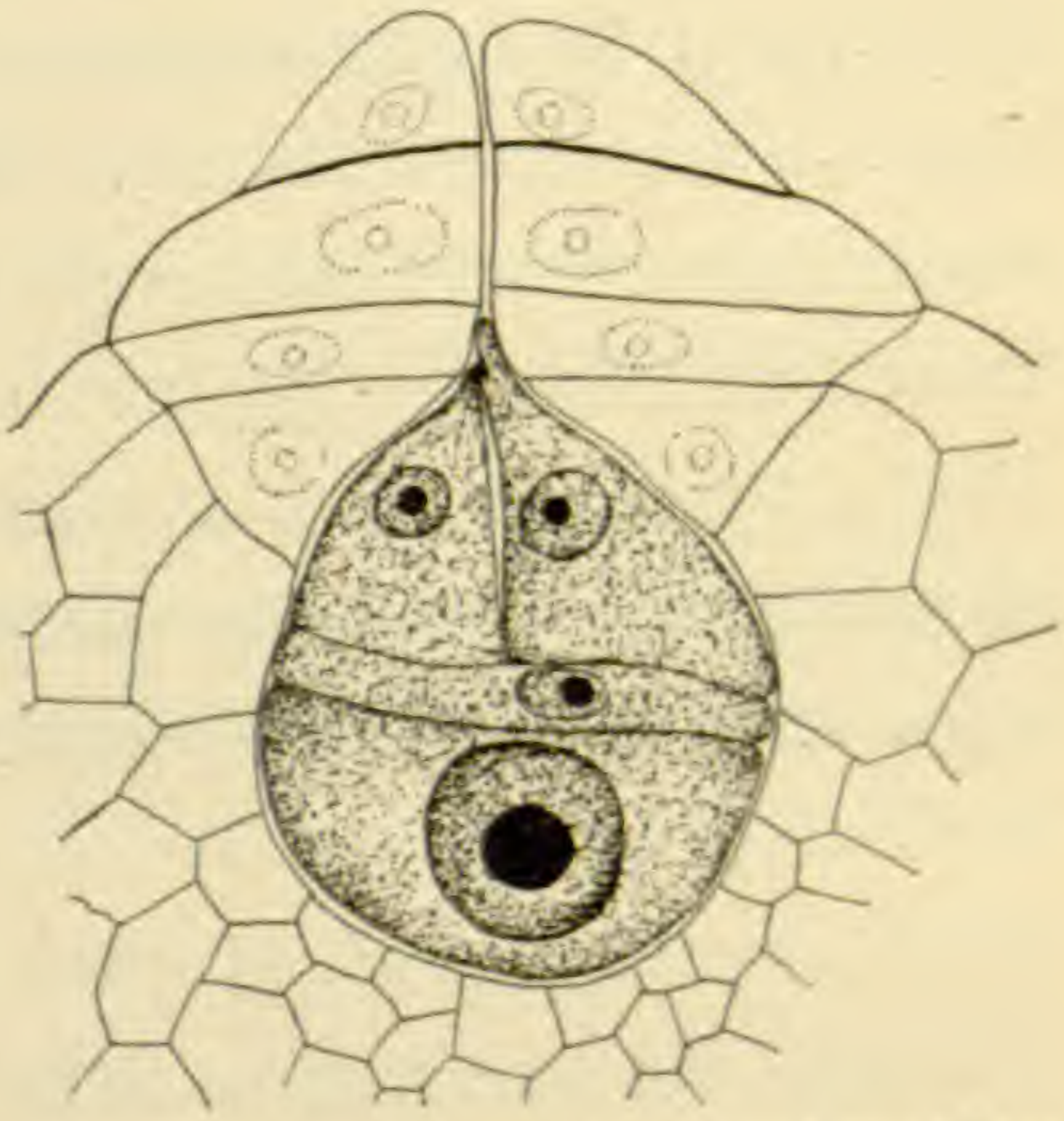

FIG. 2.—Longitudinal median section of an archegonium of *Isoetes lacustris*, showing lateral position of the neck canal cells.

But much more striking are the sex organs of at least two species of Lycopodium. It will be remembered that the gametophytes of only eleven species of this genus have ever been discovered, and that these differ so markedly among themselves as to be divided by Pritzel into five categories. They range from the simplest to the most complex gametophytes known, with the possible exception of certain mosses. I have a prothallus of *Lycopodium complanatum* bearing fifty or more archegonia; of these more than half have binucleate canal cells, and there are two instances in which the egg cell is included in the doubling (*fig. 5*). The remarkable number of cells in the axial row (often 14–16) marks these as unique amongst known archegonia of the imbedded type. I do not recall that Bruchmann (**6**), to whose notable work we are indebted for the knowledge of the gametophytes of this and other European species of Lycopodium, mentions the multiplication of the fertile cells, although one of his figures certainly shows it; but Treub (**7**) lays stress on the fact that the canal cells of *Lycopodium Phlegmaria* show a marked tendency to form two axial rows. I have taken the liberty of copying two of his figures (*figs. 6, 7*). Treub says that he frequently found archegonia of this sort, and all of his figures show it. He observed an interesting "monstrosity" twice. This was an archegonium whose upper neck canal cells increased to an abnormal number and were spermatogenous in character. He neglected to illustrate this duplex organ, but in this connection he recalls the similar phenomenon referred to by Hy (**2**) in mosses, and regards it as of importance. In all these variations there has been a tendency to increase the number of fertile cells by a lateral multiplication of the axial row.

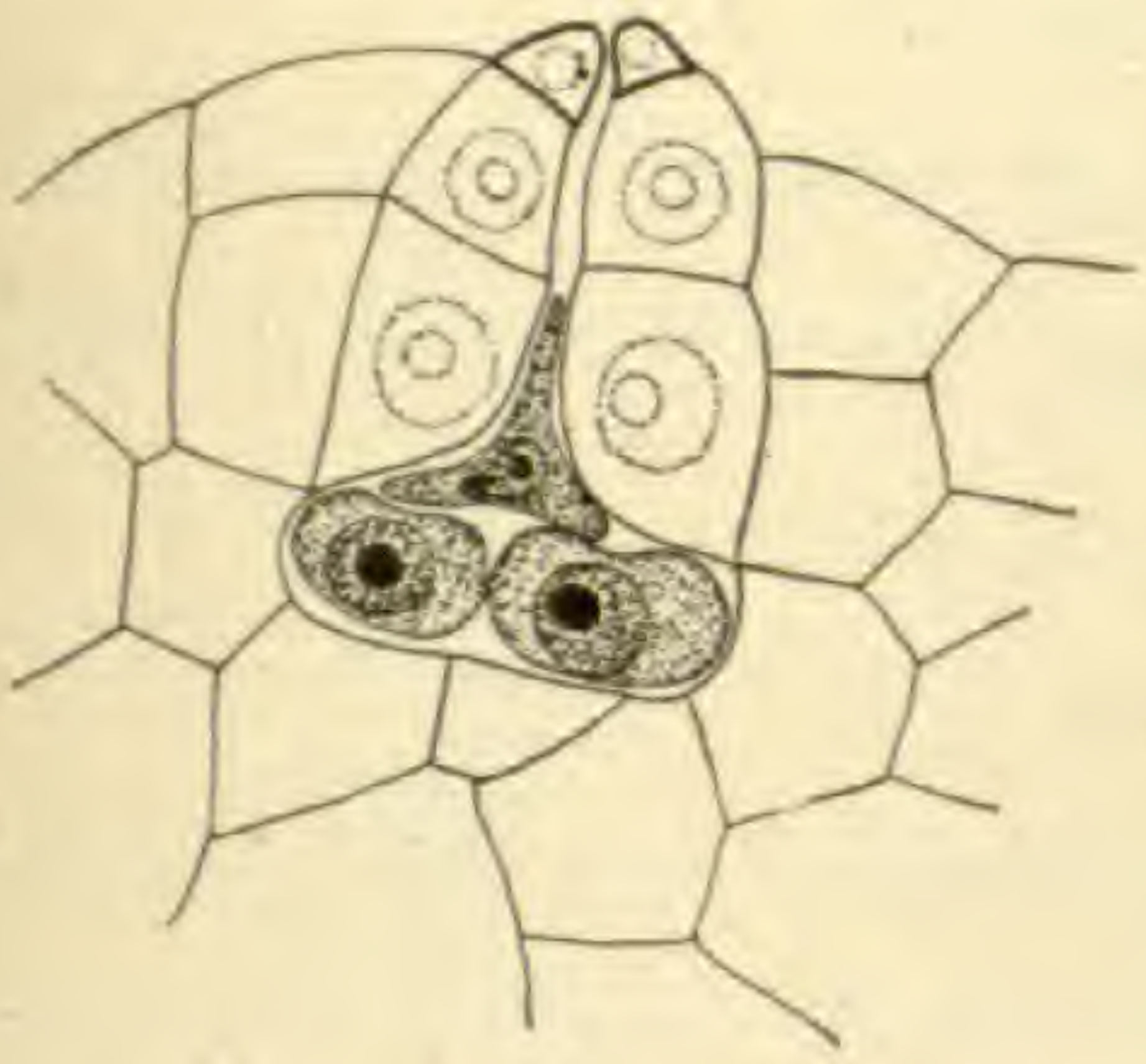

FIG. 3.—Longitudinal median section of an archegonium of *Selaginella apus*, showing lateral position of egg and ventral canal cells.

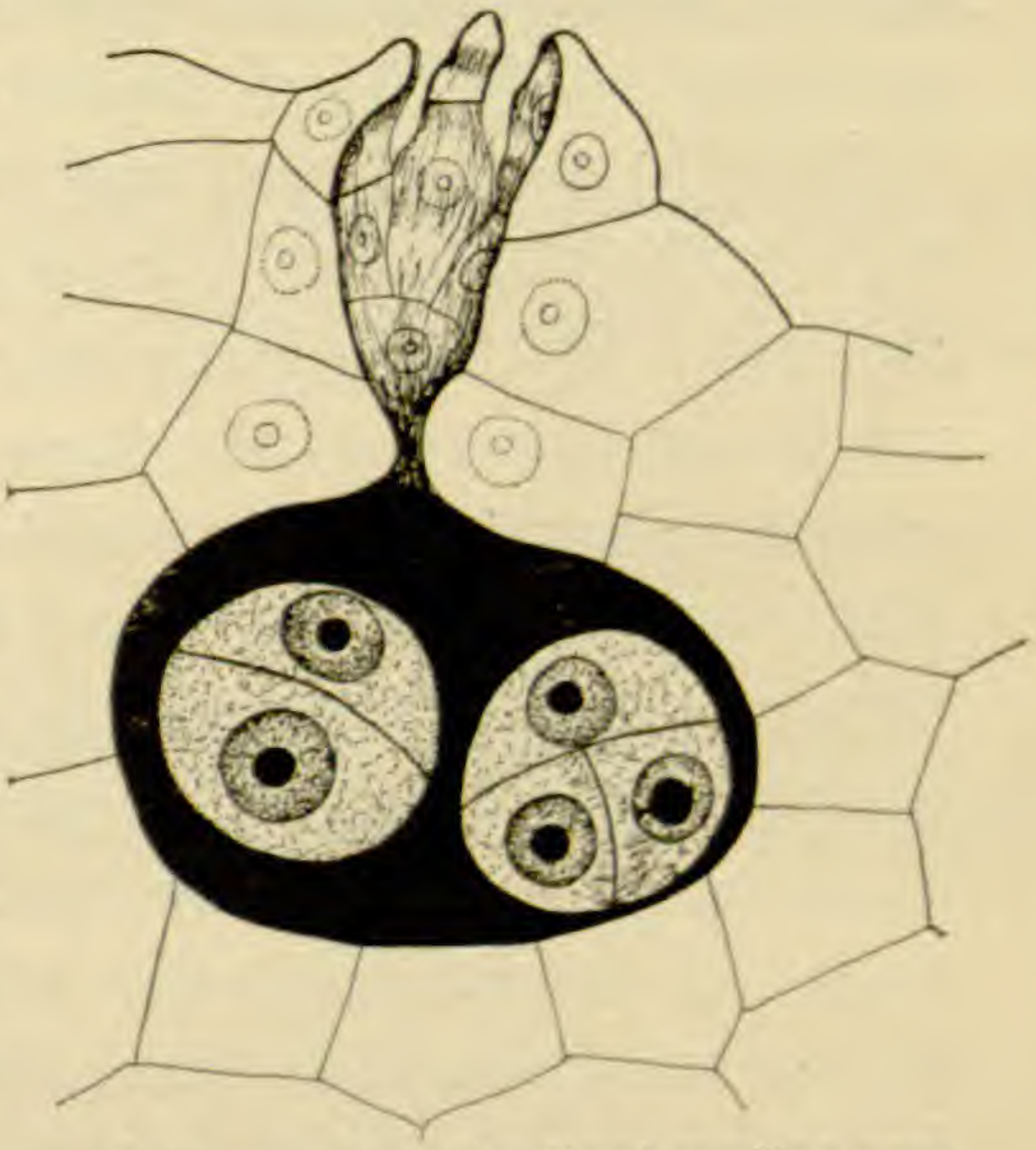

FIG. 4.—Longitudinal median section of archegonium of *Selaginella apus*, showing embryo derived from egg and ventral canal cells.

In quite another category is the archegonium of *Adiantum* *cuneatum* (*fig. 8*). Here two eggs are separated by two ventral canal cells lying below the two typical neck canal cells. Coker (8) has described and figured an archegonium of *Mnium* sp. with two eggs lying one above the other and each with a ventral canal cell. A *Funaria hygrometrica* preparation in my possession also shows this variation.

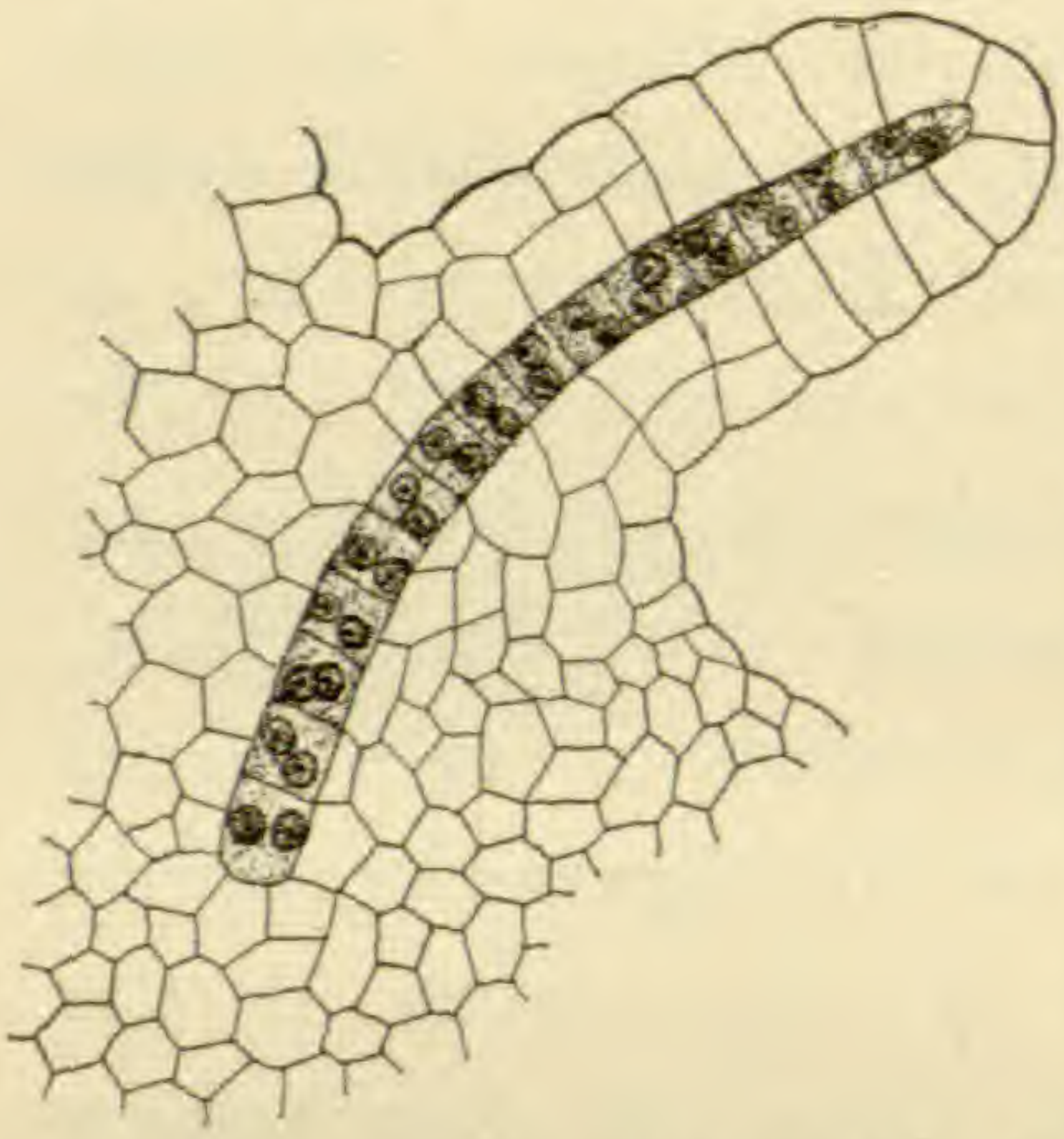

FIG. 5.—Longitudinal median section of an archegonium of *Lycopodium complanatum*, showing the lateral multiplication of the cells of the axial row.

The sex organs of some fern prothalli[1] gathered in an Indiana bog last summer display remarkable plasticity of form and character. The sex organs were developed in profusion on these prothalli, and the mat as it was stripped off a log appeared beset with young sporophytes. Everything in their appearance bespoke most luxuriant growth. Upon sectioning this material, the number of embryos formed from the sexual spores was found to be limited. Many of them are apogamous, developing most frequently from the "jacket" cells of the thallus in immediate contact with the egg. The archegonia were perfectly normal in development, the neck canal cells dissolved, the neck opened and became choked with vigorous-looking sperms, but for some reason in most cases the egg failed to become the progenitor of the sporophyte. I have not been able to determine whether there is fusion of sperms with the cells that give rise to the apogamous embryo, although there is some evidence of that condition. The archegonium neck behaves peculiarly. Instead of breaking down or becoming brown, as is the ordinary rule, in certain cases the lowermost neck cells branch and develop rhizoid-like filaments or even antheridia which mature

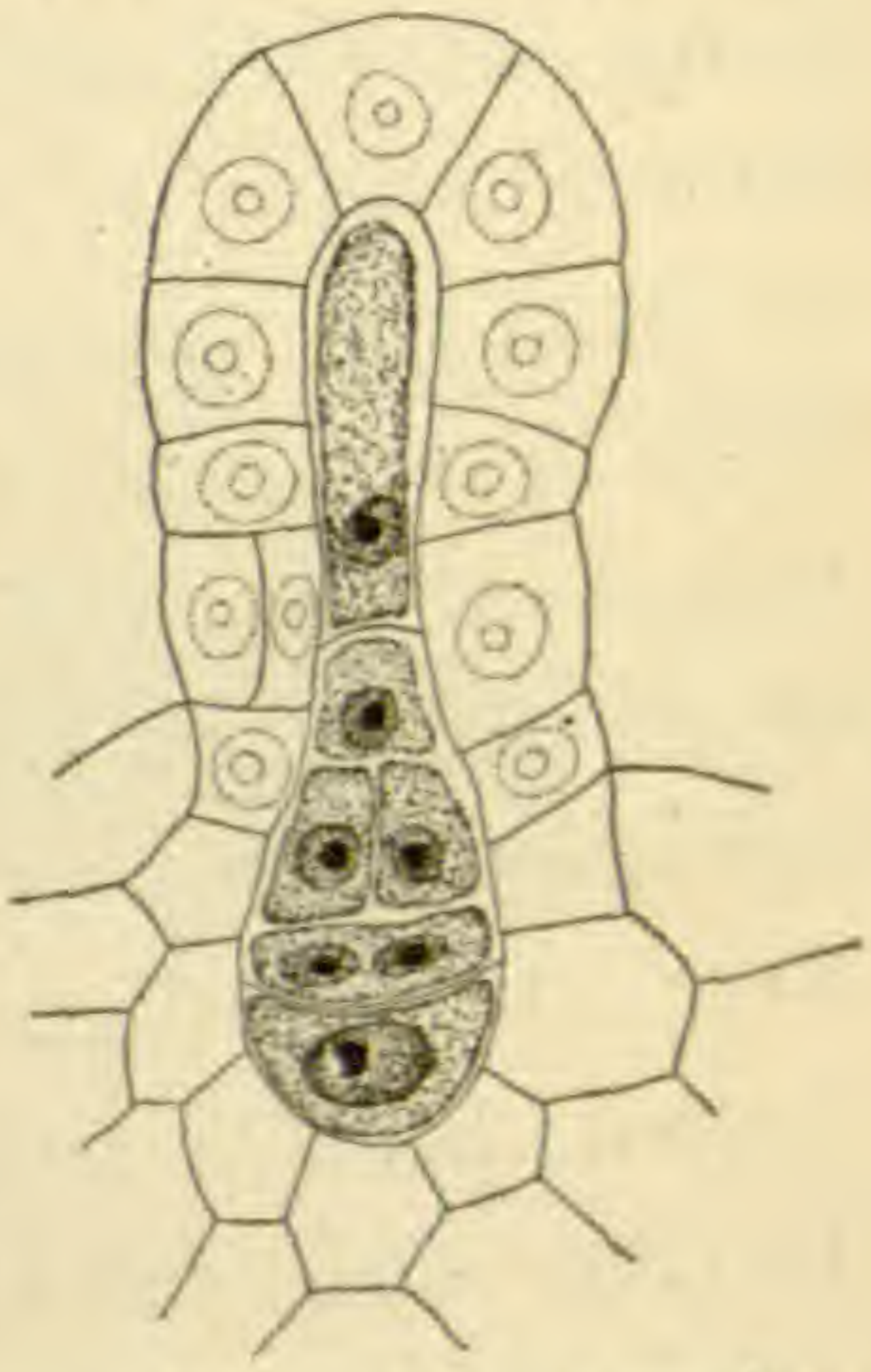

FIG. 6.—Longitudinal median section of an archegonium of *Lycopodium Phlegmaria*, showing the "doubling" of the axial row.—After TREUB.

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[1] The species was undetermined. In the immediate vicinity were growing three species of Osmunda. Probably the gametophytes belong to this genus.

and whose sperms have every appearance of being normal. The number of sperms produced, however, may be smaller than usual. Sometimes two or three antheridia are developed from the neck cells of the same archegonium (*fig. 9*). This is cogent evidence that the cervical cells of an archegonium are sterilized gametogenous cells which may regain potentiality. Goebel (**9**) describes the same phenomenon of antheridia developing from the neck cells of archegonia of *Hemionitis palmata* and *Lygodium japonica*. He comments thus: "Wir können dieses Verhalten als eine Altenserscheinung betrachten." But that can hardly be the explanation of the phenomenon in this case, for the prothalli were young and displayed unusual vigor. All stages of archegonia and antheridia appear in a single thallus.

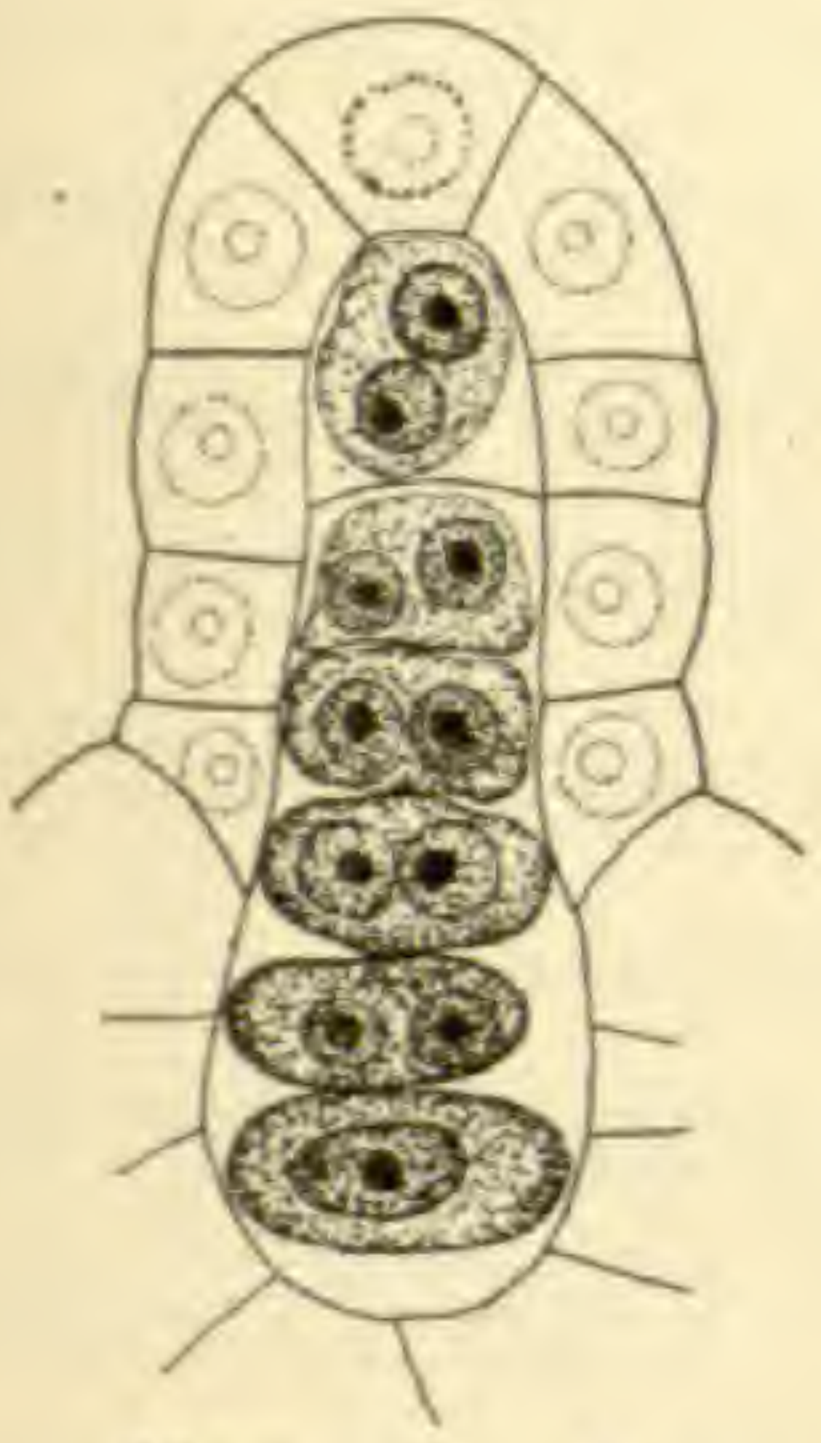

FIG. 7.—Longitudinal median section of an archegonium of *Lycopodium Phlegmaria*, showing two rows of neck canal cells.—After TREUB.

Aberrant antheridia have been less frequently noticed. The form of the male organ seems to be singularly simple and monotonous throughout the bryophytes. I have found a variation of frequent occurrence, however, in the antheridium of *Atrichum angustatum*. The spermatogenous cells are separated into two groups by a transverse septum consisting of a single layer of cells formed from fertile cells that ceased to divide early in the development of the organs, and at about the period at which the wall is differentiated. Sometimes these two groups matured *pari passu;* again, the sperms were ready to escape from the upper or under chamber indifferently, while the other group was immature (*fig. 13*). This division of the sperm mass is the rule in *Selaginella apus* either with or without the intervening diaphragm as in Atrichum and in certain Hydropterideae. As is well known, at

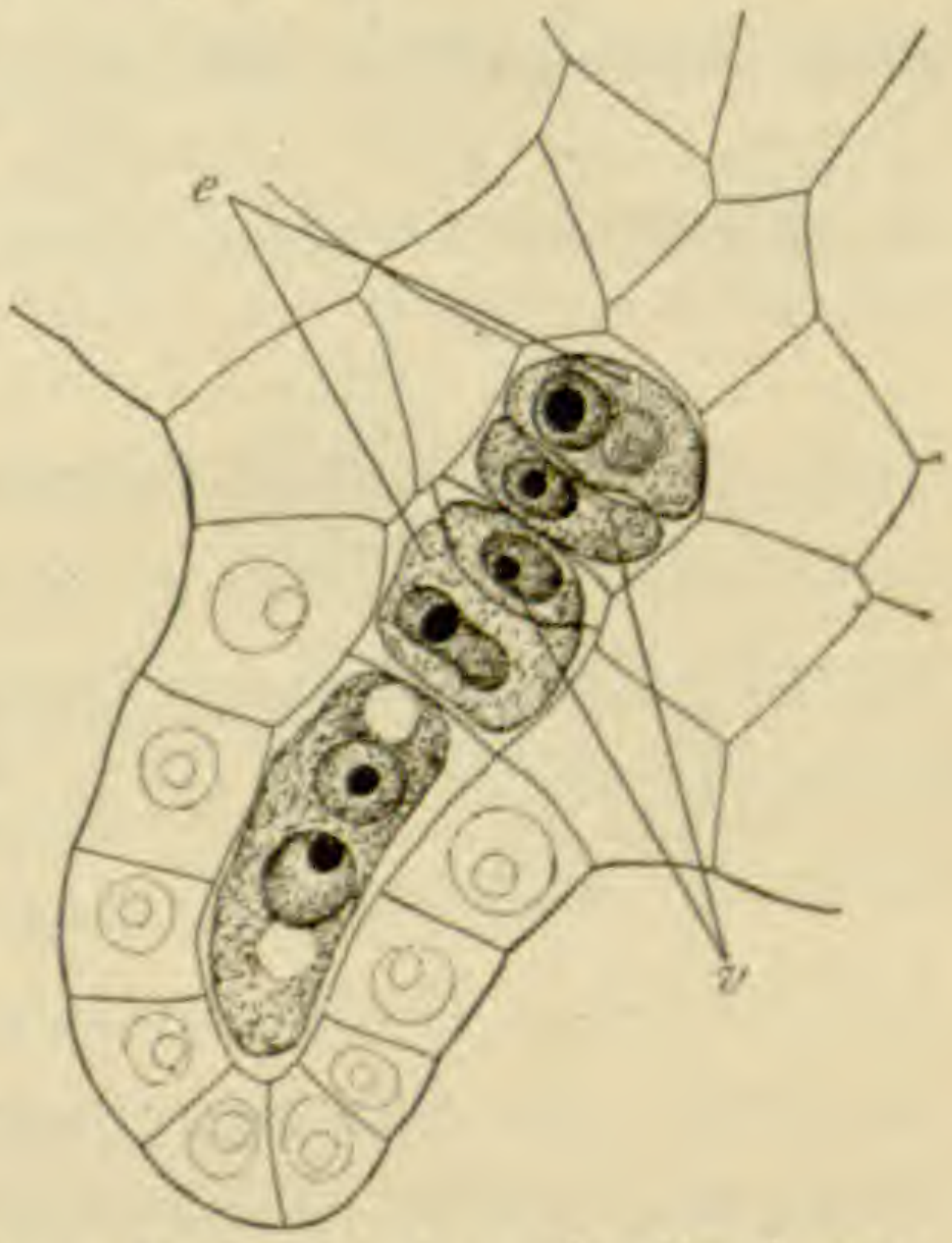

FIG. 8.—Longitudinal median section of an archegonium of *Adiantum cuneatum*, showing double egg apparatus: *e*, eggs; *v*, ventral canal cells.

the moment of the development of an antheridium, when the wall is delimited from the potential spermatogenous cells, the latter are few in number and their walls become so much thicker than those which appear in their subsequent divisions, that the mature organ in section displays conspicuous plots, which frequently mature at different periods. Not rarely one or more of these cells fails to produce the same number of generations as the others, and so certain large spherical cells (for they separate from one another) may sometimes be found intermingled with mature sperms (*fig. 10*). I am inclined to regard these as eggs. Campbell reports budding of "secondary" antheridia from the stalk of an older Anthoceros antheridium, and the same thing has been seen in this laboratory. This variation is analogous to the formation of antheridia from the neck cells of the fern archegonia.

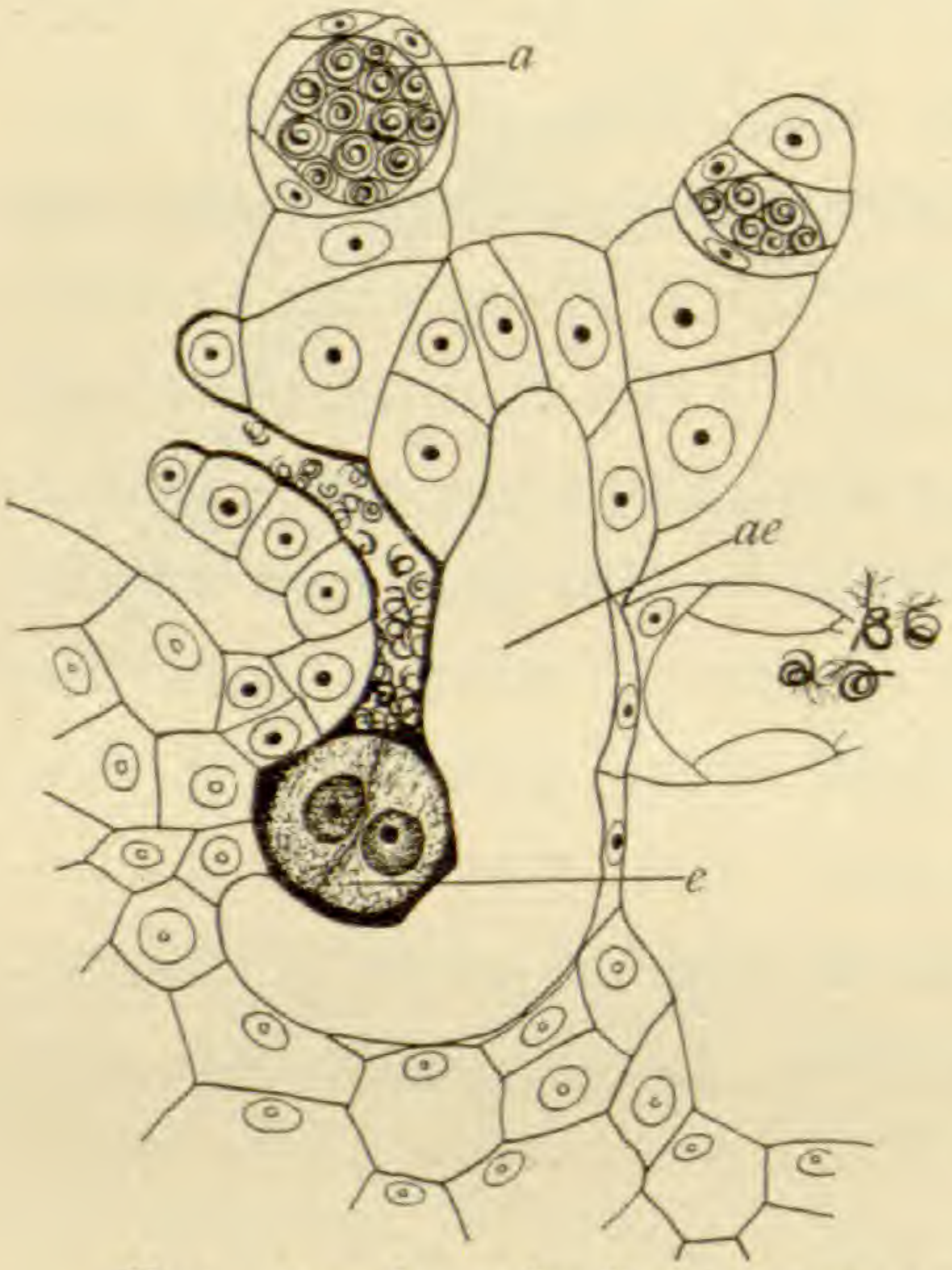

FIG. 9.—Longitudinal median section of "monstrous" fern archegonium, showing three antheridia developed from neck cells (*a*), an apogamous embryo(*ae*), and a normal two-celled embryo in the venter (*e*).

The antheridia of the apogamous fern prothalli described above were also *sui generis*. Those developed in young prothalli were typical. But those formed among the archegonia were frequently double, two antheridia on a single stalk (*fig. 11*). Upon investigation, this proved to be a case of budding of a secondary antheridium from another well advanced. Both antheridia produced perfect sperms that were voided. A frequent variant on this was a rhizoid-like branch from the stalk of the antheridium. A most interesting case of apogamy was observed twice. In these cases the embryo was formed from the stalk cell of an *antheridium!* This has not been observed, I think, by Lang (10) or any other investigator who has worked on apogamy.

In this connection and *à propos* of this unstable and plastic condition of the sex cells the preliminary announcement of apogamy in *Selaginella rupestris* may be made. It may be recalled that this is the form of Selaginella with a reduced number of functional megaspores (one or two) which are not shed until the embryo is fully equipped with leaves and root. In certain localities, the microspores are rarely produced and the embryos are frequently formed from the initial cell of the archegonium. Until the third or fourth division of this initial, it is impossible to determine whether a normal archegonium will result or an embryo.

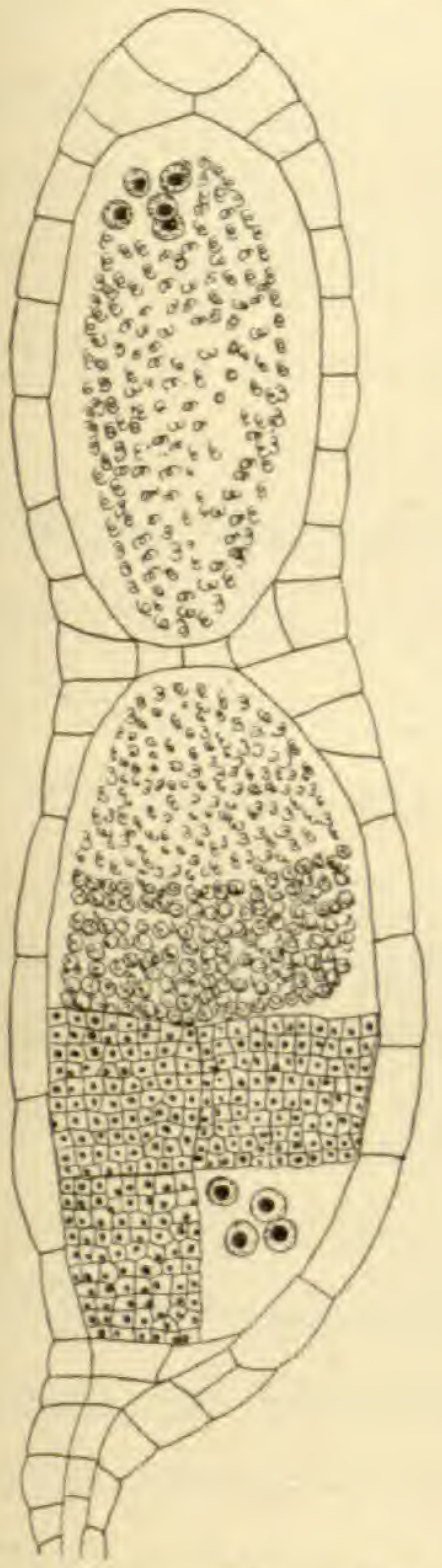

FIG. 10.— Antheridium of Atrichum, showing two chambers.

The development of the antheridium of the Anthoceros group has until recently been looked upon as unique. The male organ of no other group is known to arise from a hypodermal cell. The fact that this antheridium, sunken below compact tissue, has a well-developed wall, militates against the view that it is a primitive form. Emma Lampa (**11**) has noted Anthoceros plants which develop emergent antheridia arising from superficial cells, similar to those of other groups of liverworts, and believes them to be a reversion to an ancestral form. I do not regard them in the same class with the sunken sex organs of Lycopodium, Botrychium, Phylloglossum, Equisetum, and the archegonia of Selaginella, Isoetes, and Anthoceros, which have no sterile jacket. These, to my mind, represent a different line of evolution from the emergent sex organs with long necks and stalks. Davis's theory of the pluriculocular sporangium-like body of a definite form and bisexual character, essentially an emergence of fertile tissue from the surface of a hypothetical thallus body which came to

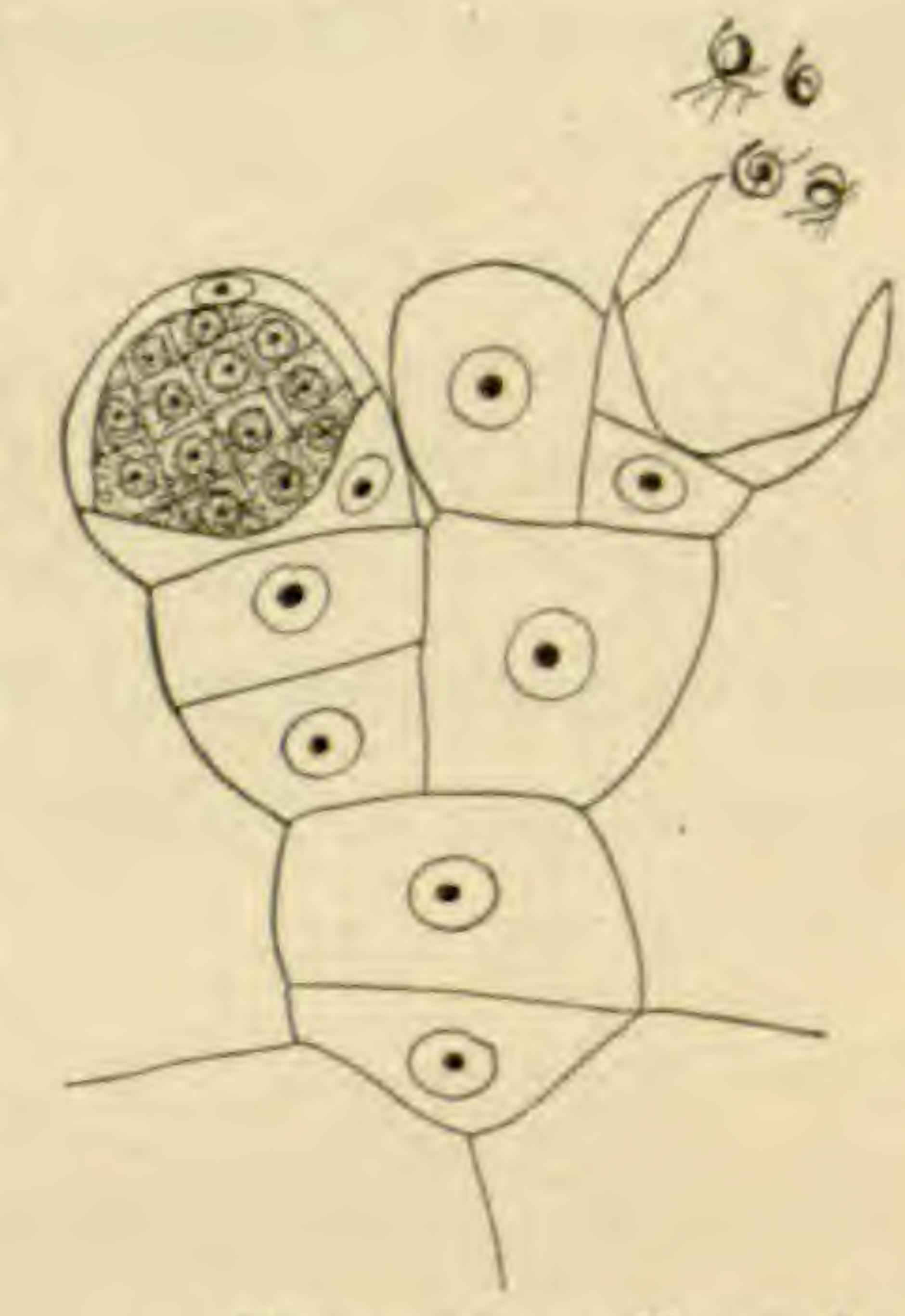

FIG. 11.— Branching antheridia of Osmunda (?).

adopt the land habit, seems to account plausibly enough for the *emergent* archegonium and antheridium of the Marchantia and moss type, but it is less convincing as the ancestral form of sunken sex organs, particularly those which have "lost" (?) stalk, wall, and other sterile cells except the cover. The sunken sex organs of all plants develop from an epidermal cell of the *dorsal* surface of the gametophyte, except in ferns and the Anthoceros forms, in which they are frequently produced on both dorsal and ventral sides. This is true of Anthoceros, but I know of no authority that it is the case in Notothylas or Dendroceros.

In speculating upon the early development of the sex organs and the significance of the variations noted above, one fact stands out prominently, that the cells concerned in the formation of the sex organs are more plastic and indifferent than has been believed, and that the region giving rise to the sex organs not infrequently displays a latent gametogenous character. One might go back further to a stage preceding the emergent plurilocular sporangium and postulate as a point of departure thallose algae with indeterminate masses of reproductive cells which pass through the plant from one surface to the opposite. With increasing thickness of the thallus, sterilization will be most likely to appear at the center of the mass and, working progressively from the center outward in both directions, would result in layers of gametogenous or sporogenous cells at each surface. These concrete masses by further sterilization might become discrete patches or "organs," if one chose so to designate them. Cover cells would arise from sterilization of the superficial cells of these regions. Up to this point there might be isogamy, or even the indefinite condition that obtains in Ulothrix, where zoospores cannot be distinguished from gametes. Differentiation of sex cells could be accounted for by certain cells ceasing to divide earlier in their development than others, resulting in eggs, as contrasted with those that by repeated divisions work out sperms. In this way some of the primitive organs in all probability would be bisexual. The emergent sex organs could evolve from these sunken forms by pushing the sterilization idea further and considering eruptions to arise from the thallus. This fertile branch could easily evolve into an archegonium or an antheridium, or an organ of mixed character.

But however fascinating and probable a scheme of evolution is, it deserves scant attention unless it can muster at least circumstantial evidence to support it. Illustrations of all the phases which I have suggested may be readily found among the algae, especially the browns. *Ulva lactuca* is a thallose green alga which consists of two layers of cells throughout, except at the period of reproduction, when irregular masses of these cells subdivide into gametes with two cilia, or zoospores with four. Thus in certain regions the thallus becomes eight or even sixteen layers of cells thick, all of these being fertile (*fig. 12*). *Phyllitis caespitosa* consists of sterile cells in the central region of its thallose body, while the layer of cells on each surface subdivides into gametogenous or sporogenous cells (*fig. 13*). *Punctaria latifolia* has patches of these cells separated into primitive organs by sterile tissue (*fig. 14*). Moreover, these patches are distinctly of two sorts, the one consisting of few large cells, the other of small cells which discharge sperms said to fuse with the larger cells (eggs?). Zanardinia has exogenous sex organs of two kinds (*fig. 15*). The branching of the male sex organs is of interest and may suggest a clue to that aberration in Anthoceros, Mnium, and the ferns hitherto

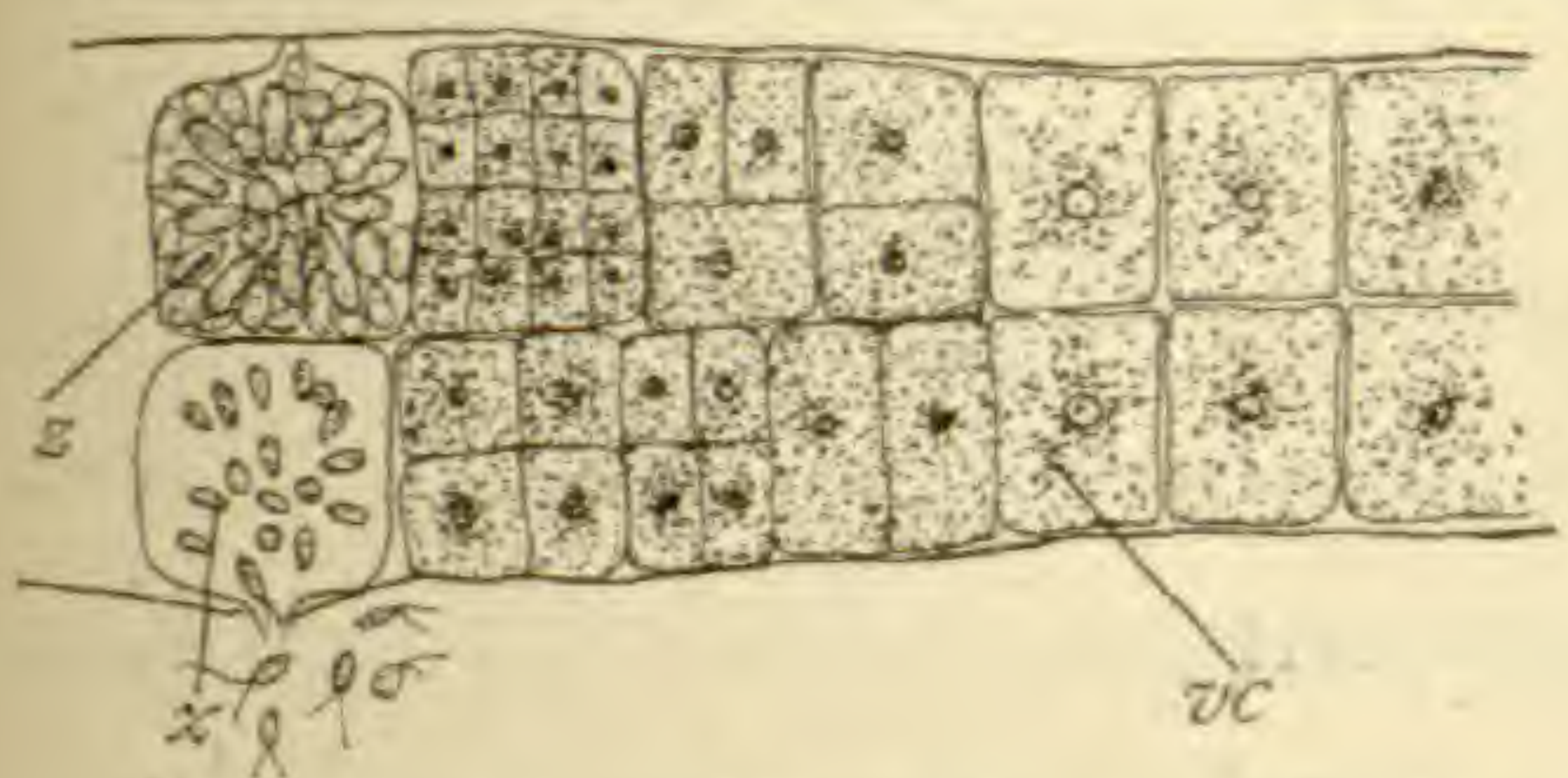

FIG. 12.—*Ulva lactuca:* dorsiventral section of thallus, showing vegetative cell (*vc*), cells in process of forming zoospores and mature zoospores of two sizes (*x*, *z*). Diagrammatic.

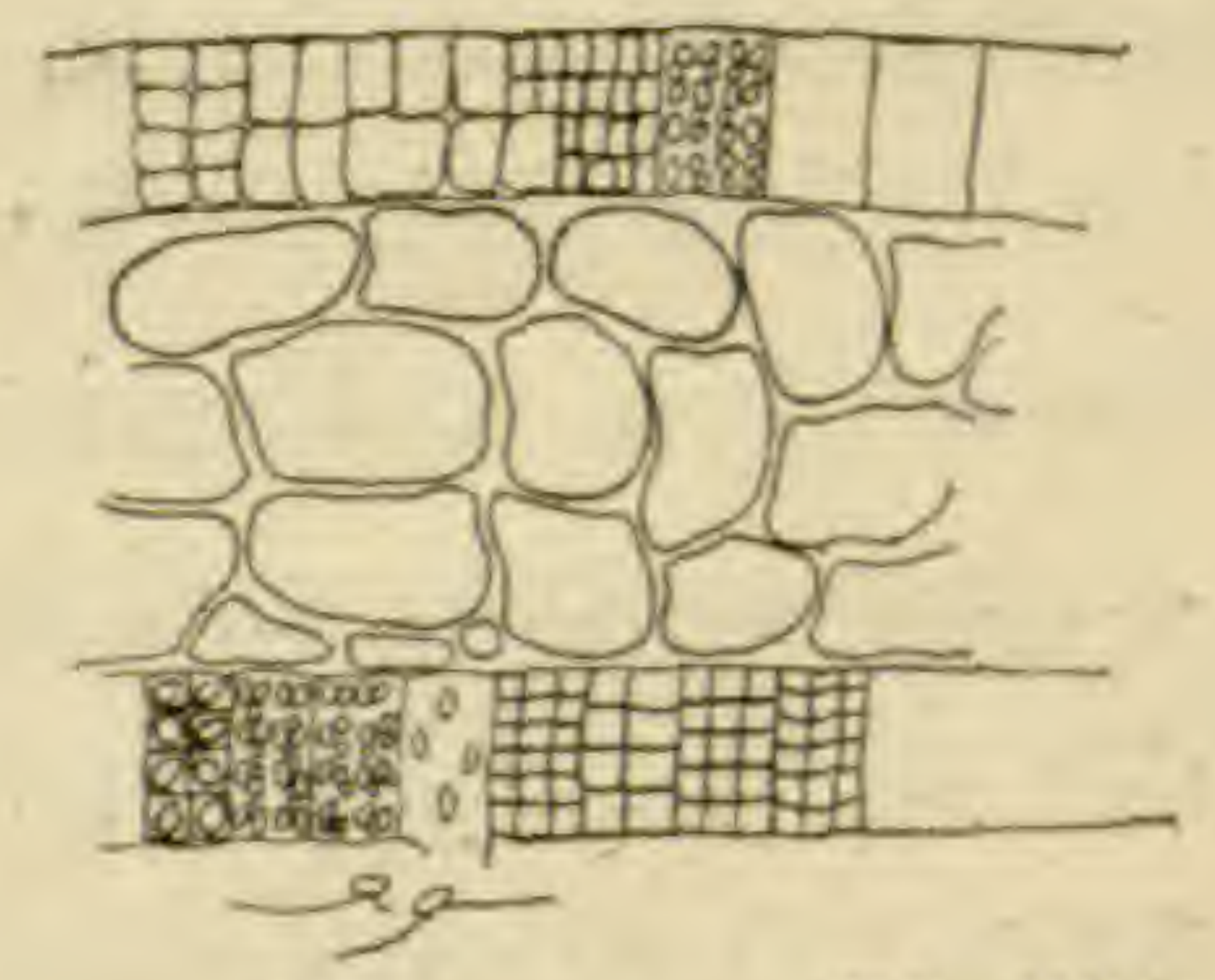

FIG. 13.—*Phyllitis caespitosa:* dorsiventral section of thallus, showing reproductive cells at both surfaces; sporangia form a continuous layer on each.—After RIOCREUX.

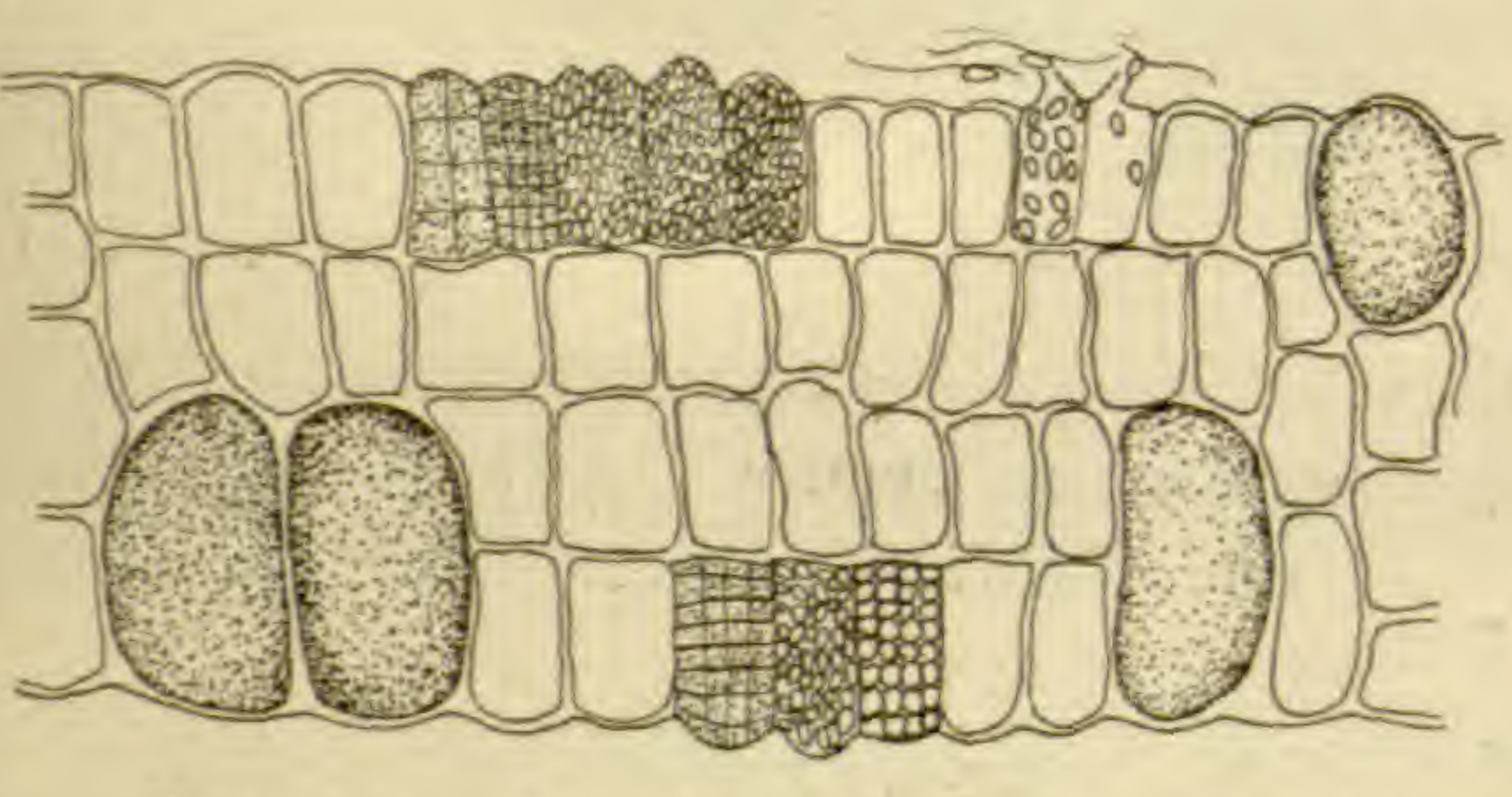

FIG. 14.—*Punctaria latifolia:* dorsiventral section, showing sexual cells in patches on both surfaces.

described. In his anatomical study of Porphyra, Janczewski (**12**) describes the two sorts of sexual cells produced, the "antherozoids" and the "octospores," and says that he considers the latter as antheridia whose final segmentation has been arrested. He says further: "Je considère comme une *anthéridie* le groupe d'*anthérozoïdes* siégeant dans une maille du réseau, correspondant à une octospore, et issu par conséquent d'une cellule végétative. Le développement des anthéridies est d'abord tout à fait semblable à celui des octospores. Il obéit ensuite aux mêmes règles, et l'on dirait que les octospores ne sont que des anthéridies dont la segmentation ultérieure a été arrêtée."

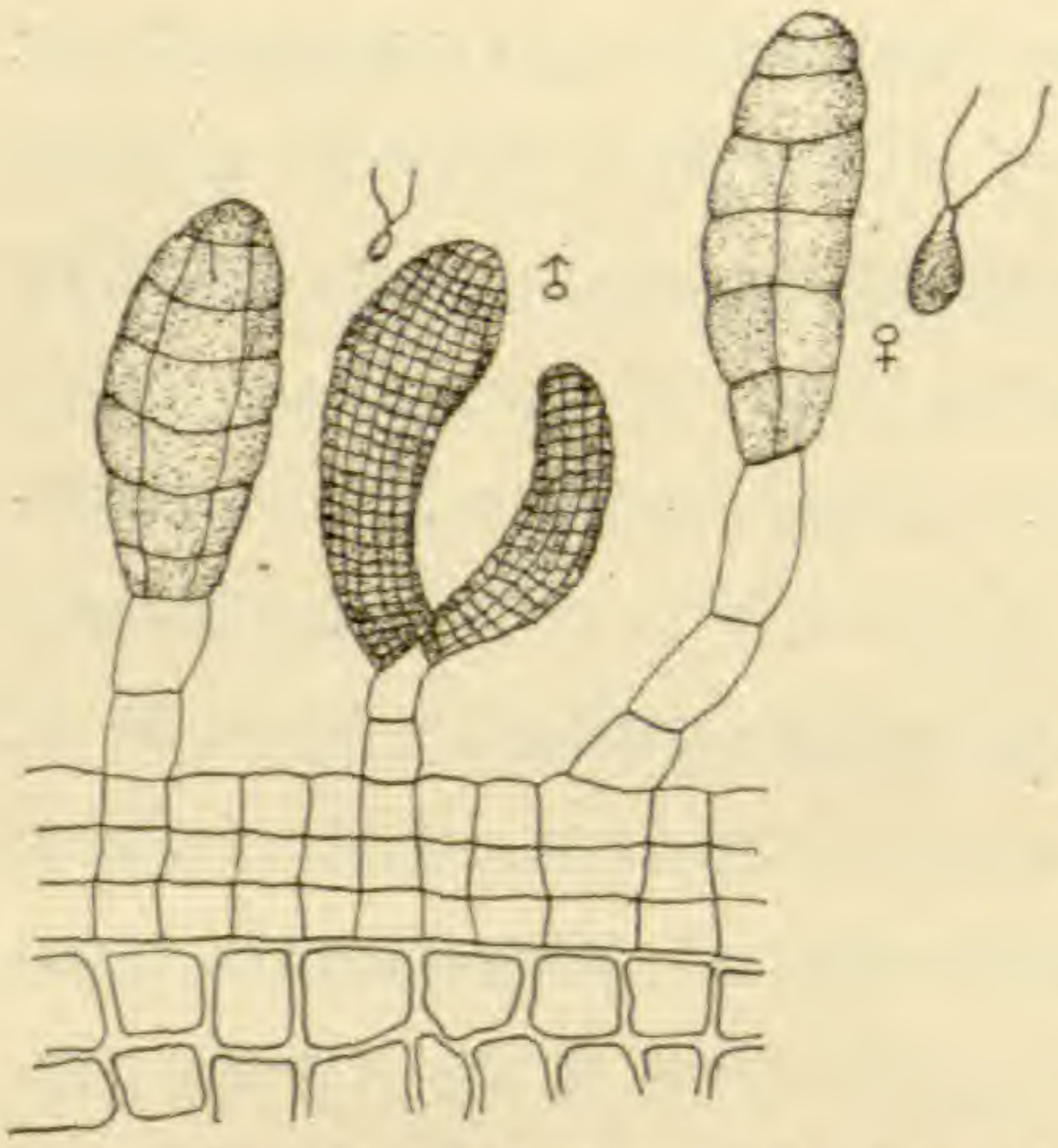

FIG. 15.—Portion of dorsal surface of Zanardinia, showing the emergent sex organs.

This view suggested to me that the conditions sometimes found in a bryophyte antheridium might be analogous or even homologous. Are the cells which are arrested in division and assume a spherical shape (*fig. 10*) homologous with eggs, and is their appearance a return to ancestral condition?

The theory I have outlined would account for sex organs on or near both dorsal and ventral surfaces, as they are known to occur in Anthoceros, in certain thallose jungermannias, and in ferns. It would explain the sunken sex organs consisting of fertile cells not surrounded by a wall, formed of sterile sister cells, as the archegonium of Anthoceros and the antheridia of Equisetum and Lycopodium. According to such a theory, existent transitional stages might be expected in which the sex organs would not have assumed a definite shape nor a definite number of cells. Precisely this indeterminate condition is to be found in certain

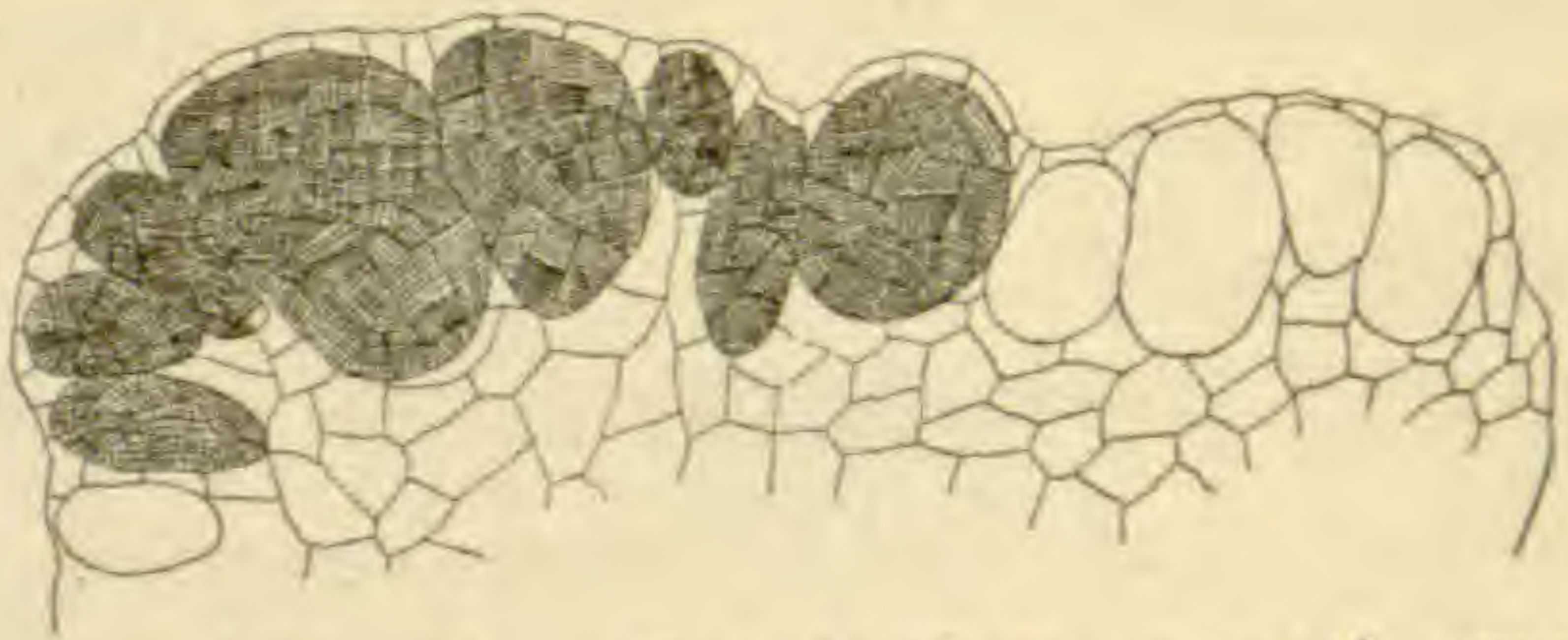

FIG. 16.—*Lycopodium annotinum:* dorsiventral section of portion of gametophyte, showing antheridia of indeterminate size and shape.

species of Lycopodium, notably *Lycopodium annotinum* (*fig. 16*), in which the antheridial region is made up of patches of spermatogenous cells quite indefinite in contour and varying in number. There is no wall of sterile cells. This appearance is not due to difference in state of development, or because antheridia are cut in different planes, as might be inferred from a single section. I have seen antheridia at maturity varying in the number of sperm cells from fifty to more than three hundred. Not infrequently groups of spermatogenous cells derived from separate initial cells abut upon one another with no intervening cell tissue, but it is generally easy to trace the individual groups. Sex organs of this type are logicallv explicable by the progressive sterilization of an indefinite superficial region, but it requires a *tour de force* to imagine the modification of an emergent sporangium of definite form into the sunken condition displayed by Lycopodium.

Archegonia and antheridia of few cells are generally regarded as the most advanced. From this standpoint, the sex organs of this species of Lycopodium are the most primitive ones known. This of course does not take into consideration the anomalous bisexual organs of *Mnium cuspidatum* described by Holferty. On the other hand, no gametophyte, with the exception of certain mosses, is so complex in the variety and specialization of its vegetative tissues as that of *Lycopodium complanatum* or of *Lycopodium annotinum*. To be sure, the gametophyte of *Lycopodium cernuum* by contrast is exceedingly simple, and that of Phylloglossum is said by Thomas (13) to show little internal differentiation of cells; but cases are frequent among animals where somatic tissues become elaborate and highly organized, while the sex organs lag behind and retain great simplicity. This would be expected in organisms where the struggle for existence is great, as it may have been among the Lycopodiums, if one may judge from the capricious germination of the spores. Moreover, the symbiotic relation of the club mosses with a fungus indicates difficulties in development. Attempts have been made repeatedly to germinate the spores of the club mosses, but the results obtained thus far have been unsatisfactory. The life history of every gametophyte of Lycopodium now discovered is full of gaps.

Several years ago, in his brilliant monograph on the evolution of the sporangium, Bower (14) suggested that emergences erupted from an indefinite concrete imbedded mass of sporogenous cells, and by progressive sterilization and branching resulted in discrete sporangia. In support of his view, he marshaled existent bryophyte and pteridophyte forms that he regards as analogous to those that may have appeared in the direct line of evolution. The same kind of argument may be applied to the origin of the sex organs. I have no idea that any of the brown or red algae represent lineal ancestors of the liverworts or ferns as we now know them; but if the Phaeophyceae are perchance an offshoot from green algae, the method in which they produce their reproductive cells may be like that of their forbears, from whom also the archegoniates have probably evolved. It is possible that the investigations of apogamy now proceeding will throw some new light on the subject. I hazard the suggestion that the origin of the apogamous sporophyte is among latent gametogenous cells of the thallus, which under unknown conditions develop sporangia without the formation of sex organs. Such a hypothesis may seem rash, but there is, I think, no inherent improbability in the theory, while it furnishes a suggestive line for investigation among the brown algae, which is a sufficient reason for its being. If Farmer's (15) preliminary announcement of the fusion of the nuclei of neighboring cells of fern prothalli, as a step preliminary to the formation of the apogamous sporophyte, is confirmed, are these fusing cells to be regarded as stable vegetative cells, or as potential isogamous gametes? If the latter, is it not conceivable that they are surviving cells of a former fertile region which normally are sterile, but on occasion may regain potentiality?

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BRIEFER ARTICLES.

THE STRUCTURE OF THE FLOWERS AND THE MODE OF POLLINATION OF THE PRIMITIVE ANGIOSPERMS.

THE purpose of this paper is to show how some questions involved in the phylogeny of angiosperms might be regarded from the point of view of the anthoecologist. The proposition to be offered is that the primitive angiosperms were entomophilous, and that the anemophilous ones are metamorphosed entomophilous flowers whose seemingly simple structures are degraded, not primitive.

The characteristic anemophilous flower has a pistil with a one-celled ovary containing a single ovule and ripening into a one-seeded indehiscent fruit. The characteristic entomophilous flower has a pistil with several ovules which ripens into a several-seeded dehiscent fruit. The explanation of the monospermy of the Anemophilae and the polyspermy of the Entomophilae is obvious when one considers the difference in the conditions of pollination. Even with a large plumose stigma the Anemophilae have enough to do to secure enough pollen for a single ovule. The Entomophilae with a small stigma can readily secure enough pollen for many ovules. The relation of many-seeded fruits to entomophilous pollination is emphasized in the orchids, where the high degree of polyspermy is correlated with the disposal of the pollen in masses. There are conditions under which entomophilous flowers become monospermous, and anemophilous flowers derived from them may show monospermy as an inherited character. But polyspermy is an entomophilous character.

Syncarpy involves polyspermy and is also an entomophilous character, the union of oligospermous fruits producing polyspermy. It is hard to imagine conditions under which an anemophilous plant would be likely to become syncarpous. Accordingly, in the absence of other entomophilous characters, and in spite of the presence of anemophily, plants may still retain the entomophilous characters of polyspermy and syncarpy. Syncarpy is important in diagnosing advanced stages of anemophilous metamorphosis because indications of syncarpy may be the only remaining evidence of a previous polyspermous condition. I also regard highly specialized inflorescences as entomophilous. At any rate, a highly specialized inflorescence is no place to look for simple structures.

According to their stages of development, three sets of anemophilous plants may be recognized: (1) those closely related to entomophilous ones and evidently of recent origin; (2) plants whose development from Entomophilae is not so evident, but which have dehiscent polyspermous fruits, one-seeded dehiscent fruits, or one-seeded indehiscent fruits developed from pistils containing more than one ovule; (3) in large groups containing no entomophilous representatives, having one-seeded indehiscent fruits ripening from one-celled, one-ovuled pistils.

The considerable number of plants of the first set shows that the independent development of anemophilous plants from entomophilous ones has frequently taken place. It shows that the change is easy. The most recent cases are of genera belonging to entomophilous groups, which are themselves entomophilous, but contain anemophilous species: Thalictrum, Fraxinus, Sanguisorba (Poterium), Acer; Salix, also, if Warming is right in regarding the Greenland species of Salix as anemophilous.[1] Less recent are Ambrosia in Helianthoideae, Ricinus in Euphorbiaceae, Rumex in Polygonaceae, Platanus in Rosales, Amarantaceae in Centrospermales, Plantaginaceae in Sympetalae, Juncaceae in Liliales. On the other hand, none of the anemophilous groups have produced forms which could reasonably be regarded as recently developed entomophilous ones.

In the recent cases the fruit does not differ essentially from that of the entomophilous forms from which they were derived.

The Plantaginaceae compose the only anemophilous family of Sympetalae and show every indication of being recent. The stigma is single, but is, no doubt, modified from a completely compound one. The number of seeds varies greatly, but some of the flowers are subject to spontaneous self-pollination and others may be more or less etomophilous.

Populus has two to four stigmas, a syncarpous fruit with two to four valves, two to four parietal placentae, and numerous coma-bearing seeds. From these characters I would suppose that Populus was not only of entomophilous origin, but recent. It has seemed to me remarkable that Müller should have regarded Populus as a primitive anemophilous form and Salix as a recent entomophilous form derived from the same stock. For the relatives of Salicaceae I would look among the entomophilous polyspermous forms having similar fruit and seeds. So,

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[1] Om nogle grönlandske blomster. Sv. V. Ak. Öfv. 1886: 116, 131, 158.

from my standpoint, and in the absence of some other consideration, I would readily accept the view that the Salicaceae should follow the Tamaricaceae, the reduction of the flowers being correlated with close crowding in a specialized inflorescence. In regard to the entomophilous origin of Populus, it may be mentioned again that Warming regards the several species of Salix occurring in Greenland as anemophilous.

The relation of Amarantaceae to an entomophilous group and its recent anemophilous character is implied by the position to which it has been assigned. Some of the family are entomophilous and polyspermous. The more familiar anemophilous species are monospermous, but still retain the useless habit of opening to discharge a single seed.

Betulaceae has a pistil with two stigmas and a two-celled ovary with one ovule in each cell. The fruit is one-seeded and indehiscent, but was evidently developed from a polyspermous one.

Fagaceae usually has three stigmas, three-celled ovaries, with two ovules in each cell, ripening into one-seeded fruits. Sometimes, however, in Castanea, the fruit contains two or three seeds, although it has lost the power of discharging them. Here we have evidence of a change from a polyspermous, entomophilous condition.

The Juglandaceae have a pistil with two stigmas and an incompletely two to four-celled, one-ovuled ovary. The fruit is apparently syncarpous and the anemophilous condition only a stage in advance of that of the Betulaceae.

The Ulmaceae appear to be syncarpous. Ulmus has a pistil with two stigmas, a one to two-celled ovary with one to two ovules, and the fruit monospermous. Morus has two stigmas and a two-celled ovary.

The Juncaceae are placed in the entomophilous group of Liliales. Some of the species are entomophilous, others autogamous or cleistogamous. The anemophilous ones are polyspermous, indicating a recent entomophilous origin. The fruit is evidently tricarpellary.

On the supposition that the Typhaceae are representatives of primitive anemophilous monocotyledons, it is hard to account for the fact that Sparganium sometimes has two stigmas and a two-celled, two-ovuled pistil ripening into a two-seeded indehiscent fruit. Typha has the fruit dehiscent, although one-seeded, and the pollen in fours. The occurrence of persistent tetrads is of itself enough to establish a presumption of an entomophilous origin. Such compound pollen grains occur in Anonaceae, Magnoliaceae, Empetraceae, Ericaceae, Vacciniaceae, Epacridaceae, Pyrolaceae, Onagraceae, Amaryllidaceae, and Juncaceae—all entomophilous except the last. In connection with the case of Typha may be mentioned the statement of Bentham and Hooker that some Araceae have "pollen in farciminula conglomeratum (pollen vermiforme)." The Typhaceae seem to be anemophilous descendants of the entomophilous Araceae. The reduction of the flowers seems to have been connected with close crowding on the spadix, followed by further reductions after the anemophilous habit was established.

In the Glumales we find a great group of anemophilous plants with the pistil one-ovuled and the fruit one-seeded. From the fact that the flowers are crowded in highly specialized inflorescences I would conclude that their seemingly simple structures are the result of degradation. The pistil has two or three stigmas, from which I conclude that the fruit is syncarpous and developed from a polyspermous stock. Anemophily may account for a stigma becoming plumose, but I do not see how it will account for the presence of two or three stigmas.

While I think the claims of any anemophilous plants which I know to being representatives of primitive anemophilous forms can be refuted without resorting to any speculative considerations, there are some speculative difficulties which may be mentioned. On the supposition that the angiospermous prototype was anemophilous, I can hardly imagine any conditions under which it would be advantageous for the ovules to become inclosed in a carpel. A single ovule could hardly be pollinated any better, and more than one could hardly be pollinated so well. If, on the other hand, the pollen was carried by insects, we can understand how a number of ovules might become inclosed in a carpel and be more effectively pollinated than they were before. So I am inclined to regard the angiospermous prototype as having been polyspermous and entomophilous. Here it may be well to cite the fact that the recently discussed cases of plants which are doubtfully dictoyledonous, or which seem to point more or less significantly to a line from which the dicotyledons and monocotyledons may have had a common origin, are entomophilous.

There are some considerations relative to pollinating agencies which may have had something to do with anemophilous metamorphosis. A change to wind pollination might be favored by close competition of entomophilous flowers for the attentions of anthophilous insects or by disturbances reducing the number of insects of that kind.

Some conditions in the behavior of bees may also have favored the resort of many diclinous plants to anemophily. The primitive anthophilous insects probably visited flowers chiefly for nectar. Adaptations to them were secured by placing the nectar so that the visitor in obtaining it would strike the anthers in one case and the stigma in the other. The advent of the bees, which feed their young principally on pollen, and whose most abundant and most efficient visits are for that purpose, has changed the conditions. The flowers best adapted to bees are those whose receptive stigmas are so near the dehiscing anthers that the bees cannot collect the pollen without coming in contact with the stigmas. Diclinous, dichogamous, and large flowers are often visited by bees which rarely touch the stigmas. The diclinous plants particularly seem to suffer from having their pollen carried away by female bees which pay little attention to the pistillate flowers. Under these conditions it is a question whether anemophily would be much more expensive or precarious for many diclinous entomophilous flowers.

In many cases the views here advanced are not supported by the Engler and Prantl classification, and involve a criticism of that system. But they are supported by the modification of the systems of Engler and Prantl, and Bentham and Hooker, proposed by Bessey in the BOTANICAL GAZETTE **24**: 145–178. 1897, and, as far as they go, tend to supplement his conclusions regarding the taxonomy of angiosperms That author says nothing about the mode of pollination, but the forms which he selects as primitive involve the conclusion that the original forms were entomophilous. Bessey places a number of controverted families in entomophilous groups: Salicaceae after Tamaricaceae in Caryophyllales; Urticaceae in Malvales; Fagaceae, Betulaceae, and Juglandaceae in Sapindales; Typhaceae with Aroideae in Nudiflorae. —CHARLES ROBERTSON, *Carlinville, Ill.*

ARCTERICA, THE RAREST GENUS OF HEATHERS.

(WITH TWO FIGURES)

IN the Harvard University Herbarium is a specimen of an ericaceous plant which has a singular and interesting history. The specimen is a mere fragment, 43^{mm} in length, yet its characters are so clear and remarkable that Dr. Asa Gray in 1885 described it as a new species, *Cassiope oxycoccoides*,[2] and the present writer, while segregating two species from Cassiope under the generic name Harrimanella in 1901,[3] found in this plant sufficient characters to warrant setting it aside as a third genus, Arcterica.

[2] GRAY, A., Proc. Am. Acad. 20:300. 26 Ja 1885; GRAY in STEJNEGER, Proc U. S. Nat. Mus. 7:534. 27 Ja 1885.

[3] COVILLE, F. V., Proc. Wash. Acad. Sci. 3:569–576. *figs. 62–66.* 1901.

The home of Arcterica is Bering Island, off the coast of Kamchatka, remote geographically from any center of civilization, and having only occasional communication with its political parent, Russia. The specimen was collected by Dr. Leonhard Stejneger, of the United States National Museum, in 1882, when as a zoologist he was investigating the fur seals of the Commander Islands, to which group Bering Island belongs. The single twig of Arcterica was picked up accidentally among some specimens of *Bryanthus Gmelini*. In subsequent visits to the island Dr. Stejneger attempted to find the plant again, but was unable to rediscover it.

It was upon Bering Island that George Wilhelm Steller, the botanist, passed the winter of 1741–42, while thirty men out of seventy-six died from scurvy and exposure, including Bering himself, the leader of the expedition. While the survivors were rebuilding their boat, Steller busied himself with collecting, and by the time the expedition sailed from the island, on August 14, 1742, he had secured a fair representation of the plants which had flowered up to that time, 211 species altogether.

With the notion that Steller must have collected Arcterica on Bering Island, and that his specimens had lain unnamed for more than a century and a half in the great botanical gazophylacium of Russia, the writer in September last visited the herbarium of the Imperial Academy of Sciences, in the city of Peter the Great, and waited in breathless expectancy at the foot of a stepladder, while the courteous curator upon its summit explored the upper pigeonholes for Steller's specimens. At last the answer came down, in the form of that conclusive and irrevocable Russian *nyet*, with which we are more familiar in its Americanized form, "nit," recently current among street boys.

There seems to be little hope that other specimens of Arcterica will come to light, except such as may be discovered hereafter by some diligent collector who searches carefully for it on Bering Island. The exact spot on which it was found by Stejneger, on August 22, 1882, was "a rounded hill, about 300 feet high, just behind the fishing settlement of Saranna. The hill rises up from the shore of Lake Saranna, and is the first one when following the track of the dog sledges to the main village." The accompanying illustration and description will aid in the identification of the plant.

DESCRIPTION OF THE TYPE SPECIMEN OF ARCTERICA OXYCOCCOIDES.

Specimen a branched twig 43^{mm} in length, bearing leaves and flowers. (*Fig. 1.*)

Twigs 1^{mm} or less in diameter, minutely pubescent, bearing at intervals of $2–8^{mm}$ whorls of three leaves.

Leaves on petioles about 1^{mm} in length, oblong, $4–6^{mm}$ long, $2–3^{mm}$ wide, apparently evergreen, very thick, coriaceous, entire, smooth or with traces of pubescence along the margins or in the median groove on the upper surface of the leaf, the margins revolute, the stout midrib very prominent beneath, the blunt apex of the leaf bearing a large gland. The leaves bear a striking resemblance in size, form, and texture to broad leaves of *Chamaecistus procumbens*, but in the latter plant the lower surface is pubescent between the midrib and the margins, and the terminal gland is wanting. The terminal gland of our plant is similar to that of *Vaccinium Vitis-Idaea* and the South American species of Gaylussacia.

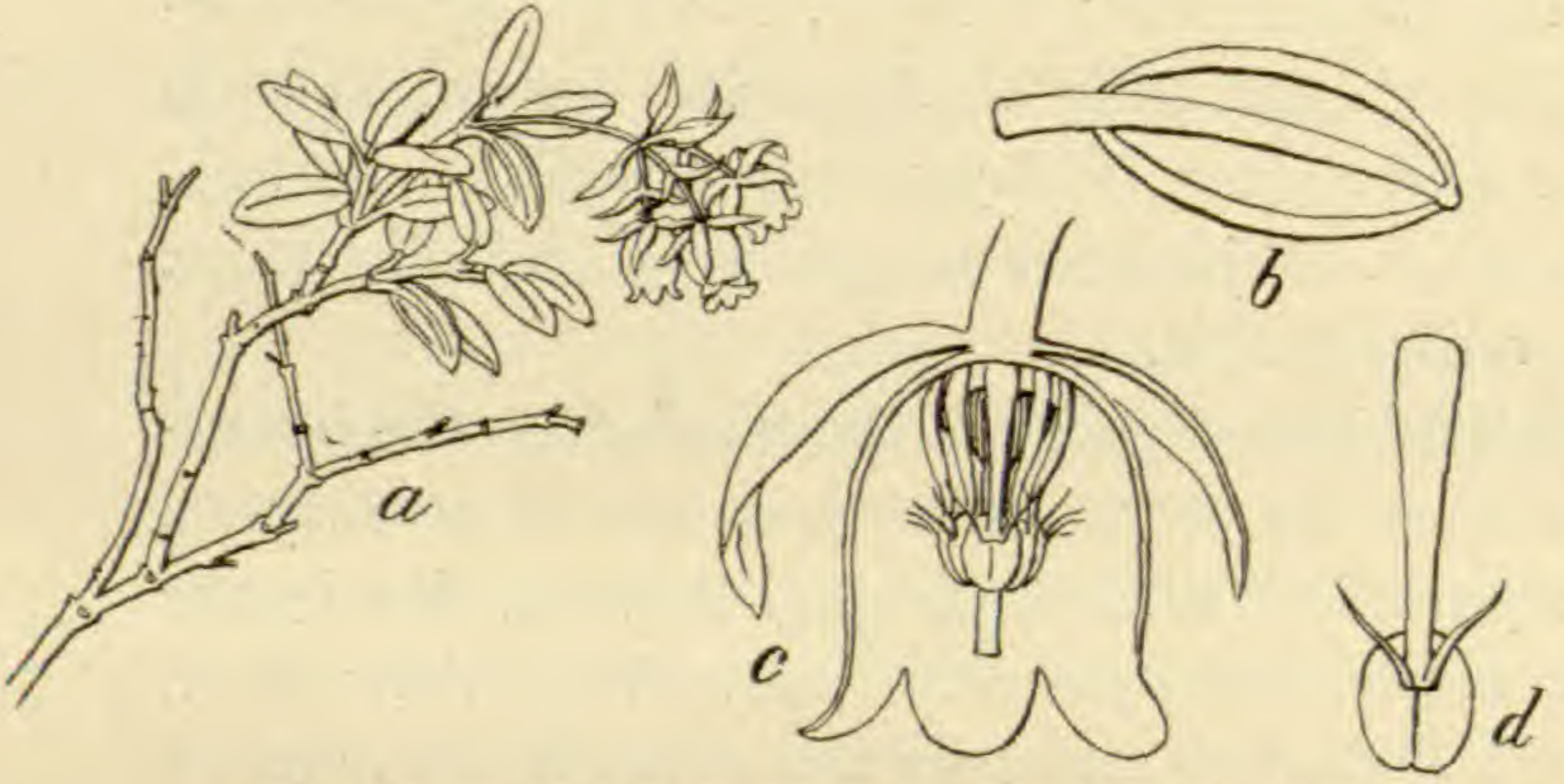

FIG. 1.—*Arcterica oxycoccoides* (Gray) Coville. *a*, the type specimen, natural size; *b*, leaf from beneath (× 3); *c*, flower, with part of calyx and corolla cut away (× 5); *d*, stamen (× 10).

Inflorescence a terminal cluster of three flowers, the peduncle 6^{mm} long and bearing at its summit a whorl of three purplish bracts, these about 4^{mm} long, the lower half conduplicate, the upper half expanding into an ovate-triangular blade; pedicels about 3^{mm} long with two opposite bracts near the middle, similar in size and appearance to the sepals.

Flower pentamerous. Calyx made up of lanceolate-oblong, purplish, acute sepals, pubescent at the apex on the margins and upper surface. Corolla cylindrical-urceolate, longer than broad, apparently white, about 4^{mm} in length, the rounded lobes about one-third the length of the tube. Ovary globose, the style cylindrical. Filaments larger toward the base, glabrous; anthers broadly oval to orbicular, biaristate near the base, the point of attachment to the filament, the dehiscence taking place through two apical pores facing the style.

The following generic characters, observed in the foliage and inflorescence, serve to distinguish Arcterica from Cassiope and Harrimanella:

CASSIOPE.	ARCTERICA.
Leaves opposite, cupressiform, imbricate, calcarate.	Leaves in whorls of three, chamaecistiform, with an apical gland.
Flowers axillary.	Flowers in terminal clusters.
Sepals with a transverse fold at the base.	Sepals not folded at base.
Anthers attached toward the apex.	Anthers attached by the base.

HARRIMANELLA.	ARCTERICA.
Leaves alternate, empetriform.	Leaves in whorls of three, chamaecistiform.
Flowers singly terminating the stems, not bracted.	Flowers in clusters, the pedicels subtended by a bract and bibracteolate at about the middle.
Style ovoid-conical.	Style cylindrical.
Anthers attached toward the apex.	Anthers attached by the base.

Illustrations of three species of Cassiope and two species of Harrimanella are given in the Washington Academy paper to which reference has already been made. In both Harrimanella and Cassiope the pollen pores, the two awns, and the point of attachment of the filament are close to the apex of the anther, but in Arcterica the filament and two awns are attached near the base of the anther, only the pollen pores being terminal. (*Fig. 2.*)

Superficially, in habit and foliage, Arcterica presents an appearance intermediate between *Chamaecistus procumbens* and *Vaccinium Vitis-Idaea*, but its leaves, situated in whorls of three, and its stamen characters suggest possible relationship to Erica. Apparently, however, it is not congeneric with any known species of that genus. Its corolla is not chartaceous; it is a depressed plant barely rising above the mosses and lichens among which it grows; its leaves have peculiar apical glands; and it is geographically isolated from the rest of the Ericae, none of which are known from either northeastern Asia or northwestern America. Whether the plant is more nearly related to Cassiope and Harrimanella, and belongs therefore to the tribe Andromedeae, or to Erica, of the tribe Ericeae, is a question likely to remain unanswered until fruiting specimens are available.

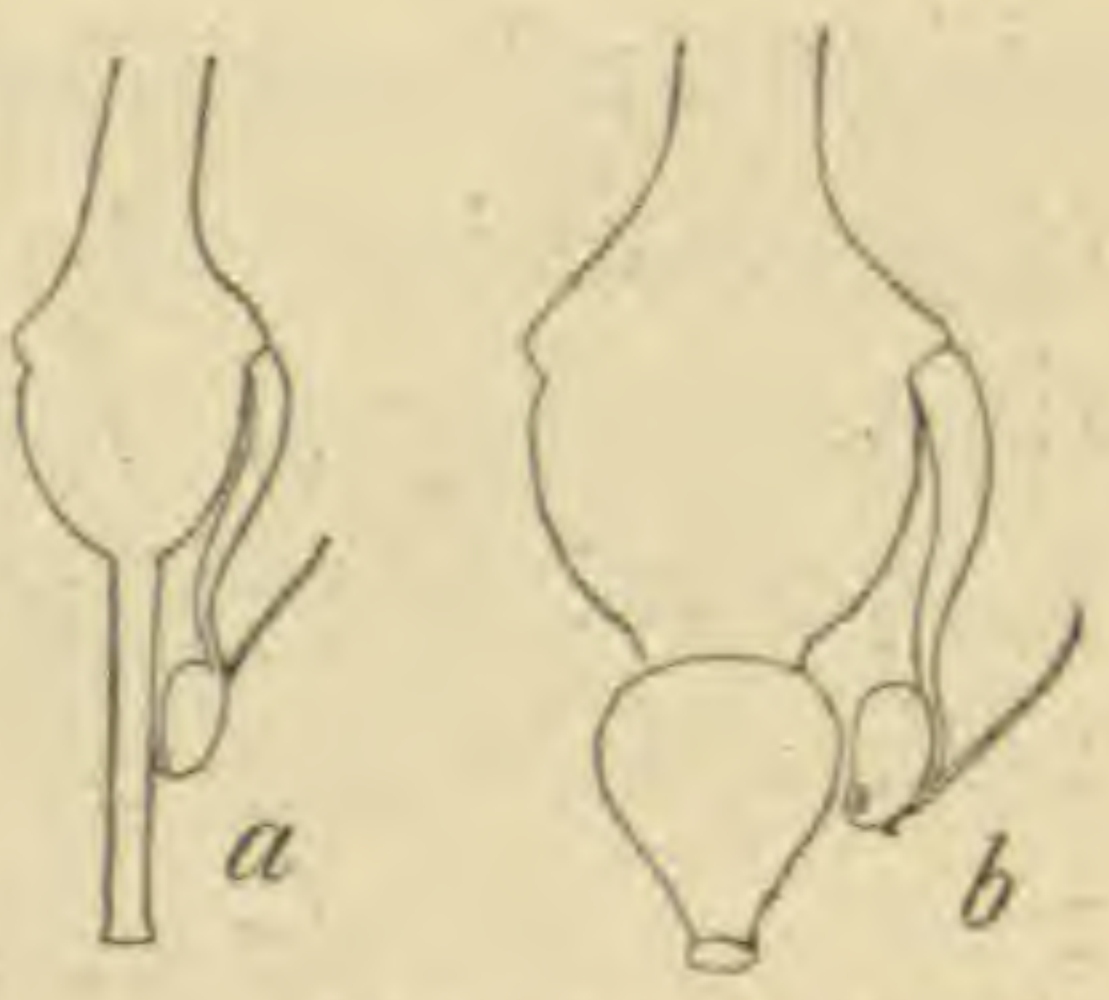

FIG. 2.—*a*, pistil and stamen of *Arcterica oxycoccoides*, showing attachment of awns and filament; *b*, the same organs in *Harrimanella stelleriana* (both × 5).

An attempt was made to explain the specimen on the ground that it was a hybrid, but there appear to be no two plants on Bering Island from which the characters found in Arcterica could be produced.—FREDERICK VERNON COVILLE, *Dept. of Agriculture, Washington, D. C.*

NEW PRECISION-APPLIANCES FOR USE IN PLANT PHYSIOLOGY.[1]

(WITH THREE FIGURES)

THE development of apparatus in this country for educational use in plant physiology has taken almost exclusively the direction of improvisation of the needful pieces from various existent physical, chemical, and mechanical articles, especially such as are very cheap and everywhere easy to obtain. In giving our inventions this turn it is evident that we have had in mind the needs of the smaller, poorer, and more backward institutions rather than the needs of the larger, richer, and more progressive; while, following the tendency usual in such cases, we have allowed ourselves to be carried to the extreme of reaction from the elaborate, costly, and mostly unpurchasable appliances previously used in this work. Improvisation has now, I believe, been carried to its utmost practical limit, and even to a greater extent than is educationally and scientifically desirable. Improvised apparatus certainly has its place and value, especially in that it permits the study of plant physiology in many places where otherwise it would be impossible, while its preparation cultivates a certain mechanical ingenuity and self-reliance. In general it is certainly true that such apparatus is vastly better than no apparatus. But it has also very great disadvantages, notably the waste of time commonly involved in its preparation and manipulation, in the inevitable inaccuracy of results, and above all in the wrong habit and erroneous ideal of scientific method inculcated by the use of such imperfect tools. Further, experience shows that the training in manipulation, while of value in itself, is gained at too great a cost of botanical training and knowledge; for usually the time and energy of the student are so fully absorbed in the preparation of the apparatus that he has little of either remaining for use in the study of the plants.

These facts, I believe, indicate that the next step needful in plant

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[1] These appliances, with others to be described later, were exhibited and explained at the Philadelphia meeting of the Society for Plant Morphology and Physiology, December 30, 1903.

physiology is a movement to what may be called normal apparatus, viz., pieces manufactured especially for the particular purpose, yielding accurate quantitative results, capable of application to their work with convenience and economy of time, and purchasable from the stock of supply companies precisely as apparatus for physics and chemistry may be. With these ideas in mind I have been trying for some two years past to develop such pieces of normal apparatus for all of the principal physiological processes, and some of the results are described below, while descriptions of others are to follow later. I have had in mind primarily their educational use, but they should also be available for investigation, especially the investigation of those physiological life-histories of plants which will form a leading feature of the ecology of the near future. In their construction, scientific efficiency (involving accurate mechanical workmanship), has been the first consideration, practical convenience and economy in manipulation the second, availability for purchase by all who have the means and wish to buy them the third, while the matter of cost has come last. I have confidence that a people so devoted to efficiency, and so wealthy, as the Americans, will ultimately not begrudge the cost of really good educational appliances, though I expect that their introduction will be very slow. In order to make them generally available I have arranged for their manufacture and sale by the Bausch & Lomb Optical Co., of Rochester, N. Y., who will presently be prepared to supply them along with other articles, chemicals, etc., needed for work in plant physiology.

The reader interested in these matters will note that this is not the first attempt to provide such apparatus. Professor J. C. Arthur, of Purdue University, some years ago offered for sale several excellent pieces designed by himself, though apparently he has not continued their development. The field is open to all, and from the many pieces likely to be offered in the near future it is probable that the survival of the fittest will provide us with physiological apparatus of great exactness and convenience and of moderate cost.

I. CLINOSTAT.

The most essential single piece of apparatus in the laboratory of plant physiology is a clinostat. Several forms have been invented, of which the best known are the Pfeffer-Albrecht, the Wortmann, and the Hansen, all of German make and more or less costly and difficult to obtain, while several home-made forms have been described by American botanists.

My instrument is illustrated in the three accompanying figures. It consists essentially of the works of a powerful American eight-day clock, geared to a revolution in fifteen minutes, inclosed in a practically dust- and moisture-tight metal case, capable of being used in any desired position. Used vertically (*fig. 1*) it stands upon three leveling-legs and carries a disk with a rim holding a 4-inch pot saucer (to take up leakage from the pot), in which may be set any size of pot up to 5-inch, though in this position it will carry a still heavier pot. In this figure may also be seen, on the left of the spindle, the nut by which the works are started or stopped, and the covers of the winding-holes. It can, of course, be wound without disturbing the plant. Used horizontally (*fig. 2*) it may, by means of the perforated screw posts and clamping-screws on the back of the case, be fixed at any desired height on the vertical rod of any common laboratory support. The spindle rod, either carrying a plant attached by

FIG. 1.

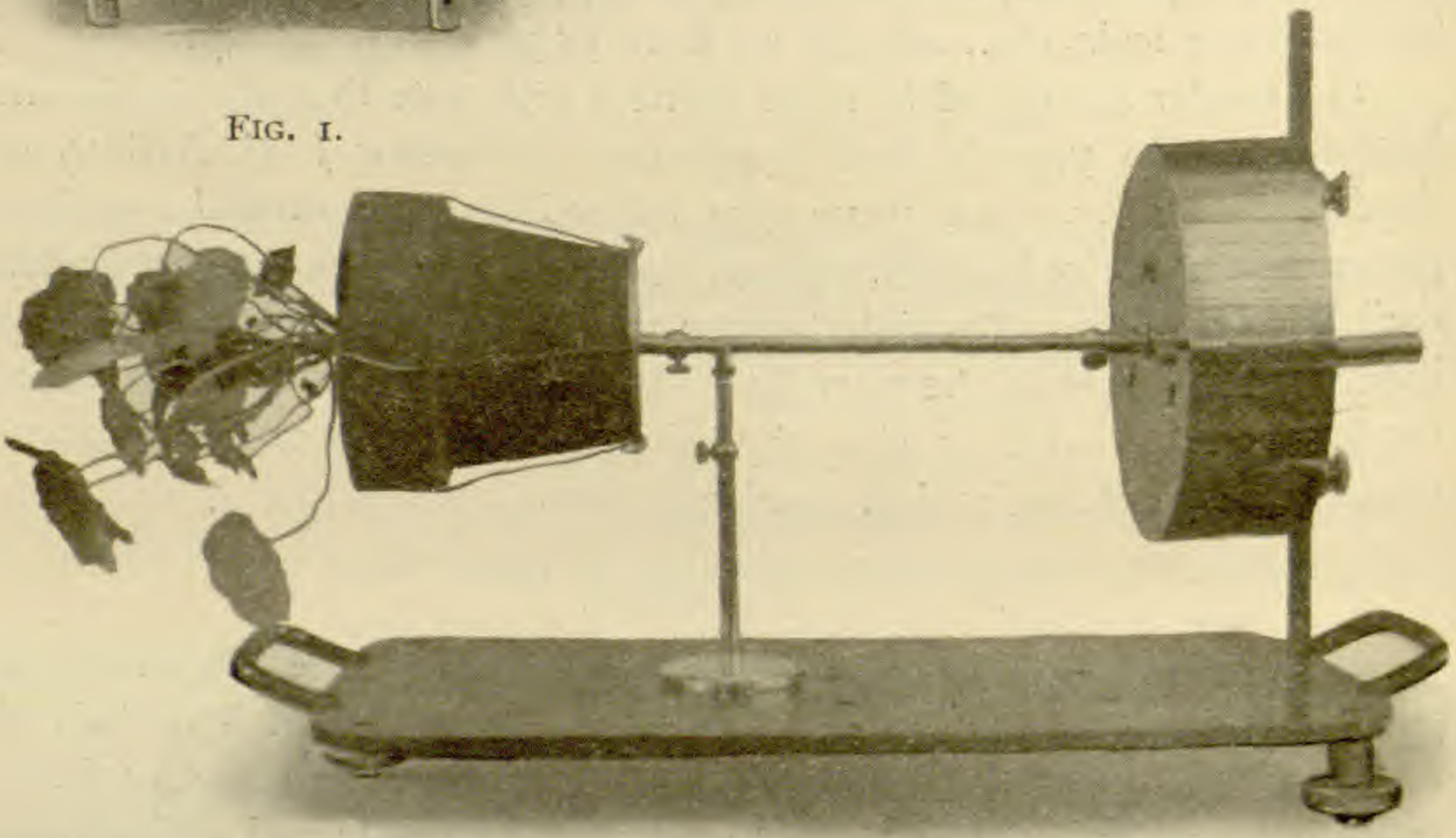

FIG. 2.

copper wire[4] to the perforated disk, as shown in the figure, or else carrying a pot, a peat-block, or a cork into a moist chamber, is supported near its distal end by a simple Y-support adjustable for height. In this position the instrument carries perfectly a 4- or 5-inch pot, and presumably a heavier one if well centered. Clamped upon a horizontal rod (*fig. 3*) it may also be used at any angle whatsoever, including complete inversion, the latter feature being, I believe, possible with none of the other obtainable forms.

Its special merits are its length of action (two days with one winding), entire efficiency in any position, compactness (whereby it may readily be placed under bell-jars, etc.), and moderate cost. Its demerits are its inability to carry plants of over 4- or 5-inch pot (though it is extremely rarely, and in educational demonstration never, the case that heavier plants are used), its single speed (though other speeds are extremely rarely, and in educational demonstration work never, needed), and its audible tick, which however is of a brisk and cheery character, quite in place in a laboratory.

FIG. 3.

II. PORTABLE CLAMP-STAND.

For many purposes in experimental plant physiology some form of clamp-stand, to support apparatus in special positions, is necessary, and one of the forms used in chemistry is generally adopted. For the

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[4] So in the figure, but the completed instrument is to have screw rods instead of the wire.

simpler uses, these answer perfectly; but when several pieces must be supported near together, and when some articles must be set level, and especially where the whole must be removed from greenhouse or wardian case to lecture or laboratory table, it is necessary to improvise some form of tray or other support to carry the stands, with a device for leveling by wedges, etc. The new portable clamp-stand illustrated in *fig. 2* is intended to meet all of these needs in a single instrument. It is made of thin cast steel, reinforced underneath on the margin and at the holes, and is some 40 × 22^{cm} in size. It is perfectly plain on top, is provided with convenient handles, rests upon three legs in which leveling-screws are set, and is pierced by holes for the upright rods at points where experience and experiment show these to be most needed. The rods are of the size and thread usual in chemical supports, two in number, one 50 and one 25^{cm} long, though of course others can be added. The clamps, not shown in the figure, but to be illustrated in a figure to follow, are of a new form, light, strong, and firm, and are adjustable at any angle or in any plane.—W. F. GANONG, *Northampton, Mass.*

(*To be continued.*)

CURRENT LITERATURE.

BOOK REVIEWS.

The desert botanical laboratory.

A REPORT upon the Desert Botanical Laboratory established by the Carnegie Institution merits much more than a passing notice. This report, prepared by Messrs. Coville and MacDougal,[1] is admirably designed to set forth the important field which the Desert Laboratory is certain to occupy in research. Coville's botanical exploration of Death Valley, more than a decade ago, led him to hope that it would be possible to carry on systematic botanical observations in some American desert under the auspices of an institution such as the one which has just been established. It was wise on the part of the Carnegie Institution to entrust the important matter of the

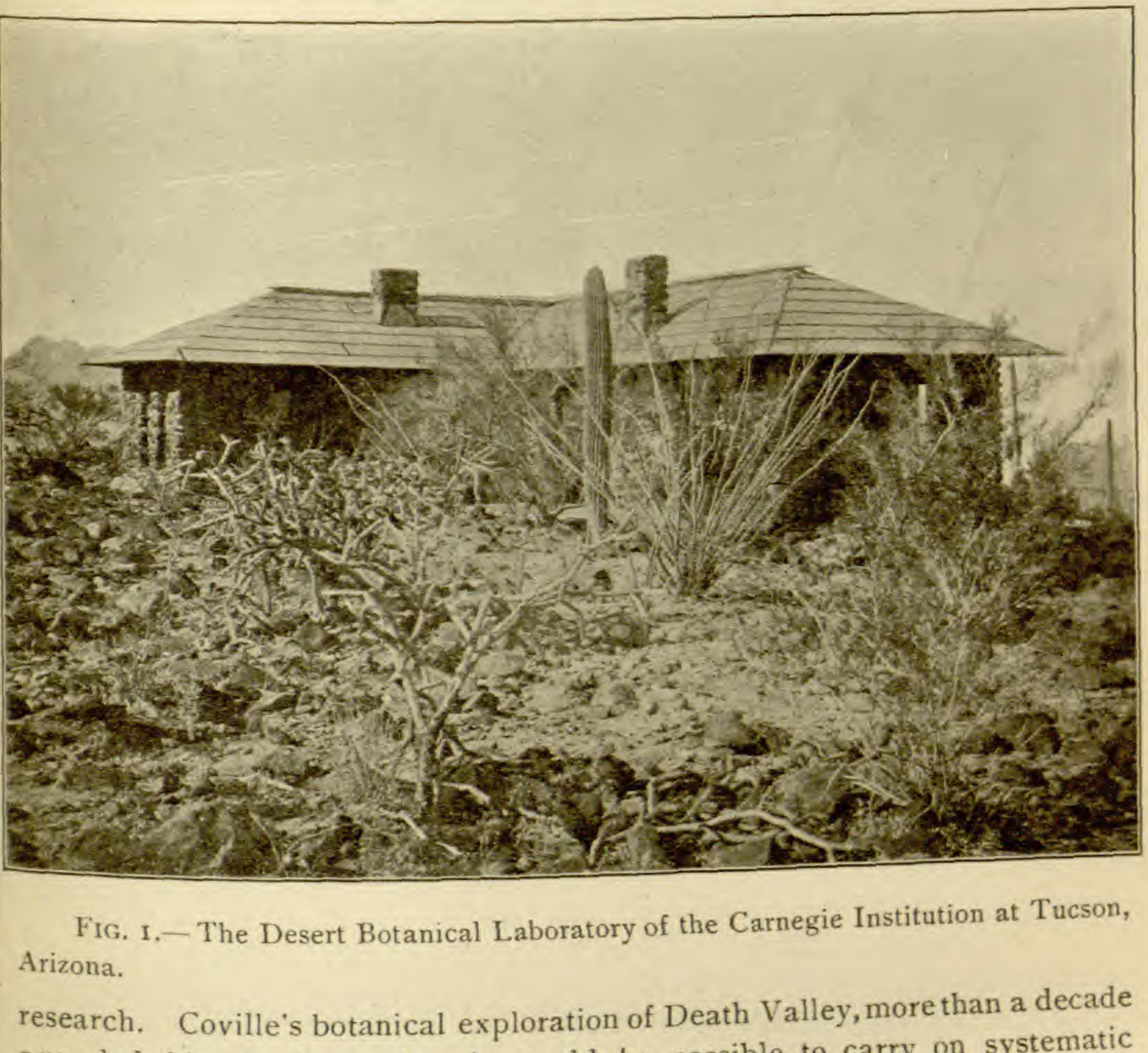

FIG. 1.—The Desert Botanical Laboratory of the Carnegie Institution at Tucson, Arizona.

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[1] COVILLE, F. V., and MACDOUGAL, D. T.: Desert botanical laboratory of the Carnegie Institution. Imp. 8vo. pp. vi + 58. *pls. 29. figs. 4.* Washington: The Carnegie Institution. November 1903.

FIG. 2.— View westward from the laboratory. In the middle distance a strictly desert vegetation, consisting of giant cactus, palo verde, ocotillo, creosote bush, prickly pears, chollas, etc.

choice of a suitable location for the laboratory to the two men who know so well the ecological and other features of our deserts.

The report of this advisory board embraces an account of the journey along the Mexican border in search of a suitable site. There are twenty-nine fine photographic reproductions of typical desert landscapes, representing not only the features of the vegetation about Tucson, but also the more interesting ecological characteristics of the other deserts, which were visited, viz., the Tularosa desert of New Mexico, with its unique gypsum sand dunes; the deserts in the neighborhood of Torres and Guaymas, Mexico; the Colorado desert about Salton, Cal.; and the Grand Cañon of the Colorado in Arizona. In deciding upon Tucson for a laboratory site, regard was had for four requirements which an ideal site should possess: a distinct desert climate and flora, a flora that is rich and varied, accessibility, and habitability. In addition to these advantages, Tucson is the seat of the state university and agricultural experiment station, and its citizens cooperated enthusiastically in the enterprise—a matter of no small moment.

The chapter on the plant life of American deserts is introduced by a consideration of their meteorological and soil features; the most interesting table here is the one which gives the ratio between precipitation and evaporation. Instructive maps and soil analyses also illuminate this section. MacDougal's experiments on transpiration and temperature, which were conducted in the Arizona deserts near Flagstaff in 1898, are also included, and suggest one of the fruitful lines of investigation which the new laboratory will make possible.

The report concludes with an excellent bibliography of desert literature, prepared by the resident investigator, Dr. W. A. Cannon. The references are grouped under four heads: general treatises, references relating to climate, references relating to soil, and references relating to water. This bibliography will prove of immense assistance to investigators at the laboratory, and to students of similar problems everywhere.

While one cannot predict the exact place which the new laboratory is to occupy in botanical research, it is our right to expect great things, particularly in physiology and ecology, in which investigators are coming more and more to feel the need of field experiments. We may not hope to torture a desert plant into revealing its secrets to us in our laboratories and greenhouses, but it may unfold the mysteries of its life to those who live with it day by day in its own haunts. It is likely too that morphologists and taxonomists will find the Desert Laboratory of much help.—H. C. COWLES.

Plant chemistry.

"THIS BOOK[2] is the outgrowth of instruction in chemistry given in the School of Agriculture of the University of Minnesota." It is intended for

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[2] SNYDER, HARRY, The chemistry of plant and animal life. 12mo. pp. xvii + 406. New York City: The Macmillan Company. 1903. $1.40.

the use of students with no previous knowledge of chemistry. The first 154 pages are devoted to elementary chemistry. The headings of the remaining chapters will indicate the scope of the rest of the book. These are: the water-content and ash of plants; the non-nitrogenous organic compounds of plants; the nitrogenous organic compounds of plants; the chemistry of plant growth; composition of plants at different stages of growth; factors which influence the composition and feeding value of crops; composition of coarse fodders; wheat; maize; oats, etc.; mill- and by-products; roots, tubers, and fruits; fermentation; chemistry of digestion and nutrition; rational feeding of animals; composition of animal bodies; rational feeding of men. Interspersed throughout the book are directions for numerous simple experiments, designed to be performed by the pupil.

The chapters on pure chemistry deal only with the most important elements and compounds which enter into the composition of plants and animals. The treatment, in this part of the book, is very elementary, and often decidedly dogmatic. Some statements occur which are not free from serious objection. Thus on page 3: "It was believed, at one time, that metals, as copper, could be changed into gold, and other substances into different forms of matter. After many centuries of experimenting it was found that this could not be done, and as a result the law of the indestructibility of matter was established." The "change of substances into different forms of matter" is one of the principal subjects of the chemist's study. On the other hand, the question of transmutation has no bearing on the doctrine of the conservation of matter. On page 4 we find: "The reasons for accepting the molecular structure of matter cannot be profitably taken up by the student of elementary chemistry." And on page 13: "The way in which atomic weights are obtained cannot at this stage of the work, be profitably considered." The subject is not considered later; but, nevertheless, the terms "atom" and "molecule" are constantly employed, as are also chemical formulas, which are introduced on the twelfth page. It is to be feared that the student will gain the idea that atomic weights and formulas are obtained in some mysterious way, and that the properties of substances are to be deduced from these data by some sort of algebraic manipulation. Thus on page 73 it is stated: "In the study of acids, bases, and salts the character of the compound can always be determined from the formula, as $Ca(OH)_2$." The treatment of valence is equally objectionable. Under the heading "Impossible reactions," page 123, it is stated that in "the case of $BaSO_4 + 2HCl$ no reaction can take place," because these substances are the products of the action of $BaCl_2 + H_2SO_4$. This would seem to teach the impossibility of reversible reactions. Some statements are inaccurate. Thus, page 24: "Liquids are never weighed, but always measured;" page 40, "Hydrogen is liquefied with greater difficulty than any other element." This ignores helium. On page 58, speaking of water of crystallization, it is said: "Without this water crystals could not be formed." On page 113, benzene (C_6H_6) is referred to as benzine and benzol; the term "benzine" is (correctly) used on page 110 to designate the petroleum product. On page 195 gum arabic and the gums of peach and cherry trees are mentioned as typical examples of gums. In the next line is the statement: "When treated with dilute acids the gums are converted into dextrose sugars and acid products." The gums mentioned as examples all give pentose sugars and not dextroses. Page 201: "Beeswax, for example, is composed of palmitic and ethyl radicals." The chief constituent of beeswax is myricyl palmitate, not ethyl palmitate. The whole of page 20 is devoted to description of plates I and II. On page 267 plate III is mentioned. There are no plates in the book. On page 406 there is a table of "Corrections;" but no such errors exist on the pages indicated.

In spite of some faults, there is a judicious selection of subjects, and in the applied part of the book a clear and concise treatment of the matter presented. While the book is not recommended as a text for elementary chemistry, the applied portions should prove very useful to students of agriculture, and interesting to all who, having an elementary knowledge of chemistry, are concerned in the subject of plant and animal nutrition.— H. N. McCoy.

The Bonn text-book.

THE FACT that this book,[3] addressed to college students, has reached its sixth edition in ten years is ample evidence of its popularity. One notices at once the name of Dr. G. Karsten instead of the late Dr. A. F. W. Schimper, who wrote the chapters on phanerogams for the previous editions. As before, the first three sections on morphology, physiology, and cryptogams, are treated by Strasburger, Noll, and Schenck respectively. In these three sections the sequence of topics and the method of treatment are practically the same as in the fifth edition, the principal revision appearing in the changes which have been necessary in order to keep the work fully abreast with recent contributions.

In the section on morphology the new figures and perhaps the most extensive revision of the text concerns the central cylinder of vascular plants. In the section on physiology the chapter on the "Stability of the plant body" has received a much more extended treatment than heretofore. More attention has also been given to ecology. In the cryptogams several new figures have been added, and slight changes, occasioned by recent studies, appear in the text.

In the treatment of the phanerogams one cannot speak of revision, for the entire section has been rewritten by Dr. G. Karsten. The gymnosperms receive more attention than previously. The arrangement of the angiosperms is practically that followed in Engler and Prantl's *Pflanzenfamilien*. By abbreviating the diagnoses of orders and families, Professor Karsten has

[3] STRASBURGER, E., NOLL, F., SCHENCK, H., and KARSTEN, G., Lehrbuch der Botanik für Hochschulen, 6th ed. Imp. 8vo. pp. viii + 591. *figs. 741.* Jena: Gustav Fischer. 1904. *M* 7.50.

made room for more interesting and important material. Particular attention is given to economic plants, especially those which have medicinal properties.

The number of illustrations has been increased from 686 to 741. Many of the old figures have been replaced by new ones, and the colored figures, which have always been a feature of the book, have been much improved by recent methods. Both authors and publishers deserve commendation for the frequent editions which have kept this work so thoroughly up to date.—C. J. CHAMBERLAIN.

Alpine vegetation.

ONE OF THE most valuable of tasks today is the compilation and systematization of scattered material. Such a labor has been performed by Marie Jerosch[4] in connection with the alpine vegetation of Switzerland. No claim to original work is put forth, although the critical study of 250 titles and the molding of discordant data into a harmonious whole are at least of equal value with most original investigations.

The work is essentially floristic rather than ecological. The first chapter deals with fundamental principles and motives, such as the origin of species, plant migrations, and polytopic appearance of species. The author is favorably inclined to all of the current evolutionary theories, and gives especial attention to Wettstein's seasonal dimorphism, and to mutation; the claim is made that Heer held a view essentially equivalent to mutation. The polytopic theory of Briquet is treated fully, but not very favorably. The second chapter considers the alpine and arctic climates from a comparative standpoint. The third and fourth chapters have to do with the Tertiary and Pleistocene history of the alpine regions. Then follows an account of postglacial changes, leading to a detailed consideration of the elements of the present alpine flora, together with their age and origin. Jerosch holds that an interglacial xerothermic or steppe period has been proved by the facts of plant geography, paleontology, and geology; there is more doubt as to a similar postglacial period.

There is no better illustration than that afforded by this book of the possibilities in floristic study. The glacial and postglacial floras of Switzerland and Scandinavia with all their vicissitudes are known almost as accurately as the floras actually in existence today. The fact that almost nothing is known of the glacial and early postglacial vegetation of America ought to stimulate many to study in this important and productive field.—H. C. COWLES.

Ecology of the Lena valley.

CAJANDER has given an excellent account of the vegetation of the alluvium of the lower Lena[5], in which particular attention is paid to the genetic

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[4] JEROSCH, MARIE, Geschichte und Kerknuft der schweizerischen Alpenflora, Leipzig: Wilhelm Engelmann. 1903. *M* 8.

[5] CAJANDER, A. K., Die Alluvionen des unteren Lena-Thales. Helsingfors. 1903.

relations of the plant associations. The headwaters of the Lena are in the steppe and the mouth is in the tundra, but most of the stream traverses a forest region. While larch, spruce, and pine dominate southward, the forests nearer the mouth are composed almost wholly of larch. Alluvial savannas decrease northward. Cajander employs "Bestand" in the ordinary sense, but uses "association" where most authors use "formation." "Series" is used for a group of genetically connected associations. The forest associations usually start with a thicket of *Salix viminalis*, which is succeeded by a mixed thicket, and later in turn by alders, birch, and spruce. The final stage on areas subject to overflow is a forest of spruce and larch; on alluvium above the freshet line there are pure larch forests. Various succession series are found in the meadows, differences being largely due to variations in the character of the soil; the final stages are very similar. An interesting variation in the succession series is shown by *Equisetum arvense* which precedes *Carex acuta* in rich soil, but comes after it in pure sand. In his concluding remarks, Cajander introduces the term "vicarious associations," by which he means associations that occupy similar places in the genetic series. Associations are climatically vicarious if they occur in different regions; *e.g.*, the *Carex acuta* association replaces northward the *Carex aquatilis* association of the upper Lena. One may cite as an illustration of edaphically vicarious associations the *Equisetum fluviatile* and Eleocharis associations which occupy a pioneer position in different soils of the same region.—H. C. COWLES.

A flora of northwest America.[6]

THOMAS HOWELL, so long known as an indefatigable collector, has brought together the results of years of field experience in a large volume describing the flowering plants of Oregon, Washington, and Idaho, a corner of the United States that had been left unprovided with a handy manual. Aside from the need of a manual for this region, the flora is one of the most interesting within our boundaries. The first fascicle of the present work was issued in 1897, although we are informed that the actual writing of the flora began in 1882, and now the completed seven fascicles appear in the volume before us. The sequence is that of Bentham and Hooker, the nomenclature is conservative, and the conception of species has been held to the old lines. Of the 3,150 species and varieties described 89 are new, but Mr. Howell is further to be credited with having contributed to monographers many more new species of his collecting.

This volume has been published under such unusual conditions, which are nowhere referred to in it, that they should be recorded. In 1896, when the first fascicle was ready for the printer, no typesetter able to set the tech-

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[6] HOWELL, THOMAS, A flora of northwest America, containing brief descriptions of all the known indigenous and naturalized plants growing without cultivation north of California, west of Utah, and south of British Columbia. Vol. I. Phanerogamae. 8vo pp. 816. 1903. Portland, Oregon: The author. $5.00.

nical matter could be found in Oregon. Accordingly the author learned to set type, and for nearly eight years has "set up" form after form until the 800 pages and more have been printed. We venture the assertion that no manual of botany, and probably no botanical work, has ever been issued at such a cost of labor to the author.

The value of the book is just what the experience of the author has made it, and no one knows so well the plants of the region covered. In addition to this, Mr. Howell is to be congratulated upon his indomitable pluck, in the presence of which a few typographical errors here and there and a little lack of typographical finish must be entirely forgotten.— J. M. C.

A study in heredity.

A STUDY in heredity by W. Johannsen[7] reaches the conclusion that Galton's law of regression is true in populations made up of several pure lines, but is not true in the pure lines taken singly. By a pure line is meant a group of individuals which have descended from a single self-fertilized individual. The author shows that a monomodal curve is not sufficient evidence that a population is homogeneous, but that a process of biological analysis must precede the general mathematical analysis, to attain satisfactory results. When Galton's law is found to hold in self-fertilizing populations it is interpreted as the result of incomplete isolation of the pure lines, and when the isolation is complete, *i. e.*, in a single pure line, there is complete regression of the mean characters of the offspring to the type of that line. This absolute fixity of type is too unique to be accepted without question, but if sustained by further research is a sufficiently important principle in questions of evolution in those special cases in which pure lines are involved, as in cleistogamous and other self-fertilizing populations, and in populations arising through parthenogenetic and vegetative reproduction. But exception may be taken to the author's view that the principle is fundamental to all study of heredity.

The results are based upon weight and form of seeds of *Phaseolus vulgaris* and on certain abnormalities in heads of rye. Only three generations are involved, and no account is taken of the influence of climatic fluctuations.— G. H. SHULL.

MINOR NOTICES.

THE VERMONT Agricultural Experiment Station has issued a bulletin dealing with the flow of maple sap.[8] The bulletin sets forth an enormous amount of experimental work, a large portion of which is directed to the physiological problems of sap pressure and sap flow. The effects of external

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[7] JOHANNSEN, W., Ueber Erblichkeit in Populationen und in reinen Linien. pp. 68. *figs. 8.* Jena: Gustav Fischer. 1903.

[8] JONES, C. G., EDSON, A. W., and MORSE, W. J., The maple sap flow. Bull. 103, Vermont Agric. Expr. Sta. pp. 43–184. *figs. 6. pls. 17.* 1903.

conditions (temperature, light, etc.) and the location of the sap stream were extensively studied, though not always in the light of physiological knowledge already available. It seems clear from the results that both gas pressure due to rising temperature and osmotic pressure in living cells cause sap to flow from the tap holes, but it is obvious that the latter agency is much more important than has hitherto been believed. The practical problems of the sugar orchard have also been considered, and the results of the experimental work regarding them certainly furnish a basis for better practice than has obtained hitherto.— C. R. B.

T. A. BONSER has given a detailed account of Big Spring Prairie, Ohio, involving the results of several years of careful study.[9] The place is of much interest, since it represents a type of the edaphic prairies of the east. The study was also peculiarly timely in view of the artificial changes which the place is now undergoing, The prairie, like most edaphic prairies, represents a former lake bed. The author thinks that the general absence of trees is due to the dense sod, which precludes germination. That trees and shrubs thrive in the prairie is shown in burns and other modified places, where a foothold is given. The order of encroachment of trees in such places as well as on ridges of sand, clay, and rock, was studied and reported in detail. A matter of floristic interest is that this prairie is the most southern known habitat of *Betula pumila* in Ohio.— H. C. COWLES.

THE NEW YORK Forest, Fish, and Game Commission has recently issued a valuable publication on tree planting on streets and highways.[10] Among the subjects discussed are: the selection of trees, street planting, pruning, protection from insects, autumn foliage, municipal control, and the legislation of several states in regard to tree planting. The improvement of highways in the country and of property in the city by tree planting is forcefully presented. In regard to the latter the author says the planting and care of trees belongs to the city government as much as street paving. The work contains many excellent illustrations of the beautifying of streets by tree planting; also numerous plates showing the natural coloration of autumn leaves.— C. D. HOWE.

THE CHIEF interest in a paper by Émile Boulanger on the mycelium of the truffle lies in his claim that it is composed of polyhedric cells, and that several Hyphomycetes are conidial forms of the truffle![11] —H. HASSELBRING.

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[9] BONSER, T. A., Ecological study of Big Spring prairie, Wyandot county, Ohio. Ohio Acad. Sci. Special paper no. 7. pp. 96. Columbus. 1903.

[10] FOX, W. F., Tree planting on streets and highways. Imp. 8vo. pp. 50. pls. 21. Albany: J. B. Lyon Co. 1903.

[11] BOULANGER, E., Les mycelium truffiers blancs; and Germination de l'ascospore de la truffe. pp. 20 and 23. *pls. 5.* Rennes, Paris: Published by the author. 1903.

NOTES FOR STUDENTS.

THE MUCH-STUDIED glandular hairs of *Dipsacus sylvestris* have been again examined by Rostock,[12] who finds no absorption of food materials, as F. Darwin suggested, and no absorption of the water itself, which is purely a protection to the leaves against snails and caterpillars. — C. R. B.

A SOMEWHAT EXHAUSTIVE STUDY of *Fegatella conica*, by F. Cavers[13] seems to indicate that in large measure it repeats the well-known history of Marchantia. Contrasting features are the simple air pores, the more differentiated thallus, the "mycorhizal zone," the larger sperms, and the fact that the cover-cell of the archegonium does not contribute to its elongation (which may be true also of Marchantia). — J. M. C.

RICHARDS AND MACDOUGAL[14] find that when the nitrogen of the air is replaced by CO or by illuminating gas, which contains *ca.* 40 per cent. of CO, seed plants of various kinds show toxic effects, growth, irritability, and chlorophyll formation being notably retarded or inhibited. Mosses were less affected, some enduring CO or "gas" for three months, with injury only to older leaves. In "gas" there are evidently present other toxic agents than CO. — C. R. B.

TONDERA finds[15] in the young internodes of the Cucurbitaceae the "starch-sheath" supplied with fine-grained starch, equally distributed through the protoplasm; whereas only in the older internodes which are not geotropic are there coarse grains that lie on the lower side of the cell. This, he argues, militates against the statolith theory of geotropism. He thinks the "starch-sheath" a storage region during the formation of the zone of mechanical tissue (stereome or collenchyma) which adjoins it.—C. R. B.

RAUNKIÆR[16] has arranged the species of Potamogeton into groups based mainly upon anatomical characters, such as the build of the central cylinder, presence or absence of cortical strands, nature of the endodermis. The author considers that anatomical distinctions are more satisfactory than any others in recognizing the different species. He claims to settle on anatomical grounds the vexed question as to what constitutes *P. fluitans* Roth, and concludes that two quite different plants have been included under this name. — M. A. CHRYSLER.

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[12] ROSTOCK, R., Ueber die biologische Bedeutung der Drüsenhaare von *Dipsacus sylvestris*. Bot. Zeitung **62**^{1}: 11–20. 1904.

[13] CAVERS, F., On the structure and biology of *Fegatella conica*. Ann. Botany **18**: 87–120. *pls. 6–7*. 1904.

[14] RICHARDS, H. M., and MACDOUGAL, D. T., The influence of carbon monoxid and other gases upon plants. Bull. Torr. Bot. Club **31**: 57–66. 1904.

[15] TONDERA, F., Contribution à la connaissance de la gaine d'amidon. Bull. Acad. Sci. Cracovie, Math. Nat. Cl. **1903**: 512–516. *pl. 1*.

[16] RAUNKIÆR, C., Anatomical Potamogeton-studies and *Potamogeton fluitans*. Botanisk Tidsskrift **25**: 253–280. 1903.

W. C. WORSDELL[17] has published a valuable historical sketch of the views that have been held as to the nature of the ovule. It is a great convenience to have the extensive literature of the subject digested and available in compact form. The views of the numerous contributors to the literature of the subject are put under three categories: (1) axial theory; (2) foliar theory; and (3) *sui generis* theory, which means that the ovule is to be regarded as an independent structure, borne either on stem or foliar organs. The bibliography contains 149 titles under 82 authors.— J. M. C.

KARSTEN AND SCHENCK have issued three more numbers of their valuable *Vegetationsbilder*.[18] The sixth number was prepared by Karsten and portrays the following tree monocotyledons: Pandanus, Zanthorraea, Yucca, Nolina, Dendrocalamus, Ravenala. In the seventh number Schenck illustrates the strand vegetation of Brazil, giving several photographs of the Pes-Caprae and Restinga formations. Karsten and Stahl prepared the eighth number, which treats of Mexican xerophytes. Excellent illustrations of cacti, agaves, and other desert forms are brought together. These numbers maintain the high standard of the earlier parts, and it is more apparent than ever that this publication is of great practical value to all botanical libraries and laboratories.— H. C. COWLES.

ERWIN F. SMITH AND DEANE B. SWINGLE[19] have published the results of their study of the dry rot of potatoes. The "bundle blackening" and "dry end-rot" are found to be two stages of the same disease, which begins in the field in the underground stems and roots. A fungus, which has proved to be a Fusarium, is always present in the darkened vascular bundles of the tubers. The fungus tolerates large amounts of certain acids, as malic, citric, and tartaric, and is inhibited by small amounts of others, as formic, acetic, and butyric. It attacks the plants from the soil and winters over in the earth, so that in land frequently planted to potatoes it can probably maintain itself indefinitely. Infected land should be planted to other crops for a series of years, and great care should be taken to avoid the infection of healthy land by planting diseased tubers.— J. M. C.

MOLISCH, seeking to check Friedel's and Macchiati's results, which indicate that photosynthesis is an enzymatic process,[20] reports experiments upon several plants, using the luminosity of *Micrococcus phosphoreus* as a reaction for the evolution of oxygen (Beijerinck's method, the sensitiveness of which

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[17] WORSDELL, W. G., The structure and morphology of the "ovule." Ann. Botany **18**: 57–86. 1904.

[18] KARSTEN, G., and SCHENCK, H., Vegetationsbilder. Hefte 6, 7, 8. *pls. 31–48.* Jena: Gustav Fischer. 1903. Single parts *M* 4; to subscribers *M* 2.50.

[19] SMITH, ERWIN F., and SWINGLE, DEANE B., The dry rot of potato due to *Fusarium oxysporum.* U. S. Dept. Agric., Bur. Pl. Industry, Bull. 55. pp. 64. *pls. 8.* Issued Feb. 16, 1904.

[20] Reviewed in BOT. GAZ. **32**: 430. 1901; **33**: 315. 1902; **35**: 226. 1903.

he tested and confirmed).[21] Green sap, obtained by rubbing up fresh leaves in a mortar or by compression and filtering through paper, can set free oxygen. Leaves of *Lamium album* dried at room temperatures or in an oven at 35° C., so that they felt quite dry and had completely lost their vitality, were rubbed up with water and yielded a sap of like powers. But this, as shown by microscopic observation, was dependent upon the plasma particles and chloroplasts which pass through filter paper; for the same sap after filtration through a Berkefeld or Chamberland tube, whether from living or dead leaves, had no such reducing power. Molisch also attempted to repeat Friedel's and Macchiati's experiments, but unsuccessfully. His results with Lamium, however, incline him to think that it may yet be possible to study photosynthesis apart from the living cell.—C. R. B.

THE SUBJECT which Professor Seward[22] treats in a general way in his presidential address at the Southport meeting of the British Association is one of commanding importance to all students of plant evolution and geographical distribution, and yet it is a branch of the science much neglected by the students of modern groups. Professor Seward divides the world into twenty-two entirely arbitrary regions, and discusses briefly the rise and fall of the various botanical types that have moved across the stage from the pre-Devonian to the present time. It would seem to the writer that the differences between the northern and southern floras in the Carboniferous are emphasized somewhat more strongly than the evidence warrants, and that Professor Seward unduly depreciates paleobotanical evidence other than what is based on anatomical studies of tissues and fructifications. While it is unfortunately true that the latter Mesozoic formations furnish us with almost nothing but carbonaceous impressions, and while we might wish it otherwise, still we cannot afford to ignore what facts we have of the days when the angiosperms were rapidly assuming the leading rôle in the vegetation of the world. The whole address is a most able and earnest plea for a sympathetic study of ancient floras and for a wider viewpoint among specialists in that field of botanical activity. It is eminently desirable that it should receive more attention from American botanists than it is likely to attract.—EDWARD W. BERRY.

PALEOBOTANICAL NOTES.—KATZER,[23] in a short paper on the geological development of the *Braunkohlenschichte* of the Zenicer depression in Bosnia, enumerates fourteen well-known species of Miocene plants. This

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[21] MOLISCH, H., Ueber Kohlensäure-Versuche mittelst der Leuchtbacterienmethode. Bot. Zeitung **62**^{1}: 1–10. 1904.

[22] SEWARD, A. C., Floras of the past: their composition and distribution. British Assn. Adv. Sci. Southport. 1903.

[23] KATZER, F., Geološki razvoj naslage mrkog nglja n zeničkoj kotlini. (Geol. Entwickelung der Braunkohlenschichte der Zenicker Depression) Glasnik gemalj. muz. n Bosni i Hercegov. **15**: 101. 1903.

paper is followed by a more lengthy paper by Engelhardt,[24] who enumerates sixty-two species of plants from this region in Bosnia in beds of the Miocene age. Two species of *Tilia* from Doboj and Kakanj are described as new. The flora shows a considerable mixture of northern and southern forms, and includes twenty-six species common to the American Tertiary.—KIDSON[25] has described the Carboniferous plant remains from the border region of Canobie and Dumfriesshire, Scotland, and parts of Cumberland and Northumberland, England. They include remains from both the lower barren measures and from the upper measures, some of the horizons of the latter not before known in this region. A new genus, *Eskdalia*, is proposed for the reception of certain fern stems, and a number of new species in other genera are described.—ARBER and NEWELL[26] have a paper on homoeomorphy among fossil plants illustrating that well-known tendency exhibited in some groups of unallied forms to show an aggregate of common characters. While the term is not exactly synonymous with what has been called convergence, it seems to be the same as the term "homoplasy" as used by the zoölogists Lankester and Osborn, or the "homomorphy" of Fürbringer. POOLE[27] contributes a short paper on a remarkably well-preserved section of Stigmaria from the coal measures of Stellarton. The scalariform tissue of the medulla is particularly well shown. There are over thirty vascular bundles, each containing from five to fifteen radial rows of rectangular cells, with about forty cells in each row.—Contributions of minor importance are an anatomical paper by STOPES[28] on the epidermoidal layer of calamite roots; a paper on *Xenophyton radiculosum* and on a stigmarian rootlet probably related to *Lepidophloiois fuliginosus*, by WEISS;[29] a paper by KERNER[30] describing a new locality for Tertiary plants in Dalmatia; a paper by KIDSON[31] entitled Notes on some Scottish floras of Lower Carboniferousage; and a paper by STERZEL[32] on the character of the floras of the Carboniferous and Permian from the well-known locality of Zwickau in Saxony.—EDWARD W. BERRY.

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[24] ENGELHARDT, H., Prilog poznavanjn fosilne flore is naslage smegjeg ngljena n kotlini Zenica-Sarajevo n Bosni. (Beitr. z. Kennt. der foss. Fl. aus der Braunkohlenschichte im Sarajevo, Zenicer, Kassel in Bosnien) *Ibid.* **15**: 115–136. 1903.

[25] KIDSON, R., The fossil plants of the Carboniferous rocks of Canonbie, etc. Trans. Roy. Soc. Edinburgh **40**: 741–833. *pl. 1–5* and *fig. in text.* 1903.

[26] ARBER and NEWELL, Geol. Mag. N. S. **10**: 388–395. Sept. 1903.

[27] POOLE, H. S., Proc. & Trans. Nova Scotia Inst. Sci. **10**^{3}: 345–347. *pl. 2.* Oct. 1902.

[28] STOPES, M. C., Ann. Botany 792–794. 1903.

[29] WEISS, F. E., Mem. & Proc. Manch. Lit. & Philos. Soc. **46**: pt. 3. 1902.

[30] KERNER, F., Verh. k.k. Reichsanstalt **1903**: 342–344.

[31] KIDSON, R., Summary of Prog. Geol. Surv. United Kingdom for 1903. pp. 130–137.

[32] STERZEL, T., Erl. geol. Specialkarte Königr. Sachsen. 2 Aufl. Leipzig 1901. pp. 85–139.

VERNON H. BLACKMAN[33] has published a preliminary notice of the results of his study of the Uredineae, the full paper, with figures, to appear later in the Annals of Botany. The forms studied were *Phragmidium violaceum* Wint. and *Gymnosporangium clavariaeforme* Rees. Sapin-Trouffy's cycle of nuclear development was confirmed, which is as follows: the mature teleutospore is uninucleate and this condition persists through sporidia and the aecidial mycelium; in the young aecidium the nuclei become paired, and this condition persists through aecidiospores, the ensuing mycelium, the uredospores, and into the young teleutospores; in the maturing teleutospores the two nuclei fuse. It was this fusion in the teleutospore that Sapin-Trouffy regárded as fertilization.

Blackman concludes that the spermatia are male cells that have become functionless, basing his conclusions upon the cytological characters, which are clearly those of male cells and not of conidia. The aecidium of *P. violaceum* arises as a layer of rectangular uninucleate cells just beneath the epidermis of the leaf. Each of these cells becomes divided into a short sterile cell above, which soon degenerates, and a fertile cell below, which becomes binucleate and gives origin to a row of binucleate aecidiospore mother-cells. Thus the condition of paired nuclei starts in the fertile cell and is continued to the teleutospore. The fertile cell, which the author regards as a female cell, does not become binucleate by division of its original single nucleus, but by the migration through the walls of the nucleus of a neighboring vegetative cell. This association of the two nuclei he regards as representing fertilization, rather than the act of fusion in the teleutospore.

This means a sharply marked alternation of generations among the Uredineae. The gametophyte starts with the uninucleate teleutospore, the production of the four sporidia representing a tetrad division; from these the mycelium of the gametophyte develops and produces later the spermogonia and aecidia. The fertilized cell in the aecidium starts the sporophyte generation with paired nuclei, from which the aecidiospores almost immediately arise; the sporophyte mycelium bears later uredospores and finally teleutospores. The fusion of nuclei in the teleutospore cannot then be looked upon as a process of fertilization, but merely as the secondary process which brings about the disappearance of the special cytological conditions initiated by fertilization, *i. e.*, change from the sporophytic to the gametophytic condition; it must accordingly be looked upon as a reduction process. Like the reduction process in higher plants, it is followed by a tetrad division. These conclusions apply also to the fusion of nuclei in the basidium, as Maire has shown that Basidiomycetes also have paired nuclei that fuse in the basidium.

Just how the fusion of sexual and vegetative nuclei is to be regarded as fertilization is not clear, but such cases loosen up the previous rigidity of

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[33] BLACKMAN, VERNON H., On the fertilization, alternation of generations, and general cytology of the Uredineae. Preliminary notice. New Phytologist 3:23–27. 1904.

ideas concerning fertilization. Farmer's phrase "apogamous fertilization" is a proper expression of uncertainty in reference to the definite criteria of fertilization.—J. M. C.

TWO PAPERS by Fitting constitute a very valuable contribution to our knowledge of the physiology of tendrils. The earlier paper[34] is a quantitative study of the growth of stimulated and unstimulated tendrils. Special attention is given to curvatures resulting from contact stimulus, but those resulting from amputation, temperature variation, and mechanical bending are also considered.

The growth of unstimulated tendrils is intercalary, being most intense in the basal half and manifesting two distinct phases of acceleration separated by a period of diminished rate. Growth is uniformly distributed in the tendrils in the first of these two phases, but in the second curvature appears as a consequence of unequally distributed growth, which is maximum at the periphery of the side becoming convex and gradually diminishes to zero at the periphery of the concave side.

Especially notable is the author's discovery of high perception capacity associated with low reaction capacity. It has long been known that some tendrils react to stimuli applied on any side and others only when stimulated on one side. The latter are, however, sensitive on all sides, even though unable to respond to stimuli not ventrally applied. This is shown when a stimulus dorsally applied inhibits response to one ventrally applied. In such tendrils a dorsal stimulus will even inhibit the completion of a curve already commenced in response to a ventral stimulus.

The stimulation of opposite sides does not appreciably affect growth in either uniformly reacting or locally reacting tendrils. The curvature formed in response to contact stimulus is after a period of hesitation followed by a reverse curve which accomplishes straightening and is regarded by Fitting as autotropic. The mechanism is the same in each of these curves, the growth of the middle zone being accelerated. This eliminates turgor variation as a factor in curvature, especially since the growth of the concave side is not actually retarded.

The correction of artificial bendings mechanically formed coincides in process with formation of curves in response to contact stimulus. Haptrotropic curvatures are distinguishable from other tropic curves by the manifest acceleration in growth of middle zone. The encircling of a support is accomplished by curves formed in response to a series of contact stimuli. Prolonged contact is not a stimulus to effect an acceleration of growth. Exception is taken to Noll's "Reizfelder" hypothesis.

The later paper[35] is a further study of the curves produced in tendrils as

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[34] FITTING, HANS, Untersuchungen über den Haptrotropismus der Ranken. Jahrb. Wiss. Bot. **38**: 545–634. 1903.

[35] FITTING, H., Weitere Untersuchungen zur Physiologie der Ranken. *Ibid.* **39**: 424–526. 1903.

a result of decapitation and amputation, together with a consideration of the physiology of stimulus transmission in tendrils and in Mimosa.

When tendrils of *Passiflora* sp. are severed at the base, a strong apical curvature appears in one or two minutes. This curvature is limited to the haptrotropically sensitive zone and becomes corrected if the tendril has its cut surface in water. Both curvature and recurvature are true growth phenomena, being dependent upon an accelerated growth of the middle zone. Similar responses may be obtained with tendrils belonging to widely different families, although minor modifications appear. In some tendrils a fluid drop exudes from the exposed surface, and in others no such drop appears. The incision must enter the central cylinder in order to produce a curve. Piercing with a fine needle is a stimulus if the central cylinder is penetrated. The impulse travels from the locus of amputation toward the motor zone very rapidly, even as fast as 20^{mm} per second, and the actual rate is probably greater because the larger portion of time elapsing between stimulation and response is to be considered as a latent period.

From old and new experiments it is evident that the process of transmitting a wound stimulus in Mimosa coincides in all essential particulars with such a process in tendrils. All indications are that in Mimosa transmission occurs in the living cells. Since in some cases an impulse is carried beyond a deadened zone it seems improbable that the plasma actively participates in the transmission. Haberlandt's theory of a diminution of hydrostatic pressure in the conductive tissue as an explanation of the transmission process is inadequate because it occurs in plants which are without *Schlauchzellen*.—RAYMOND H. POND.

NEWS.

Dr. D. H. Scott has been elected president of the Royal Microscopical Society for the ensuing year.

Émile Laurent, professor of botany in the State Agricultural Institute, Gembloux, Belgium, died *en route* from a fever contracted while recently visiting Sierre Leone.

Professor Hugo de Vries, of Amsterdam, will give a series of five lectures at the University of Chicago, August 22–26 next. He lectures earlier in the summer at the University of California, but we are not informed as to details.

William M. Canby, of Wilmington, Delaware, died on March 10 at Augusta, Georgia, while on a visit to the South for the benefit of his health. The name of Mr. Canby is a very familiar one to American taxonomists, and it stands to them not merely for one of our best-known older botanists, but for a friend who was always genial and helpful.

The session of the biological laboratory of the Brooklyn Institute for 1904 will be held at Cold Spring Harbor, beginning July 6 and continuing six weeks, under the general charge of Professor C. B. Davenport of the University of Chicago. Instruction in cryptogamic botany will be given by Professor D. S. Johnson and Mr. A. H. Chivers, and in plant ecology by Mr. Forrest Shreve.

Dr. Burton E. Livingston, of the University of Chicago, has received a grant from the Carnegie Institution to be used in an investigation of the relations which exist between soil properties and vegetational characteristics in the arid region of New Mexico, Arizona, and California. The work will be carried on during the coming summer, with headquarters at the Desert Botanical Laboratory at Tucson, Arizona.

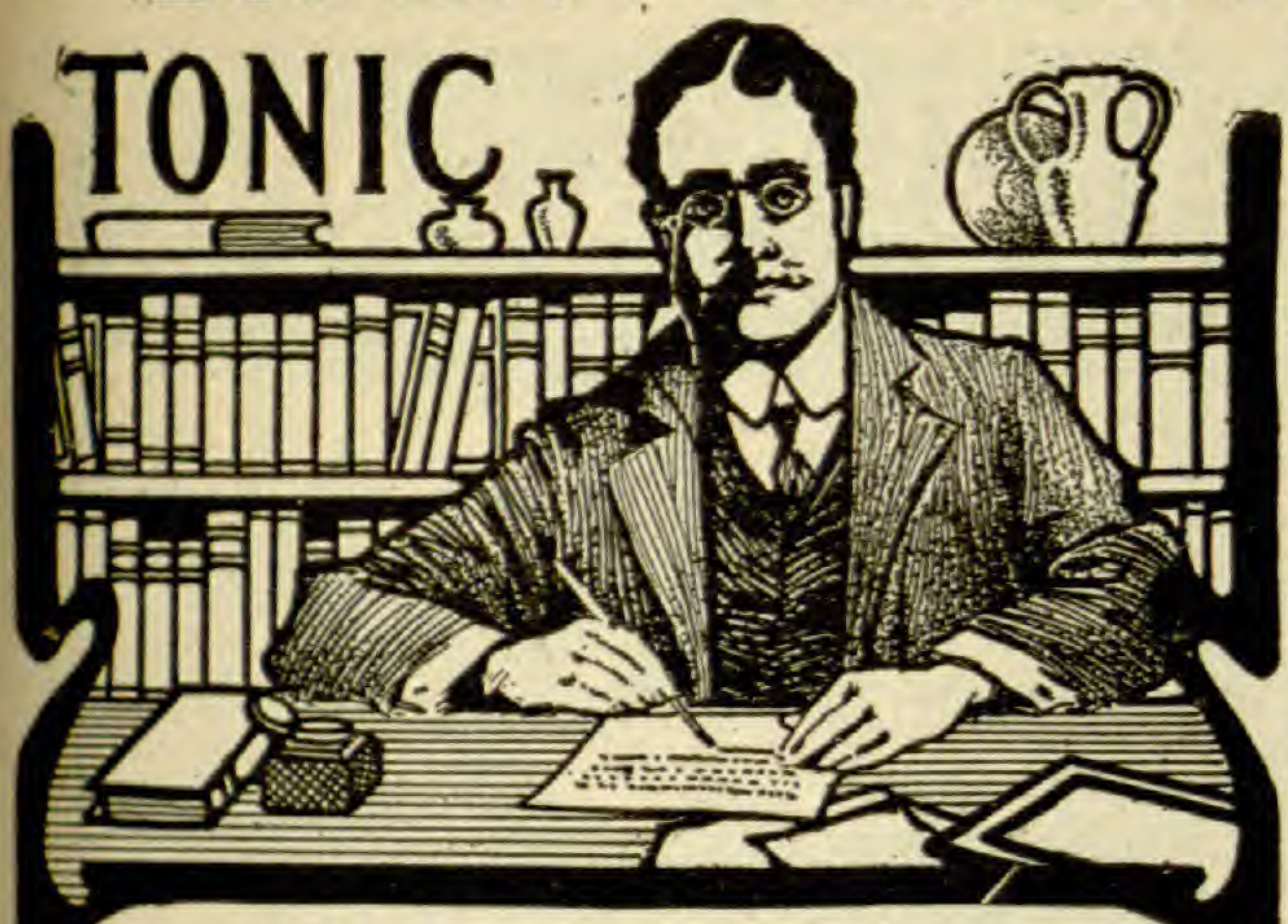
The season of the Minnesota Seaside Station for 1904 begins about the middle of July and continues for six weeks. The botanical work will be under the general direction of Professor Conway MacMillan, who will conduct special laboratory courses upon the ecology and morphology of the kelps, and upon the anatomy and classification of the liverworts and mosses of the region. Miss Josephine E. Tilden will give courses upon algae, and Dr. Albert Schneider will offer work upon the lichens, and will also give lectures upon bacteria and nitrogen assimilation.

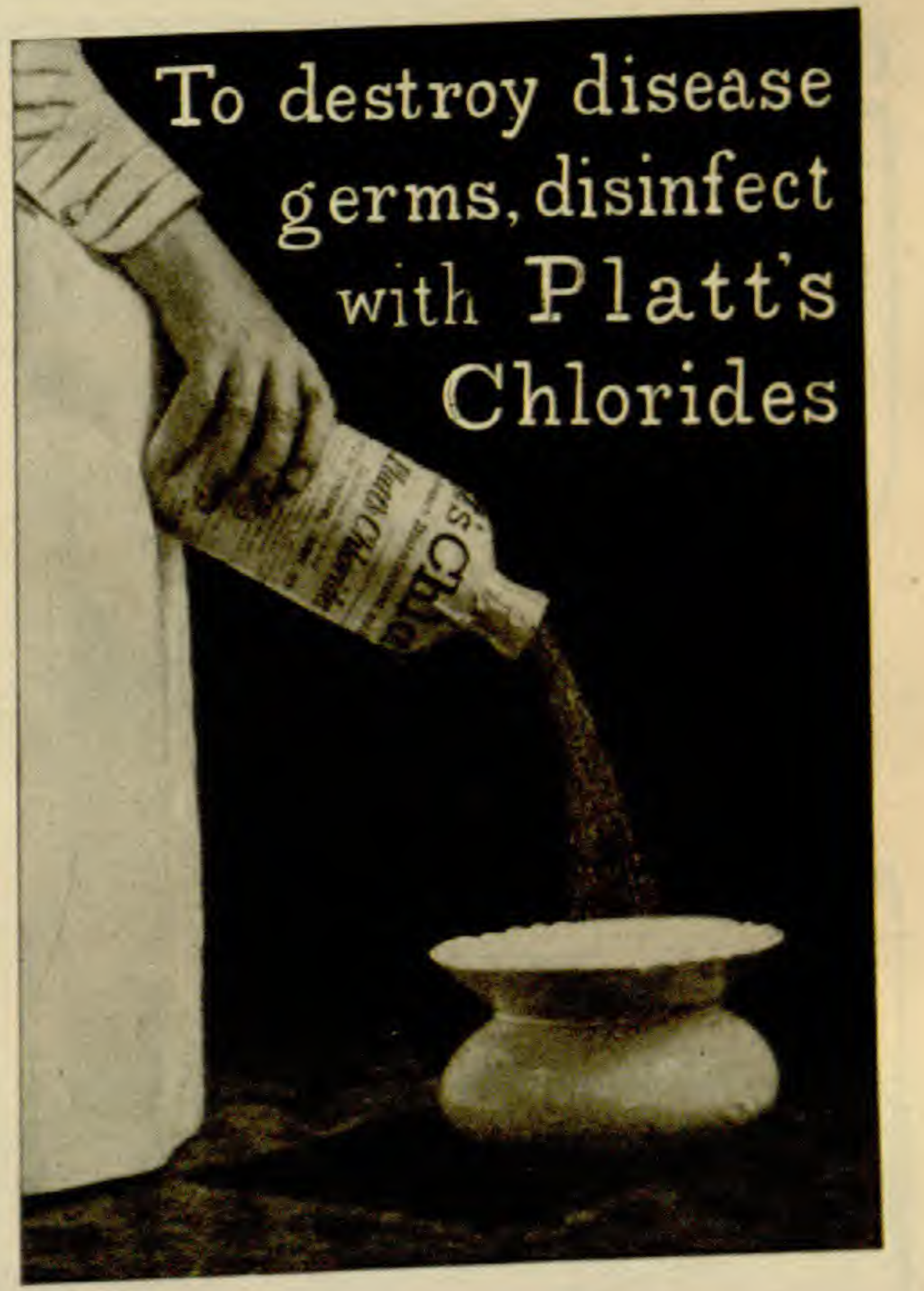
The seventeenth session of the Marine Biological Laboratory at Woods Hole will begin June 1 and close October 1. The instruction in botany consists of a course on thallophytes from June 29 to August 10, which will be given by Professor Davis (Chicago) who is in general charge of the botanical department, and Dr. Moore (U. S. Dept. Agric.). Other members of the staff, who may be consulted regarding research, are Messrs. True and Kearney (U. S. Dept. Agric.), Lyman (Dartmouth) and Wolfe (Harvard). The usual course of general lectures may be expected.

THE BERMUDA BIOLOGICAL STATION for research, at Flatts, Bermuda, will be open again for six weeks during the coming summer. The Station is under the direction of Professor E. L. Mark of Harvard University and Professor C. L. Bristol of New York University, and every opportunity will be given to those botanists and zoölogists who come to the station with definite problems. The date of sailing from New York is July 2, and the total expense of the six weeks, including transportation, board, and lodging, will be $100. Applications cannot be received later than May 1.

THE COMMITTEE in charge of the scientific congresses at the Louisiana Purchase Exposition have arranged for the presence of several distinguished foreign botanists, who will give addresses. Acceptances have been received from Professors K. GOEBEL of Munich; F. O. BOWER of Glasgow; J. WIESNER of Vienna; O. DRUDE of Dresden; CH. FLAHAULT of Montpellier. Dr. H. DE VRIES of Amsterdam has also been invited to give an address and it is probable that he will accept. The botanical congress begins Sept. 19. Announcement of American speakers and presiding officers will be made later.

THE PREPARATIONS for the second international botanical congress to be held at Vienna in June 1905 are progressing under the direction of various committees. Of course, as the nomenclature question is to occupy a prominent place in the deliberations, and as the proposals must be submitted far in advance of the meeting, it appears at this time as though nomenclature was the sole subject before the congress. But other parts of the program will be developed in due time. The general secretary of the international commission on nomenclature, John Briquet, has already received from Otto Kuntze a *Codex brevis maturus*, which the author desires to have solely control the organization of the congress and form the basis of its discussions! About this remarkable proposition there has been the usual vigorous and even vituperative correspondence, which has been disseminated by Dr. Kuntze. The motto of the Kuntze party has been well formulated by Dr. Ernst H. L. Krause, "Aut Kuntze aut nihil!" Twenty-three Swiss and Belgian botanists have also submitted proposals. The American committee on nomenclature recently held a meeting in Philadelphia and completed the formulation of its proposals, which will be submitted in due form before June 30. Doubtless there will be still others. We trust American botanists will not neglect to contribute to the proposed exposition, fully announced by the Association Internationale des Botanistes in the *Botanisches Centralblatt.*





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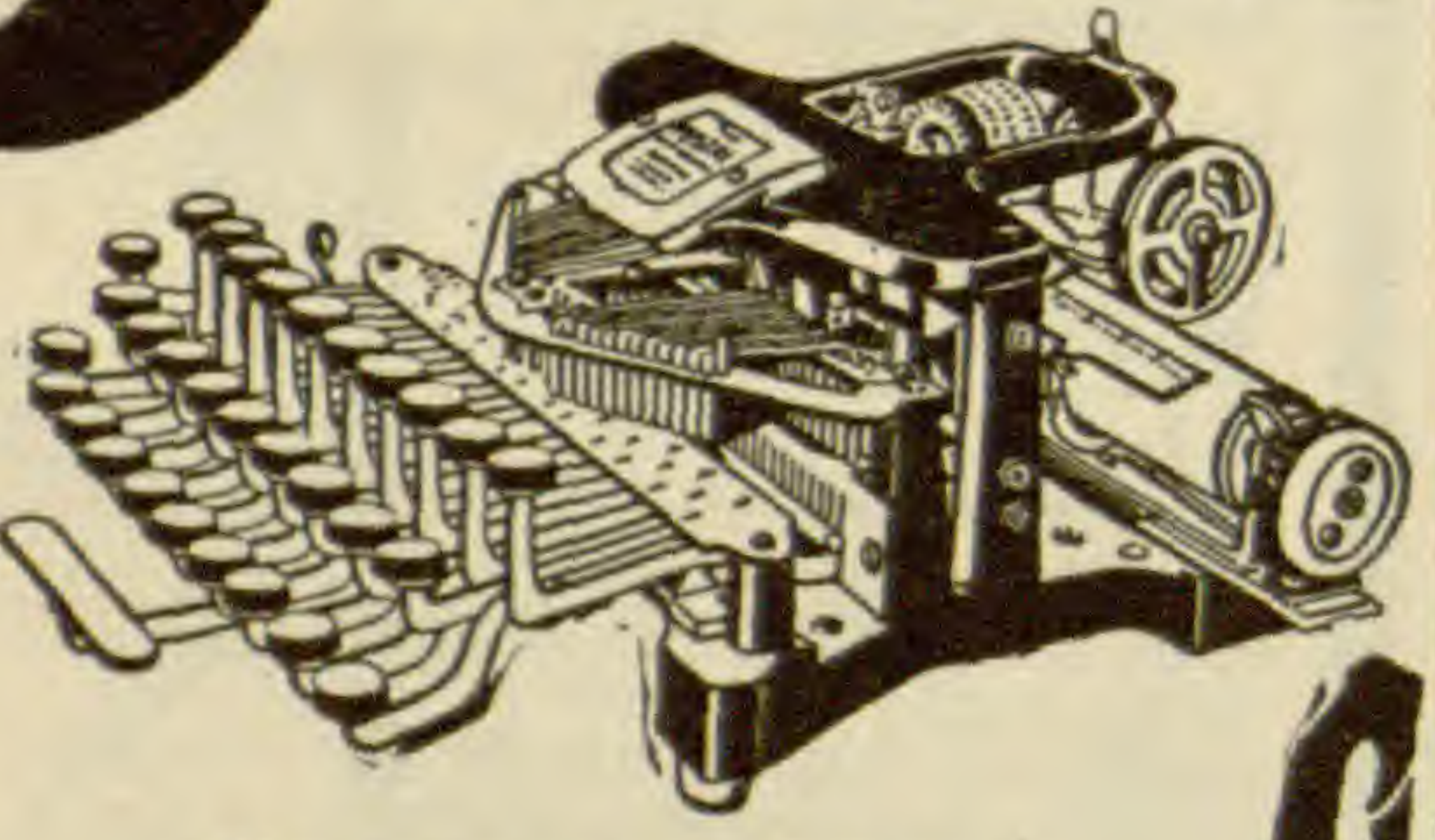

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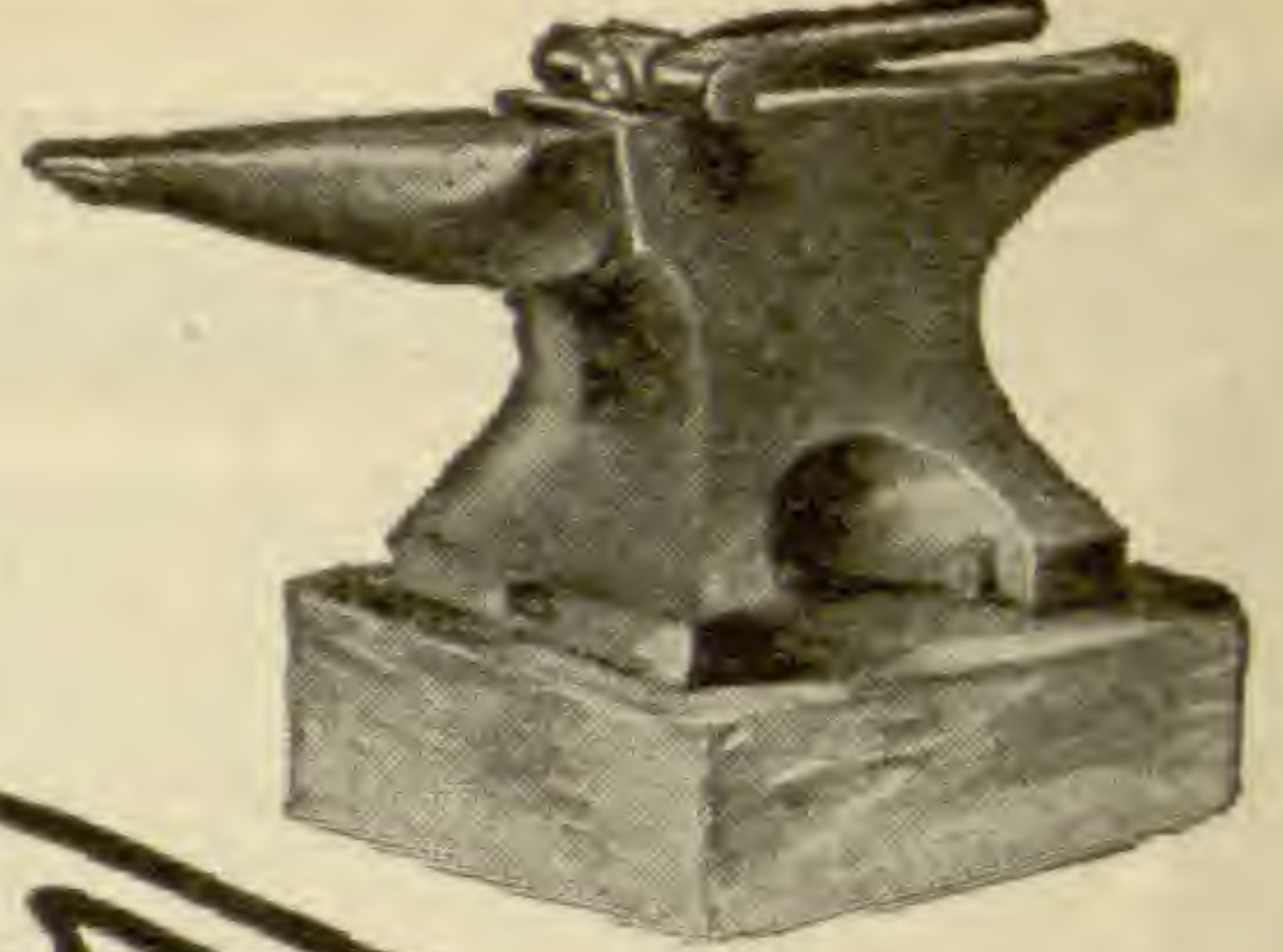

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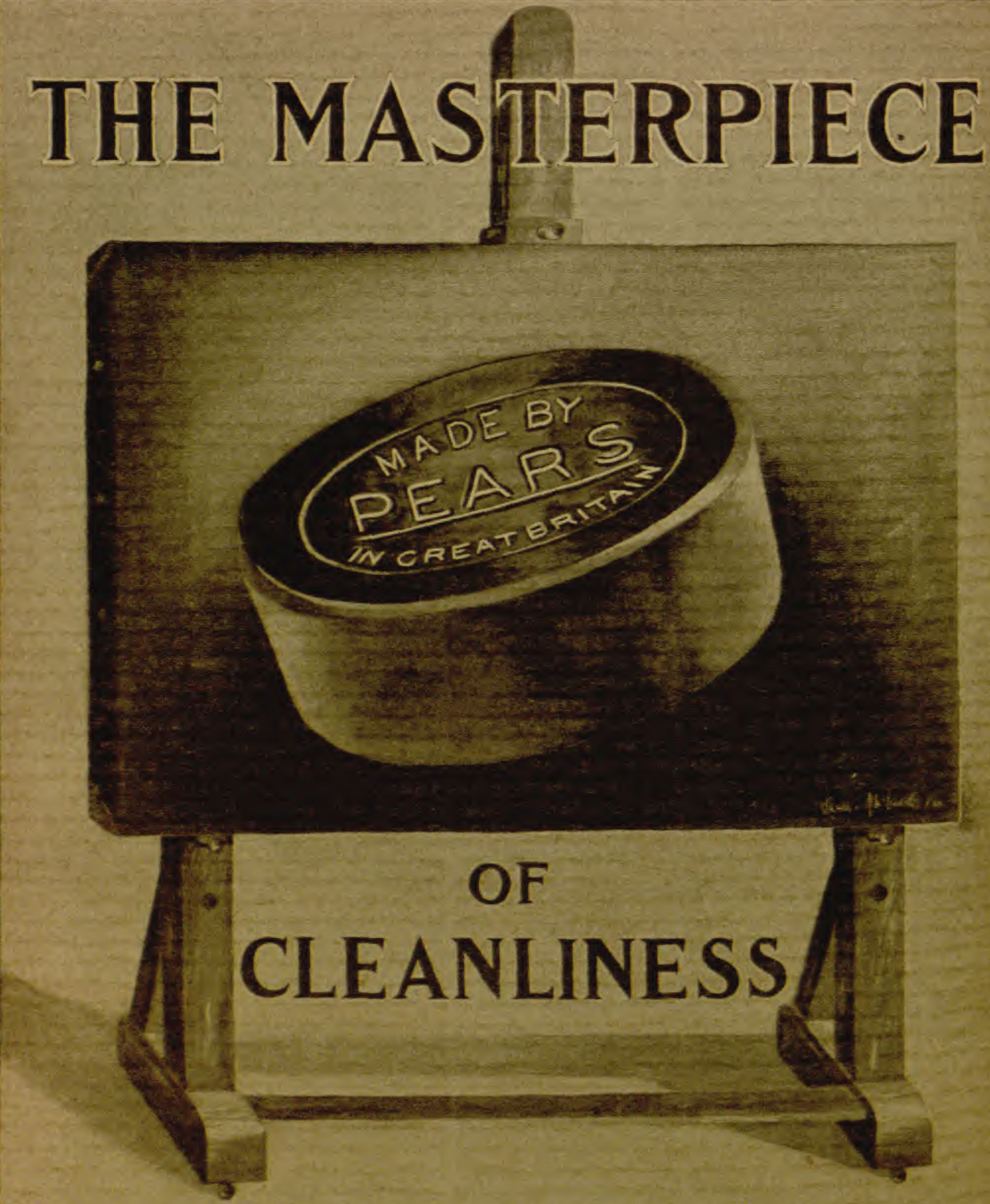

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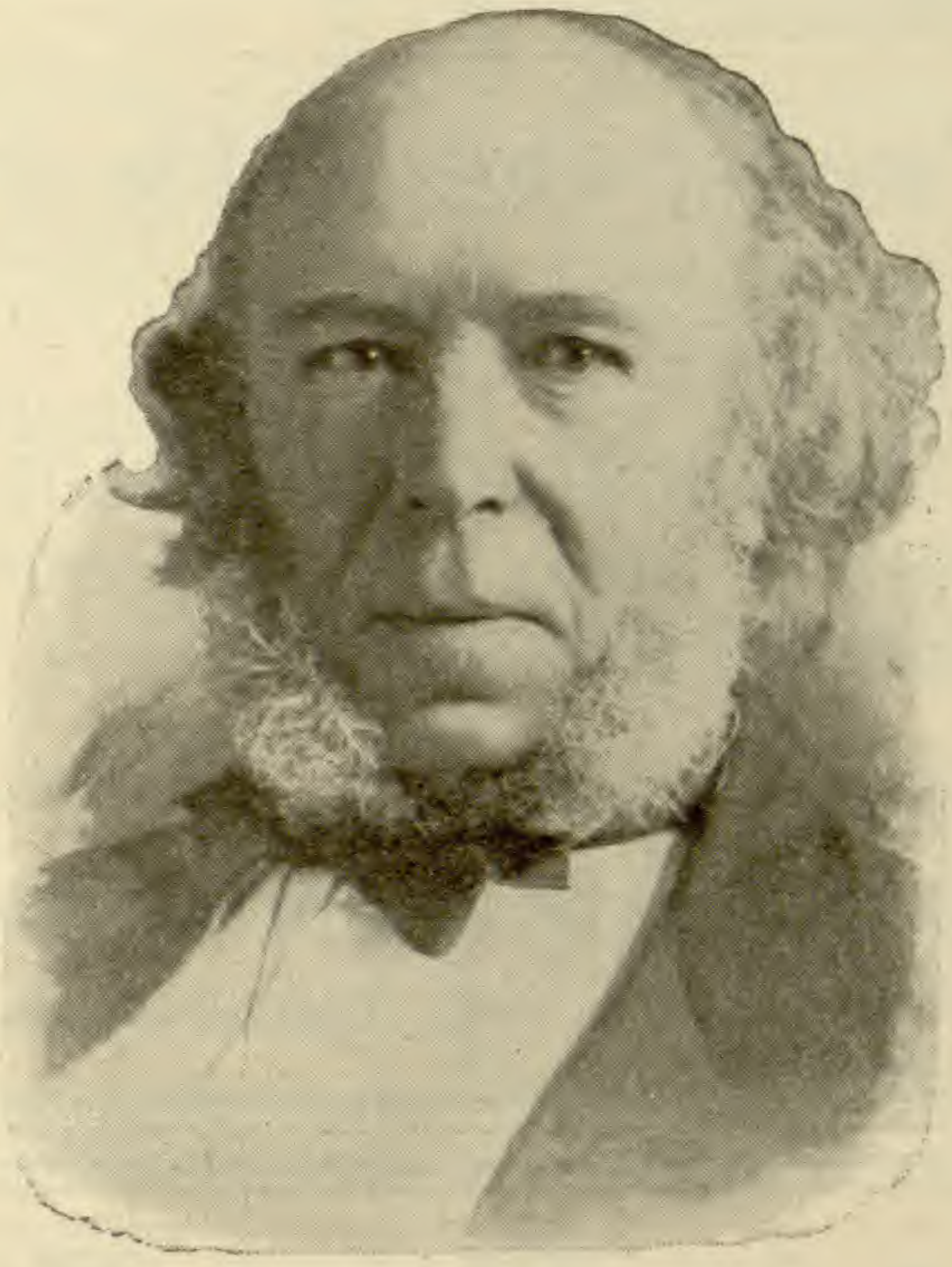

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THE EVOLUTION OF MONOCOTYLEDONS.

ETHEL SARGANT.

(WITH SIX FIGURES)

NO SUBJECT is of more general interest to botanists than the early race-history of angiosperms. In a recent paper[1] I have attempted to justify the publication of a new hypothesis on this subject by a detailed account of the embryological evidence on which it is founded. The details of such work, however, have little interest for any but specialists, and I wish to deal here with the wider aspects of the subject. The argument of the following pages is in substance that contributed to a discussion on the evolution of monocotyledons which was held in September, 1903, at the Southport meeting of the British Association for the Advancement of Science. The whole paper has been recast since then, much has been added, and something omitted; in particular several passages have been introduced in answer to objections raised during the discussion.

There is a remarkable absence of direct geological evidence concerning the origin of angiosperms and the comparative antiquity of the two races included in that group. In the present state of our knowledge all conclusions with regard to the race-history of angiosperms must be founded on the comparative morphology of living forms. On such grounds, however, I have ventured to assume that monocotyledons and dicotyledons will ultimately be traced back to a common ancestor which in all

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[1] SARGANT E., A theory of the origin of monocotyledons. Annals of Botany 17:1. 1903.

essential features was an angiosperm, in spite of the fact that several modern authorities hold the contrary opinion.[2]

The isolation of the angiosperms, long recognized, has been emphasized by recent work. On the one hand, the connection of gymnosperms with pteridophytes has been so far traced through forms now extinct that the degree of relationship between those groups can be estimated, while no link has been found to connect the angiosperms with any other group. Thus our ignorance of their genealogy is the more obvious by contrast with increasing knowledge concerning that of other vascular plants. On the other hand, the internal structure of the embryo sac both before and after fertilization has been shown of late to separate angiosperms from other forms even more completely than was formerly supposed.

The gulf which separates angiosperms from all other plants is indeed of unknown depth. By comparison the internal boundary which divides monocotyledons from dicotyledons is very insignificant. The points of resemblance between members of these two classes are far more numerous and more important than those in which they differ.

Translated into the language of evolution, this means that the angiosperms are a race of considerable antiquity, which at some epoch in its history gave rise to two branches, monocotyledons and dicotyledons. If this is the case, it is clearly a point of great importance to obtain some notion of the structure of the primitive angiospermous stock.

Whatever the primitive angiosperm may have been, we may fairly assume that it was not a perfect mean between the monocotyledon and dicotyledon, nor on the other hand totally unlike either. Which did it most resemble? In other words, which type is the more primitive?

This is no new problem. It has been debated for upwards of fifty years, and during that period most botanists have maintained the superior antiquity of monocotyledons. Of late this

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[2] BALFOUR, I. B., Presidential address to section K of the British Association. 1901. COULTER, J. M., The phylogeny of angiosperms. Decennial Publ. of University of Chicago. 1903.

opinion has lost ground. The evidence which supports it has been criticised, and more than one observer has brought forward facts in favor of the claim of dicotyledons to be considered the elder branch.

EVIDENCE FOR THE PRIMITIVE MONOCOTYLEDON.

The case for monocotyledons rests on evidence drawn from three distinct lines of research: (1) the direct evidence of fossil botany as to the geological succession of forms; (2) comparison of the stem anatomy in the two classes; (3) the study of the developing embryo within the embryo sac.

1. Direct historical evidence from the succession of fossil forms would of course be more conclusive than any based on comparative morphology. But unfortunately the geological record is particularly imperfect at the epoch which separates the gymnospermous flora of the Mesozoic age from the earliest fossil floras in which angiosperms can be recognized with certainty.[3]

2. The absence of a normal thickening ring in the stem of monocotyledons was formerly considered a primitive character. This was a very natural inference at a time when a normal cambium was unknown except among gymnosperms and dicotyledons. It led to the now discarded classification which united gymnosperms with dicotyledons, of which traces may still be found in systematic text-books.

But now that the anatomy of many fossil cryptogams is as well known as that of any living forms, we realize that cambial thickening was a commonplace in vegetable anatomy long before the advent of angiosperms. Some of the ancestors common to monocotyledons and dicotyledons must almost certainly have possessed it, and if so, its absence from the stem of monocotyledons must be regarded as the loss of a primitive character.

3. The argument from the history of the embryo within the embryo sac is that which has perhaps had the most weight with botanists. The facts are shortly these:

In both classes the cotyledons are commonly the first mem-

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[3] SEWARD, A. C., Presidential address to Section K of the British Association. 1903.

bers differentiated from the mass of meristem which constitutes the embryo. Among monocotyledons the single cotyledon forms a club-shaped termination to the axis, and the boundary between these members is first clearly defined by the appearance of a lateral cleft within which is formed the growing-point of the stem. Thus the cotyledon is apparently terminal in monocotyledons, the stem bud lateral (*fig. 3* on p. 340).

In the dicotyledonous embryo a similar enlargement appears at one end, but it is sooner or later divided into two lobes by a median cleft, within which the stem bud is formed. As soon as this takes place the cotyledons appear lateral, the stem bud terminal.

The accepted interpretation of these facts is that the club-shaped enlargement of the dicotyledonous embryo before lobing begins is equivalent to that which gives rise to the single seed leaf of monocotyledons. Its subsequent bifurcation indicates the origin of both cotyledons from that of an ancestor which possessed but one. This interpretation has been recently urged by Mr. Lyon in his paper on Nelumbium.[4] In this species the meristematic mass at the end of the embryo attains some size before it gives rise to a pair of cotyledons. The stem bud first appears in a lateral position with regard to it, and later reaches a symmetrical station between the cotyledons by degrees. The embryo is said by Mr. Lyon to pass through a monocotyledonous stage, and he is even prepared on the strength of these observations to class Nelumbium among monocotyledons. Professor Strasburger[5] has observed with great force that the position of the embryo at one side of the embryo sac of Nelumbium has probably more to do with its one-sided development than any ancestral reminiscence.

A similar criticism may, I think, be applied to the whole argument. A parasitic mass of meristem which is forced to develop within very narrow limits naturally assumes the most convenient form, and any detail of shape is at least as likely to be due to its environment as to inheritance from remote ancestors.

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[4] LYON, H. L., Embryogeny of Nelumbo. Minnesota Bot. Studies 2 : 643. 1901.

[5] STRASBURGER, E., Ein Beitrag zur Kenntniss von *Ceratophyllum submersum*. Jahrb. Wiss. Bot. 37 : 477. 1902.

This view is strengthened by what we know of the development of the embryo among pseudo-monocotyledons. Scattered here and there among normal dicotyledons are species, or small groups of species, which on germination show a single seed leaf. There is no doubt whatever as to the affinities of these forms. We can safely assume that at some geologically recent period the common ancestor from which sprang all the species in the genus Corydalis, for instance, must have possessed two distinct cotyledons. Most species of Corydalis still possess two, but *C. cava* and a few allied forms have but one. There can be no doubt here that the species with a single seed leaf are derived from an ancestor with two. It would seem that the early history of the embryo ought to throw light on the way in which this took place. In such a form as *Corydalis cava* we should expect to see the bifurcation begin in the very young embryo, and that the two members thus indicated would later be reduced to one, either by the abortion of one of them or by the union of both.

Hegelmaier[6] described the formation of the embryo in several pseudo-monocotyledons in 1878. He worked out every detail in three species, beginning with the fertilized ovum and ending with the ripe seed. In each case he examined for comparison the embryos of closely allied species in which both cotyledons were present. His work has been completed by that of Sterckx[7] and Schmid,[8] who have traced the development of the embryo in those three species through its long period of maturation within the ripe seed down to the epoch of its germination.

In *Ranunculus Ficaria*, *Corydalis cava*, and *Carum Bulbocastanum* the history of the embryo from fertilization to germination is now complete. In all three species the cotyledon is single from the first. No bifurcation appears at any stage, though the cotyledon of *Ranunculus Ficaria* soon becomes—and remains—slightly two-lobed. The plumule is formed in a deep cleft which marks

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[6] HEGELMAIER, F., Vergleich. Unters. über Entwick. dicot. Keime. Stuttgart, 1878.

[7] STERCKX, R., Recherches anat. sur l'embryon et les plantules . . . . des Renonculacées. Mém. Soc. Roy. Sci. Liège III. **2**:—. 1899.

[8] SCHMID, Beitr. zur Embryo-Entwick. einiger Dicotylen. Bot. Zeit. **60**: 207. 1902.

the level dividing the axis of the embryo from its cotyledon. But as the cotyledon develops it does not appear terminal as it commonly does among true monocotyledons. The plumule soon comes to lie in a straight line with the axis, and the cotyledon is a hollowed structure which partly surrounds it. Indeed, the whole embryo at this age closely resembles that of Tamus as described by Solms-Laubach, in which the cotyledon appears lateral from the first (*figs. 4, 5, 6*, p. 340).

Hegelmaier indeed describes a single abnormal embryo of *Carum Bulbocastanum* in which the lower lip of the usually lateral cleft containing the plumule attains some size, and he interprets this structure as the rudiment of a second cotyledon. Little weight can be attached to an isolated case of this kind. We do not even know whether the lump of tissue he figures would have become a leaf-like member. This is the only ground for considering the absence of a second cotyledon in any pseudo-monocotyledon as due to its early abortion. We may therefore fairly say that the comparative study of the young embryo in the genera Ranunculus, Corydalis, and Carum does not indicate the process by which a species within those genera has come to possess a single cotyledon where its ancestor had two.

The history of the embryo within the ovule and seed then throws no light on the comparatively simple problem of the derivation of such forms as *Corydalis cava*, *Ranunculus Ficaria*, or *Carum Bulbocastanum* from the ancestral Corydalis, Ranunculus, or Carum. This consideration casts great doubt on the value of similar evidence when we attempt the harder task of tracing the origin of monocotyledons from an ancestor far more remote.

To sum up, research conducted on the three lines hitherto considered does not afford evidence of any great value in favor of the superior antiquity of monocotyledons. On the other hand, it does not so far support the opposing claims of dicotyledons.

EVIDENCE FOR THE PRIMITIVE DICOTYLEDON.

Two observers, M. Quéva and Professor E. C. Jeffrey, have recently appealed to anatomical evidence of a kind hitherto neglected. M. Quéva has made a careful anatomical study of several monocotyledons, including the liliaceous climber *Gloriosa superba*.[9] In this species he finds a well-marked cambium within the bundles of the second-year tuber and of all succeeding tubers. Secondary elements are added to the xylem and phloem of each bundle by its cambium, which is active throughout the two seasons during which the tuber lasts. Moreover, the bundles in the climbing stem of the seedling possess a cambium, though the elements which it contributes to the xylem and phloem soon lose their radial arrangement by further growth. M. Quéva comes to the following conclusion: "La persistance de la zone cambiale dans certains faisceaux des Monocotylédonées prouve qu'il est logique de considérer ces plantes comme dérivant de Dicotylédonées inférieures par extinction précoce de la zone cambiale et par augmentation du nombre des faisceaux de la trace foliaire" (*l. c.*, p. 147).

It will be remembered that Miss Anderssohn in 1888 described a cambium in the bundles of the young stem of several monocotyledonous seedlings.[10]

Professor Jeffrey has recently expressed his phylogenetic conclusions without reserve: "In the present state of our knowledge we are apparently justified in considering the monocotyledons to be a modern, strictly monophyletic, and specialized group, derived from dicotyledons or their parent stock, possibly by adaptation in the first instance to an amphibious mode of life."[11]

The evidence on which this view is based is the comparison of the mature stem anatomy with that of the seedling in what may be called the third period of its life. The first includes all the time during which the embryo is completely inclosed by the ovule or seed. The second period begins with germination, and while it lasts the seedling consists mainly of cotyledon, hypocotyl, and primary root. The young stem bud is present, but is

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[9] QUÉVA, C., Contributions à l'anatomie des monocotylédonées. Mem. de l'Université de Lille. 1900.

[10] ANDERSSOHN, S., Ueber d. Entwickel. d. primären Gefässbündelstränge d. Monokotylen. Bihang till K. Sv. Vet. Akad. Handl. **12**: 188 (Bot. Centralbl. **38**: —. 1889).

[11] COULTER and CHAMBERLAIN, Morphology of Angiosperms 316. 1903.

small compared with the cotyledon, and is usually more or less protected by it.

In the third period the stem bud becomes the ascending axis, and the cotyledon—even if persistent—is dwarfed by its rapid development. In the early part of its third period the plant is still very far from maturity. The epicotyl of monocotyledons contains at this time a single ring of collateral bundles, which may even show traces of a cambium. The stem, in fact, resembles that of a dicotyledon. In some monocotyledons the mature rhizome and the nodal regions of the aerial stem are characterized by amphivasal bundles. These are not found in the seedling (Jeffrey, *l. c.*).

There is nothing forced about the explanation of these facts given by Professor Jeffrey. As the characters of the young stem recall those of a dicotyledon, the features of monocotyledons appearing later in life, it is to be concluded that the stem anatomy of the common ancestor was essentially dicotyledonous. As has been said already, the anatomy of fossil cryptogams establishes a presumption that the primitive angiosperm possessed secondary thickening. The traces of the process found in the immature stem of monocotyledons strongly confirms this presumption.

For some years I have been employed on a comparative examination of monocotyledons soon after germination—as a rule during what I have called their second period of growth. About this epoch the vascular system of the immature structure is first completely defined by the lignification of the xylem.

This work has led me to the conclusion that monocotyledons are descended from an ancestor with two cotyledons, and that the single cotyledon which distinguishes them is a member formed by the fusion of the pair. For the nature and strength of the evidence I must refer to a previous paper.[12] It is sufficient to say here that the absence of a true midrib is a very general character in the cotyledon of monocotyledons, that its place is commonly supplied by two equivalent bundles, and that in the

[12] SARGANT, E., A theory of the origin of monocotyledons. Annals of Botany 17:1. 1903.

more primitive forms these bundles are massive and very widely separated.[13] The suggestion that each represented the midrib of an ancestral cotyledon seemed an adequate and simple explanation of the phenomenon, and it was much strengthened when I examined a number of dicotyledons—all from the Ranales—in which the cotyledons are partially united. The simplification of structure caused by this incomplete union was found to reduce the vascular symmetry of the ranal seedling (Eranthis, Podophyllum) to a skeleton much resembling that previously described as primitive among monocotyledons (Anemarrhena, Albuca).

An angiospermous plant possessing two seed leaves and exogenous stem structure would certainly, if now discovered, be ranked among dicotyledons, even though in other characters it should resemble a monocotyledon, or differ from both classes. Assuming an ancestor with these two characters, monocotyledons must be considered as derived from a dicotyledonous stock, not necessarily at one epoch or from a single strain. Can indications be found in the structure of living plants to suggest the conditions which operating for a length of time on such a stock might lead to the formation of a race or races essentially of the monocotyledonous type?

Beginning with the most general character and that which gives its name to the class, we may ask: Under what circumstances is the possession of a single cotyledon in place of two an advantage to the plant? An answer to that question is naturally sought among the few dicotyledons which possess but one seed leaf. I have compiled a list of species with this character.[14]

[13] The forms to which I refer are liliaceous: Anemarrhena, Albuca, and others nearly allied to these very distinct genera both in mature and in seedling characters. I believe them to be primitive among the Liliaceae after making a careful comparative study of seedlings from forty-five genera of that family. Systematists differ as to the position of the Liliaceae among monocotyledons. Some believe the type to be an ancient one from which many simpler monocotyledons are derived by reduction. My observations on the structure of seedling monocotyledons from a number of families incline me to accept this view, and on general grounds I prefer to attribute simplicity of structure when found in such advanced types as the angiosperm to reduction rather than antiquity. Anemarrhena and Albuca, then, if primitive among the Liliaceae are primitive also among monocotyledons in general.

[14] SARGANT, E., *l. c.*, p. 76.

They belong to eight genera which are systematically scattered, for they represent six families, Ranunculaceae, Fumariaceae, Umbelliferae, Primulaceae, Lentibularieae, Nyctagineae. Clearly these species cannot have inherited the peculiar form of their seedling from a common ancestor. It must be due to similar external conditions affecting certain species of very different descent in the same way.

One feature is common to all the pseudo-monocotyledons in my list—they all possess some underground member which is thickened into a tuber. In *Ranunculus Ficaria* one of the earlier cauline roots becomes tuberous; in the other species the hypocotyl is more or less thickened.

Moreover, the most complete list I can make of dicotyledons with their cotyledons partially united for some distance from the base upwards includes twenty genera.[15] It contains but one genus—Rhizophora—in which the hypocotyl is not very much shortened, if not actually thickened. In the great majority the hypocotyl becomes a conspicuous tuber. The seeds of the single exception germinate under peculiar conditions,[16] which would account for almost any amount of modification in the structure of the seedling.

The association of a tuberous habit with the reduction of the cotyledonary members has been noticed by several observers. Darwin in the *Movements of Plants*[17] says: "From the several cases now given, which refer to widely distinct plants, we may infer that there is some close connection between the reduced size of one or both cotyledons and the formation, by the enlargement of the hypocotyl or of the radicle, of a so-called bulb."

Now the formation of a shortened and generally thickened rootstock, whether morphologically a stem or a root, is characteristic of the plants which Professor Areschoug[18] has called geophilous. Such plants are found in regions where the conditions during part of the year are unfavorable to vegetation.

[15] SARGANT, E., *l. c.*, p. 73.

[16] KERNER and OLIVER, Natural History of plants 1:602–4.

[17] DARWIN, C., The power of movement in plants 97. 1880,

[18] ARESCHOUG, Beiträge zur Biologie der geophilen Pflanzen. Lund, 1896.

During the winter of temperate, alpine, or arctic climates, during the prolonged drought of regions with a periodical dry season, such plants lose all their aerial organs and are left with the underground stock only. This is commonly a squat axis with roots and foliage buds—perhaps flower buds also—attached to it. A store of nourishment is always laid up in some part of this subterranean structure, as a rule in the enlarged stem.

The more rigorous the conditions, the more pronounced the adaptations to them. When the growing season is short, the flower of a geophyte often comes up with or before the leaves. No part of the genial weather is then lost with regard to the formation and ripening of the seed. When once ripe, the seed fears neither frost nor drought, but the seedling is less hardy. The great problem before a seedling which germinates under such conditions is how in the course of the short growing season it may best prepare to face the rigor of the coming months. Its first care is to form an underground storehouse in the shape of a swollen stem or root to which the food packed in the seed may be transferred. This store of food is plunged in the soil, at first by the downward growth of the seedling as it leaves the seed coats, and later by the contraction of the root system which drags the tuber lower still.[19]

In some species this is all that the seedling accomplishes in its first season (Arum, Erythronium,[20] Veratrum): it has lived on part of its food capital in order to place the rest in safety. But as a rule one, or even two, green leaves are sent up soon after germination, and then the contents of the storehouse are replenished by the activity of the assimilating surface.

The formation of assimilating organs in the seedling of a geophilous plant is, however, very greatly limited by the shortness of the growing season and the necessary formation of subterranean organs. Here lies the explanation we were seeking; the reduction of the cotyledons and the formation of a tuber are both adaptations to the geophilous habit.

Suppose a race of primitive angiosperms to be specialized as

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[19] RIMBACH, Ber. Deutsch. Bot. Gesell. 15:—. 1897.

[20] IRMISCH, Beitr. z. vergleichenden Morphologie der Pflanzen. Halle. 1854.

geophytes. Their originally distinct cotyledons become more and more closely united in order to economize material. In the end a single cotyledonary member is formed by their complete fusion. A monocotylous race might easily be derived in this way from one with two cotyledons.

But monocotyledons are distinguished from dicotyledons by other characters besides the single seed leaf. Taking these characters one by one, are they consistent with the hypothesis that monocotyledons were derived from a stock of dicotylous angiosperms by adaptation to the geophilous habit?

As has been said (p. 332), there are independent grounds for believing that monocotyledonous stem anatomy is derived from that of an ancestor framed on the dicotyledonous type. Modification of the ancestral stem structure in this direction might well follow on the gradual assumption by succeeding generations of the geophilous habit. For in every plant which passes part of the year underground a large foliage bud is formed on the subterranean stock in the course of a growing season, and this bud after remaining quiescent through the bad weather will push up as the next period of growth approaches. Such buds are formed even in the least specialized geophytes.

Scale leaves form the outer covering of such a bud; then follow the radical leaves which sometimes, but not always, surround the rudiment of an erect stem which will bear flowers as well as leaves. Scale leaves and radical leaves alike are broad-based; the insertion of each on the squat axis occupies a considerable segment of its circumference. When growth begins with the first genial weather, the axis does not elongate, or those basal internodes, at any rate, are suppressed which separate the whorls of scale leaves and of radical leaves from each other. The traces which enter the axis from those leaves fall naturally into concentric circles within it. In fact, they are at once arranged like the leaf traces of a monocotyledonous stem.

In many geophytes the parenchyma of the axis becomes a massive tissue packed with food stuff. This development of the tissue which surrounds them naturally tends to isolate the leaf traces from each other. The interfascicular cambium first disappears, and then the cambial layer within each bundle, for no development of secondary elements is needed.

The structure of some living geophytes illustrates this process. In the first and second year tubers of Eranthis[21] and Arum,[22] for example, we find the slender leaf traces isolated among the abundant parenchymatous tissue which is packed with starch. The Cyclamen tuber is formed in a similar way.

Though this method of tuber formation is quite common, it is not universal. Jost's researches on *Corydalis solida*[23] show the tuber to be formed in this species by the activity of a normal cambium which adds a mass of parenchymatous elements to xylem and phloem alike. The reserve food is stored in the tissue thus produced. Each year sees a fresh tuber formed within that of last year, which it destroys. My own observations on first-year seedlings of *Anemone coronaria* and *Delphinium nudicaule* show that their tubers are formed in a similar way. The tissues—chiefly parenchymatous—which thicken them are added by a normal cambium. I have not examined older seedlings or mature plants.

Podophyllum offers the best example with which I am acquainted of a dicotyledon which, according to the present hypothesis, may be considered as arrested on the way to become a monocotyledon. A full account of the seedling and mature plant of *P. peltatum* is given in Mr. Holm's interesting memoir,[24] to which I must refer readers who wish for fuller detail. Owing to his kindness in sending me seeds, I have been able to examine the first-year seedling anatomically.

As in *Eranthus hiemalis*, the blades only of the cotyledons are distinct. Their petioles are united into a long tube, the base of which is beneath the surface of the soil. The hypocotyledonary axis is vertical and very short, but not swollen into a tuber. Its tissues are packed with starch. It is terminated

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[21] SARGANT, E., *l. c.*, pp. 57–61, and *pl. 6.*

[22] SCOTT and SARGANT. The development of *Arum maculatum* from the seed. Annals of Botany **12**: 404–413. 1898.

[23] JOST, Die Erneuerungsweise von *Corydalis solida* Sm. Bot. Zeit. **48**: 257. 1890.

[24] HOLM, TH., *Podophyllum peltatum*. BOT. GAZ. **27**: 419. 1899.

above by the cotyledons and next year's bud; below by the primary root which is large, stout, and branched. At the end of the first year the stem bud is set free underground by the withering of the cotyledons, and in the following spring it throws up a single green member and adds a few very short internodes—separated by scale leaves—to the squat vertical axis underground. This axis is again terminated by a bud which will develop in the third season.

The plant continues to grow in this fashion for several seasons. Each year's period of activity adds a few very short internodes to the vertical subterranean axis and produces several scale leaves, together with one or two foliage leaves. At the end of four or five years a season comes in which the terminal bud remains dormant. The bud which develops is found at the end of a horizontal rhizome produced in the previous season from the axil of a scale leaf; it resembles the terminal bud in structure and in the leaves it bears. The flower-bearing stem arises from the axil of one of the upper leaves of such a bud.

The bundles of the flower-bearing stem and of the vertical axis are arranged in the scattered fashion characteristic of monocotyledons. The whole structure of the plant indicates that this is primarily due to the number of leaf traces entering an axis so greatly reduced in length. Within the lateral rhizome—which possesses elongated internodes and bears small scale leaves—the bundles are arranged in a single circle. The number of traces entering the axis from a single foliage leaf is indicated in *figs. 6* and *7* (Holm, *l. c.*, pp. 425–6). Cambial layers exist within each bundle, but the bundle sheaths are thick-walled, and there is no interfascicular cambium.

Thus in Podophyllum partially united cotyledons and a close approach to monocotyledonous stem anatomy are found in connection with the geophilous habit. The genus must be fairly ancient, as indicated by its rather isolated systematic position and the distribution of its species. Four are included in the *Index Kewensis*. One is found in the Himalayas, two in China, and the fourth in North America. Possibly it reproduces some of the characters found in an ancestor which had become somewhat differentiated from the primitive stock of angiosperms by adaptation to a geophilous habit, and was thereby tending to a monocotyledonous structure.

The development of the embryo within the embryo sac of monocotyledons has already been described at some length, and the value of the phylogenetic argument based on it has been criticised. Nevertheless, since great importance has been attached to the apparently terminal position of the single cotyledon, it is worth while to consider how the facts appear from a new standpoint. If the cotyledonary member be derived from the two cotyledons of an ancestor, its rudiment cannot be really terminal, but must represent the congenital fusion of two lateral members. The terminal position is readily understood by comparison with such a seedling as that of *Delphinium nudicaule* (*figs. 1* and *2*). In this species the leafy stem bud develops in the same season as the cotyledons, and so soon as the first leaf attains any size it breaks through the cotyledonary tube near its base. For a short time this leaf appears to be laterally inserted on the cotyledonary axis (*fig. 1*), but as the leafy stem develops the cotyledons are pushed to one side, and then appear as a single lateral member (*fig. 2*). These errors are easily corrected; the stem bud is seen to be terminal, and the tube of the united cotyledons a fusion of two lateral members.

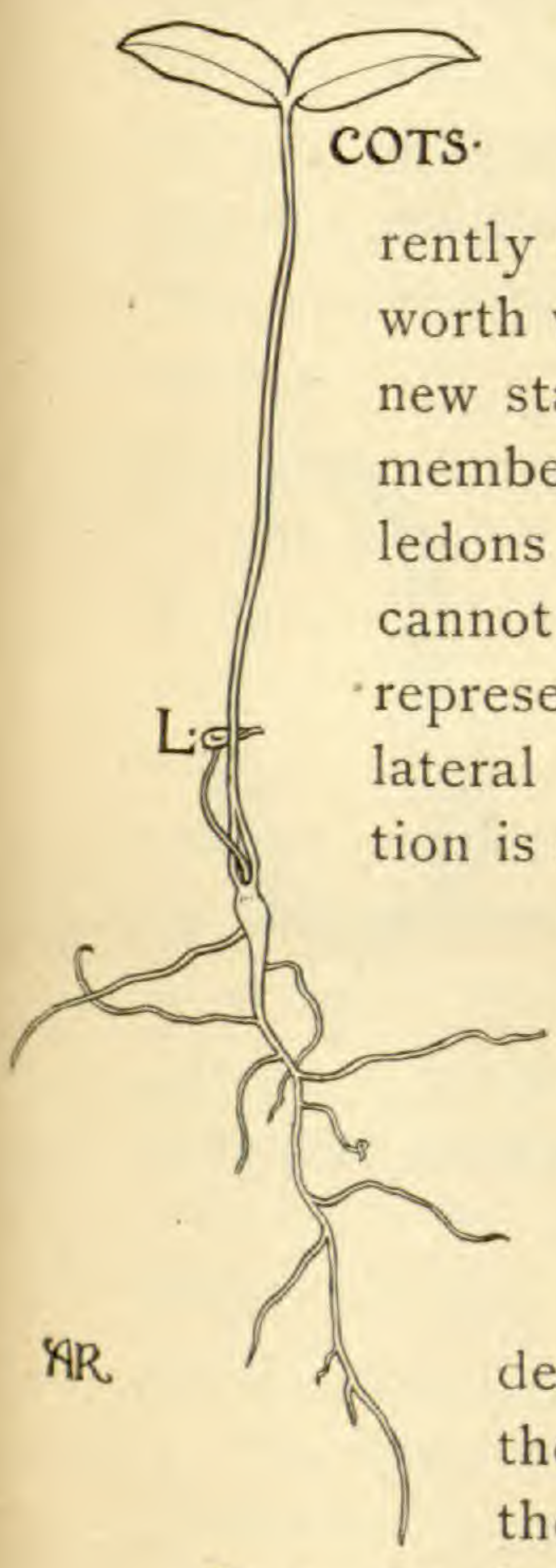

FIG. 1.—*Delphinium nudicaule.* Seedling eight weeks after seed was sown.

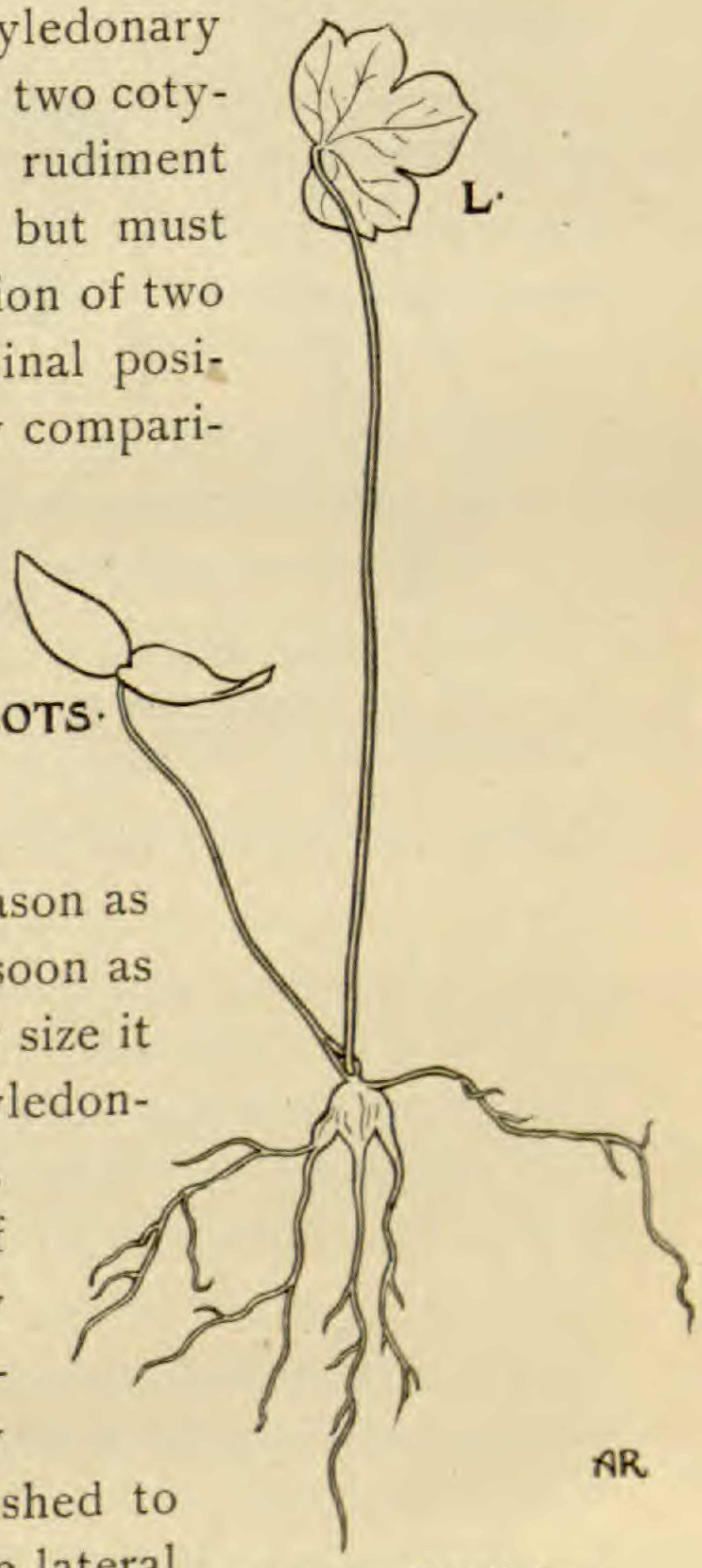

FIG. 2.—*Delphinium nudicaule.* Seedling fourteen weeks after seed was sown.

Now, suppose the cotyledons to become completely united by both margins, and that in the end this union is congenital. In order to develop freely, the stem bud must make its appearance at one side of the united members. As a rule, the cotyledons are differentiated some time before the growing point of the stem appears; in this case the single rudiment which represents both cotyledons is naturally formed in a straight line with the suspensor and the future axis. The rudimentary plumule when formed is forced to take up a lateral position (Alisma. *fig. 3*). As a rule, it attains the terminal position after germination, forcing the cotyledonary member to one side. In Tamus and Commelyna the growing point of the stem appears terminal, the cotyledonary rudiment lateral, from the first[25] (*fig. 6*).

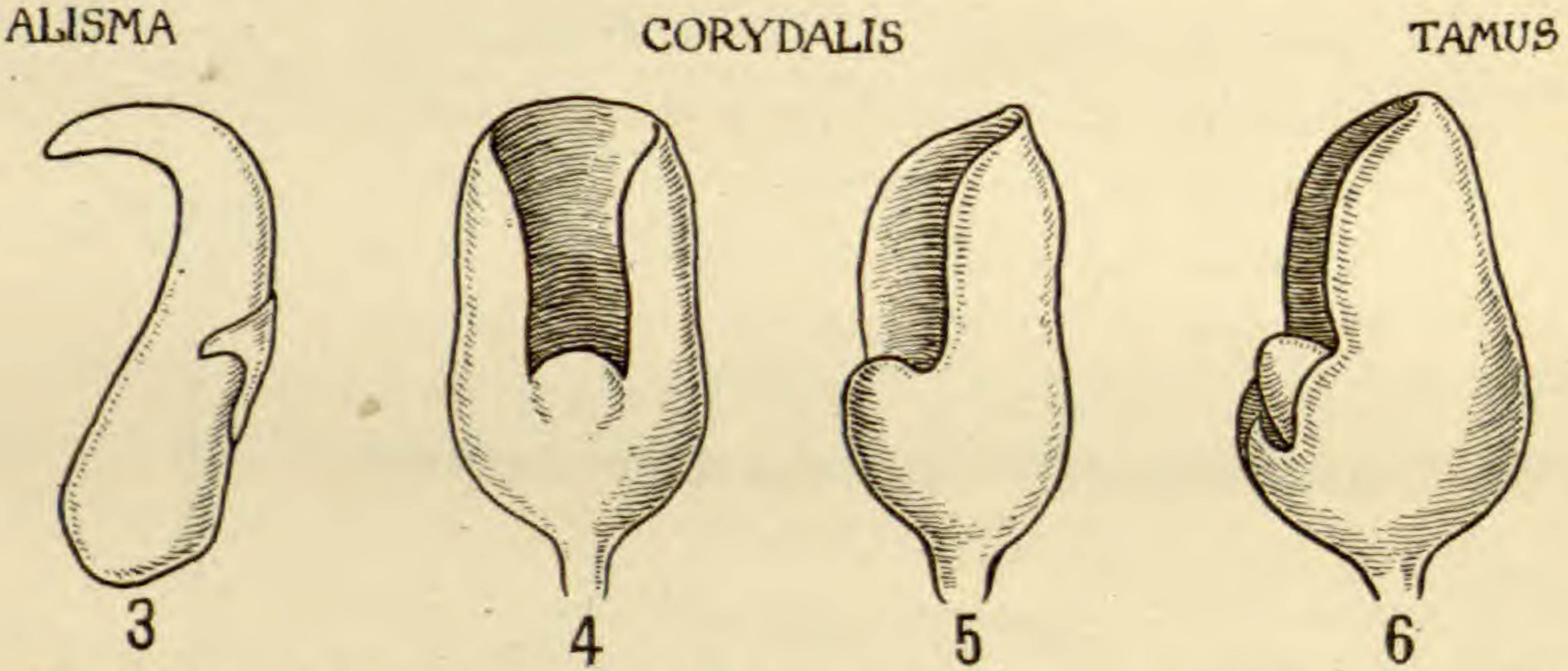

FIG. 3. *Alisma Plantago* (after HANSTEIN). FIGS. 4–5. *Corydalis cava* (after SCHMID); *fig. 4*, front view; *fig. 5*, side view. FIG. 6. *Tamus communis* (after SOLMS-LAUBACH).

The single cotyledon in the ripe seed of *Corydalis cava* strikingly resembles that of Tamus in form and position (cf. *figs. 4* and *5* with *fig. 6*). The simplest explanation of both structures is that they represent the fusion of two ancestral cotyledons, but that on account of the early formation of the rudimentary plumule, or perhaps because the cotyledons have united by one margin only—as in *Ranunculus Ficaria*—the stem bed has never lost its terminal position.

This hypothesis accounts for the structure of the monocotyledonous embryo in a very simple way, and avoids the difficulty of

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[25] SOLMS-LAUBACH, Ueber monocotyle Embryonen mit scheitelbürtigem Vegetationspunkt. Bot. Zeit. 36:65. 1878.

supposing its single cotyledon to be a terminal leaf—a difficulty so formidable that the supporters of its terminal character have been obliged to assume that cotyledons are not true leaves, but organs *sui generis*. Their structure lends no support to this view.

The other characters which separate monocotyledons from dicotyledons are by no means so constant as the three already discussed; namely, the single cotyledon, the stem-anatomy, and the development of the embryo. Parallel venation of leaves, short duration of the primary root, and albuminous seeds are characters neither universal among monocotyledons nor confined to them. They are found in geophilous plants of both classes, though far more general among monocotyledons.

The value of these three subordinate characters as evidence in favor of the geophilous origin of monocotyledons is somewhat lessened by the consideration that they are found mainly—not exclusively—among geophilous genera within that class. They may be considered direct adaptations to the mode of life adopted by the species of their more recent ancestors, rather than an inheritance from geophilous ancestors common to all monocotyledons. The presence of all three characters among the palms, however—a family composed exclusively of trees—cannot be explained by recent adaptation to geophily. I shall return shortly to the evidence for the descent of all palms from a geophilous ancestor.

The trimerous symmetry of the flower is a very important character of monocotyledons, particularly to those botanists who derive the simpler flowers of the Aroideae, Gramineae, Palmae, and other orders from the more elaborate, considering their simplicity as due to the reduction of the floral parts. But I can discover no grounds for considering the trimerous flower as an adaptation to geophily. There may be an unsuspected connection, or the prevailing floral symmetry of monocotyledons may be an inheritance from the ancestral stock. A trimerous calyx and corolla is not uncommon among the Ranales.

To sum up, of the seven characters mentioned as distinguishing monocotyledons from dicotyledons, four have been shown to occur frequently among geophytes and to be useful to the plant growing under conditions which determine the geophilous habit. They are therefore in all probability adaptations to that habit. Two more—the stem-anatomy and the apparently terminal cotyledon in the embryo—may be considered as direct consequences of such adaptations; the stem anatomy acquiring its peculiar features from the insertions of numerous broad-based leaves on a squat subterranean axis, and the embryonic cotyledonary member arising from the congenital fusion of two ancestral cotyledons. The seventh character—trimerous floral symmetry—bears no obvious relation to the geophilous habit, but is not inconsistent with it.

In a paper read before the Linnaean Society in 1892, Mr. Henslow[26] maintains that monocotyledons were derived from dicotyledons by an adaptation to an aquatic habit. He bases his argument on the large proportion of monocotyledons which are aquatic, and on the nature of the characters, external and internal, which distinguish them from dicotyledons. These are on the whole, he suggests, the characters of water plants. He considers the single cotyledon as representing one of the dicotyledonous pair, the other having disappeared.

Other botanists have suggested the derivation of monocotyledons from an aquatic or amphibious ancestor. Some of their characters would bear this interpretation, and indeed aquatic plants have several features in common with geophytes. The main axis of the great majority of water plants is hidden in the mud of the river or lake bed, and the green parts in the colder climates die down on the approach of winter. The subterranean stem is commonly a rhizome, but it bears upright buds. When broad-based leaves are inserted on the shortened axis of such a bud, their traces might naturally be arranged in the scattered fashion actually found among the Nymphaeaceae (Henslow, *l. c.*, p. 512) and monocotyledons. But, on the other hand, the tendency of an aquatic habit is to reduce the vascular tissue altogether; the leaf traces may almost disappear, and the vascu-

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[26] HENSLOW, G., A theoretical origin of endogens from exogens by self-adaptation to an aquatic habit. Linn. Soc. Journ. **29**: 485. 1892.

lar system of the submerged stem be reduced to a slender central stele with hardly any lignified elements.

There are aquatic species with parallel-veined leaves (as Vallisneria, Zostera), but this character is not common among water plants. It is almost confined to the monocotyledons among them. Circular or oval floating leaves, or the much dissected submerged leaves, are far more frequent.

The primary root of aquatic plants is often replaced early by tufted adventitious roots, a character found in many land plants with creeping rhizomes.

On the other hand, aquatic dicotyledons show no tendency to the formation of a single seed leaf in place of two, nor do they always possess albuminous seeds.

Great stress has been laid on the primitive floral structure displayed by many aquatic monocotyledons. Among the Heliobiae more than two whorls of stamens, and more than one whorl of carpels are not uncommon (Stratiotes, Hydrocharis, and others). Both stamens and carpels are occasionally indefinite in number and arranged spirally on the thalamus (Alisma, Limnocharis, and others). It is very probable that such types reproduce the floral symmetry of ancestors which were intermediate in character between the Ranales and the Liliiflorae. But even if some primitive characters are retained by aquatic species, it does not follow that the primitive monocotyledon lived in the water, and that its descendants acquired their peculiarities by adaptation to that habit. It is more probable that the aquatic forms represent ancestors of our modern monocotyledons which were crowded out by the competition on land, and took refuge in the water, or on its edge, where competition was less severe.[27] The vegetative structure of such species would be modified by the change of environment and would no longer represent that of the ancestor, but the reproductive organs might well remain unchanged. Such ancestors, if geophilous, would readily adapt themselves to amphibious conditions; their underground stems creeping in the mud which fringed the pond or stream until by

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[27] Cf. Darwin on the survival of ganoid fishes and simple vertebrates (Origin of Species, Sixth Ed. 1: 130, 154, 155, 163; 2: 99, 173. 1888.

degrees they grew beneath the water and sent up shoots more and more completely modified to an aquatic habit.

It has been objected that plants highly specialized to a particular mode of life, such as geophytes, are unlikely to give rise to a race so numerous and of such diversified form as monocotyledons. But the geophilous habit of a plant may be marked without any such profound modification in its structure as would destroy its capacity for adaptation to changed conditions. A geophyte is—as already suggested—particularly well suited to become amphibious. It acquires the climbing or twining habit with hardly less ease. *Bryonia dioica* and *Tamus communis*, two of our commonest perennial climbers, have very large tuberous rootstocks. Among the 187 genera mentioned in Bentham and Hooker's *Genera Plantarum* as belonging to the order Liliaceae, sixteen are mentioned as including species with a climbing or twining stem. Of these I find that eleven possess underground stems; rhizomes, tubers, or even bulbous, in the mature condition. Species from two of the remaining five I have examined as seedlings, and the rudiments of a tuber are very clear. Concerning the underground organs of Rhipopozon, Semele, and Behnia I have no information.

The absence of a normal cambium, which follows from the assumption of the geophilous habit, is certainly unfavorable to the production of trees. The want is occasionally supplied by the formation of anomalous thickening-rings (Aloe, Dracaena, etc.), but among the palms no such expedient is found. Without it they manage to grow into trees of great size in tropical and semitropical countries. Is it possible to trace the palms back to a geophilous ancestor?

Seedling palms are easily obtained, as they are much grown as pot-plants for indoor decoration. At this immature period of life they have many geophilous features. In the young seedling the hypocotyl is always short and commonly somewhat enlarged. The cotyledon sheathes the plumule more or less completely with its broad base. The first leaf of the stem bud is never more than a sheath; it is sometimes followed by one or two like itself before the first foliage leaf appears.[28] The stem at this time and

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[28] MICHEELS, H., Recherches sur les jeunes Palmiers, *etc.* 105. Liège. 1889.

for many years later is a squat axis surrounded by successive leaf bases. The primary root is vigorous and persists for some time, but in the end it is always replaced by a number of much stouter cauline roots. In fact, if a young palm, such as is commonly sold for table decoration, be halved longitudinally, it is seen to be formed on the model of a bulbous plant. Its structure in youth may certainly be interpreted as a reminiscence of geophilous ancestry.

CONCLUSION.

In this account of a new view on the evolution of monocotyledons, I have tried to show that it is the most consistent—as in practice I have found it the most suggestive—among existing hypotheses.

An immense amount of work remains to be done on the structure, both external and internal, of seedlings before this or any other suggestion can be generally accepted as representing, even in outline, the real sequence of events. We need observers to carry on the work so well begun by Irmisch; monographs like those of Mr. Holm on Podophyllum and Erigenia; the detailed work of anatomists like Professor Jeffrey and M. Quéva. Even if no direct evidence should be contributed from the geological record, there is little doubt that the key to the descent of monocotyledons will be found in their morphology.

QUARRY HILL, REIGATE, ENGLAND.

THE NUTRITION OF THE EGG IN ZAMIA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LVI.

ISABEL S. SMITH.

(WITH SIX FIGURES)

FOR some time previous to the cutting off of the ventral canal cell, the central cell in most gymnosperms is surrounded by large prominent cells called the "jacket cells," which contain particularly large nuclei. The inner walls of the jacket cells, in contact with the egg, are pierced by numerous pores (*fig. 2*). During the rapid growth of the central cell the jacket cells and their nuclei are prominent; but during the period of free nuclear division in the embryo the jacket becomes less conspicuous, and finally becomes indistinguishable as a definite nutritive layer. It is evident that the jacket cells contribute to the growth of the central cells, and afterward to the growth of the egg and proembryo. The passage of various contents of the jacket cells into the egg has been described by several observers.

Goroschankin (4) says in regard to Ceratozamia: "In fresh preparations mounted in water, each canal is seen to be filled with fine protoplasm that passes over sometimes into the protoplasm of the neighboring cells and sometimes into the protoplasm of the egg cell. Transverse and longitudinal sections of fruits which were carried up with strong alcohol showed me the following: under the action of the alcohol the protoplasm of the surrounding endosperm sheath seems wholly smooth or with scarce observable projections on the side nearest the egg. But as for the protoplasm of the egg, it appears covered with projections the length of which equals nearly or wholly the length of the canals. Afterward I began to make tangential sections of the egg from alcoholic preparations. Now I was able to see the sieve plates in the canal. . . . . From my observations on the egg wall in the cycads, the following conclusions were reached:

the wall is formed of cellulose and contains a large number of canals showing genuine sieve plates, through which the protoplasm of the cells of the endosperm layers communicates with the protoplasm of the egg."

Ikeno (5) in his paper on *Cycas revoluta* says: "Since Goroschankin's researches it is known that in the cycads the protoplasm of the central cell and of the wall cells are in close connection by means of protoplasmic threads. It is easy to see that the material filling the nuclei of the wall cells, which in its natural condition is a half-fluid substance, flows out from there and goes to the central cell through these intercellular breaks. Indeed, I can find various stages of the transportation of this material to the central cell, showing as granulations in fixed material, where these granules lie just outside the nuclei, then in the protoplasmic threads themselves, then in the central cell directly before the protoplasmic break. Also one finds a large mass of these granulations at the edge of the central cell, which have collected there, evidently coming completely from the neighboring wall cells."

Arnoldi claims that the nuclei of the jacket cells pass bodily into the egg through the large pores in the inner walls of the jacket cells. In writing of *Pinus cembra* he says (2): "I can show that I could observe out of a series of sections more than one hundred and fifty nuclei passing out of the jacket cells. It is also established through my observations that the small proteid vacuoles described by Goroschankin as Hofmeister's nodules are only nuclei passing out of the jacket cells."

In writing on *Cephalotaxus Fortunei* he says (1): "In the first stages of development of the jacket cells we find the little nucleoli only half inside of the nuclei. In some later stages we find them also in the protoplasm of the jacket cells. Since these small granules are fully equal to those in the nuclei in all relations of size, staining ability, etc., since they are first observed in the nucleus and later in the protoplasm, we may conclude that they pass from the nuclei into the protoplasm. In the protoplasm of the jacket cells they are heaped up in great masses, and then pass over into the egg cell. The nodules appear in the cell on the side in which the protoplasm itself is rich in vacuoles. Observation of the passage of the granules from the jacket cells into the egg is most difficult. The egg cell and the jacket cell walls with the highest magnifications show no holes. But since on both sides of the wall we find granules of a like nature, we must admit a process of passing over. If one admit that we have not small bodies, but small drops of a viscid fluid substance, filtration furnishes an explanation for the passing over."

Murrill (**8**) in his paper on Tsuga writes: "I cannot confirm for Tsuga the results of Arnoldi's recent studies (1900) on the proteid vacuoles of the Abieteae. It may be that further search on my part will reveal the passage of the nuclei of the sheath cells into the central cell, but very careful examination of numerous archegonia in all stages of development has thus far failed to show a single undoubted example of such passage. I find the nuclei of the sheath cells streaming profusely at times, as described by Ikeno (1898) for Cycas, and observe collections of granules in the outer vacuoles of the central cells which very much resemble the sheath nuclei; but the sheath cells are never found without their nuclei. The sheath remains one-layered, though its cells often divide as the archegonium grows. At points where the archegonia come into close contact, the sheath is frequently crushed and destroyed; but throughout most of its extent the cells and their nuclei continue active during the life of the archegonium."

Strasburger (**6**) upon re-examining Pinus failed to confirm Arnoldi's views. Margaret C. Ferguson (**3**) alludes to Arnoldi's study of Pinus, but fails to confirm the migration of the nuclei of the sheath cells into the egg. Land (**7**) in describing Thuja writes: "Protoplasmic connections between the jacket cells and the central cell were not seen, but it is possible they were overlooked owing to the extreme thinness of the dividing wall. It is not believed that the nuclei of the jacket cells pass into the central cell as reported in Caphalotaxus by Arnoldi."

Material of *Zamia floridana* was secured from Miami, Florida. The earliest stages studied showed the central cell of the archegonium before the mitosis which gives rise to the egg and the ventral canal nucleus. From this point up to the organization of embryos in which the cotyledons were beginning to appear the series was fairly complete.

During the earlier growth of the central cell no jacket is distinguishable, and during this time also the contents of the central cell are scanty and much vacuolated. As the central cell approaches its mature size and begins to fill with nutritive substances, the jacket appears and soon becomes very conspicuous, its single layer of cells being rich in protoplasm, but almost destitute of starch, while the cells surrounding it are nearly filled with large starch grains (*fig. 1, j, s*). This condition continues during the later growth of the central cell, during the growth of the egg, and even during the earlier stages in the development of the embryo. During their entire period the mode by which materials pass from the jacket into the interior is the same. All the figures are from stages between the formation of the ventral canal nucleus and fertilization.

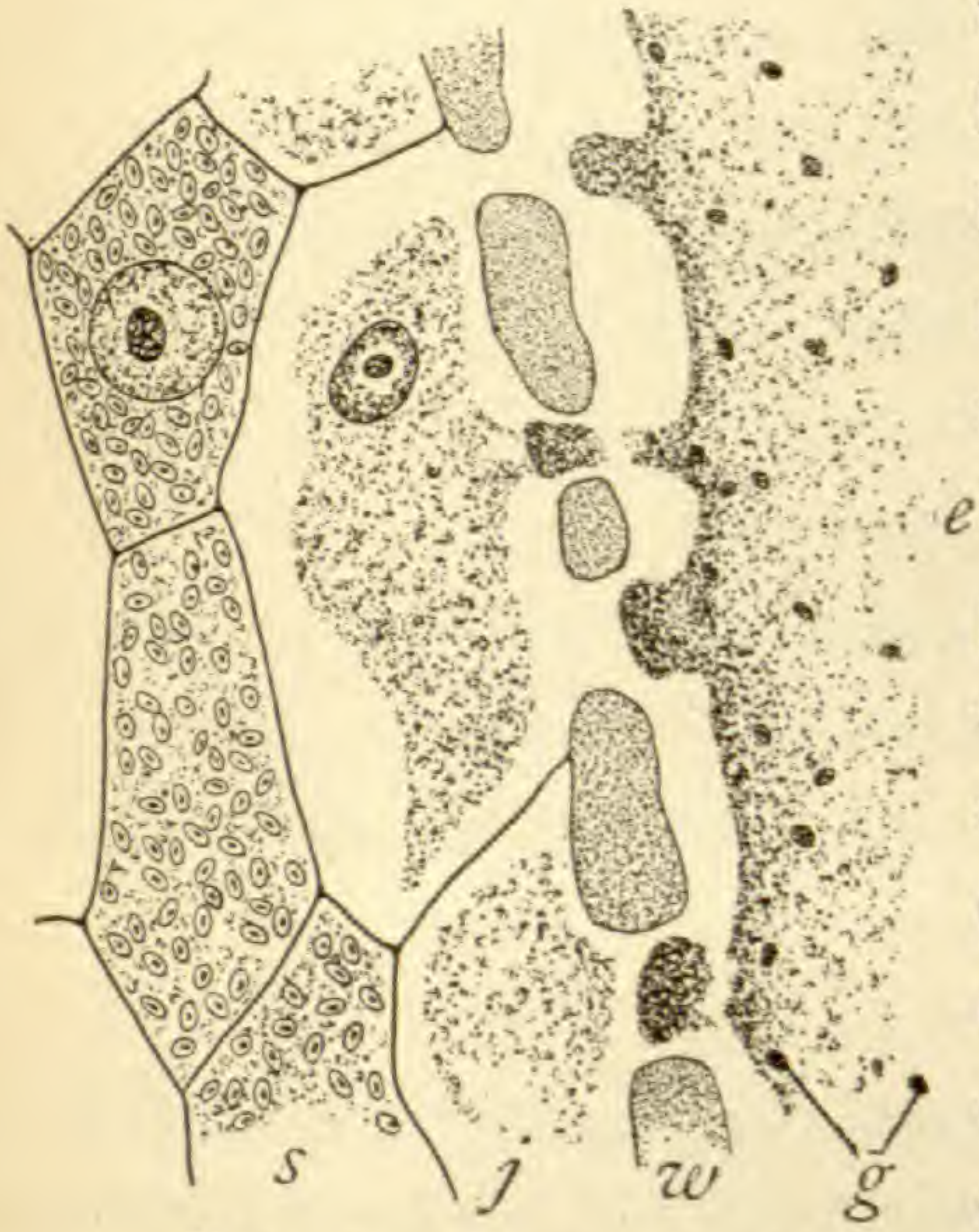

FIG. 1.—*Zamia floridana.* Portion of egg, *e*, jacket, *j*, and neighboring cells; two of the four haustoria shown are broken off; haustoria discharging contents into egg; *g*, granules passing from the haustoria into the egg; *s*, starch-containing cells outside jacket; *w*, thick inner walls of jacket cells.

The inner walls of the jacket cells become very much thickened (*figs. 1, 3–6, w*) and are pierced by numerous pores of various sizes, as shown in surface view in *fig. 2* and in section in all the other figures. Through these pits the protoplasm of the egg protrudes into the jacket cells, forming haustoria-like processes. After passing through the pits, the ends of the haustoria become distended so that the structure appears knob-shaped. The contents of the haustorium

FIG. 2.—*Zamia floridana.* Portion of inner surface of jacket showing numerous pits of various sizes.

vary, and the variation is accompanied by striking variations in the staining reactions, sometimes the end of the projection appearing as a dense, deeply staining knob in which scarcely any structure can be distinguished, and sometimes staining faintly and showing beautifully the cytoplasmic reticulum. In fact, the haustorium behaves like a gland cell, during the period of accumulation staining more and more deeply, then discharging, and during the following period of exhaustion staining faintly until the active period begins again. In *fig. 1* the haustoria are discharging, the granules (*g*) coming undoubtedly from the haustoria. The appearance of the haustoria during the period of exhaustion following the discharge is shown in *fig. 3*, *h*.

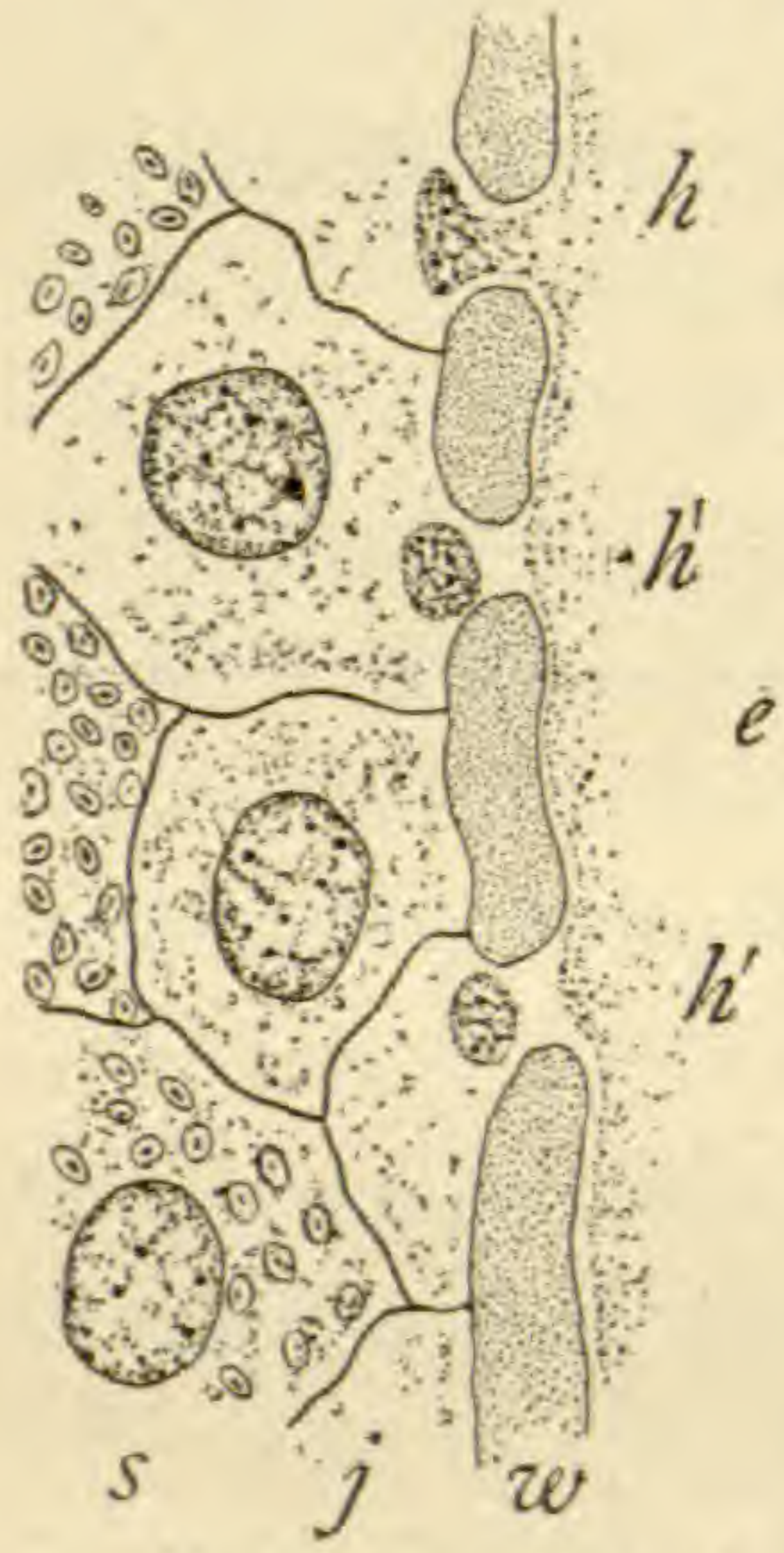

FIG. 3.—*Zamia floridana.* Period of exhaustion; *h*, haustoria; *h'*, tangential sections of the swollen ends of haustoria which might be mistaken for nuclei; *e*, peripheral portion of egg; *j*, jacket cells; *s*, starch-containing cells outside jacket; *w*, thick inner walls of jacket cells.

That the contents of the jacket cells are strongly attracted toward the haustoria is easily seen during the entire period of accumulation. In *figs. 1*, *4*, and *6* the protoplasm is shown streaming toward the haustoria, and in *fig. 4*, as is often the case, even the nucleus appears to be drawn out toward the haustorium. During the period of exhaustion (*fig. 3*) no such streaming of the protoplasm or distortion of the nuclei was observed.

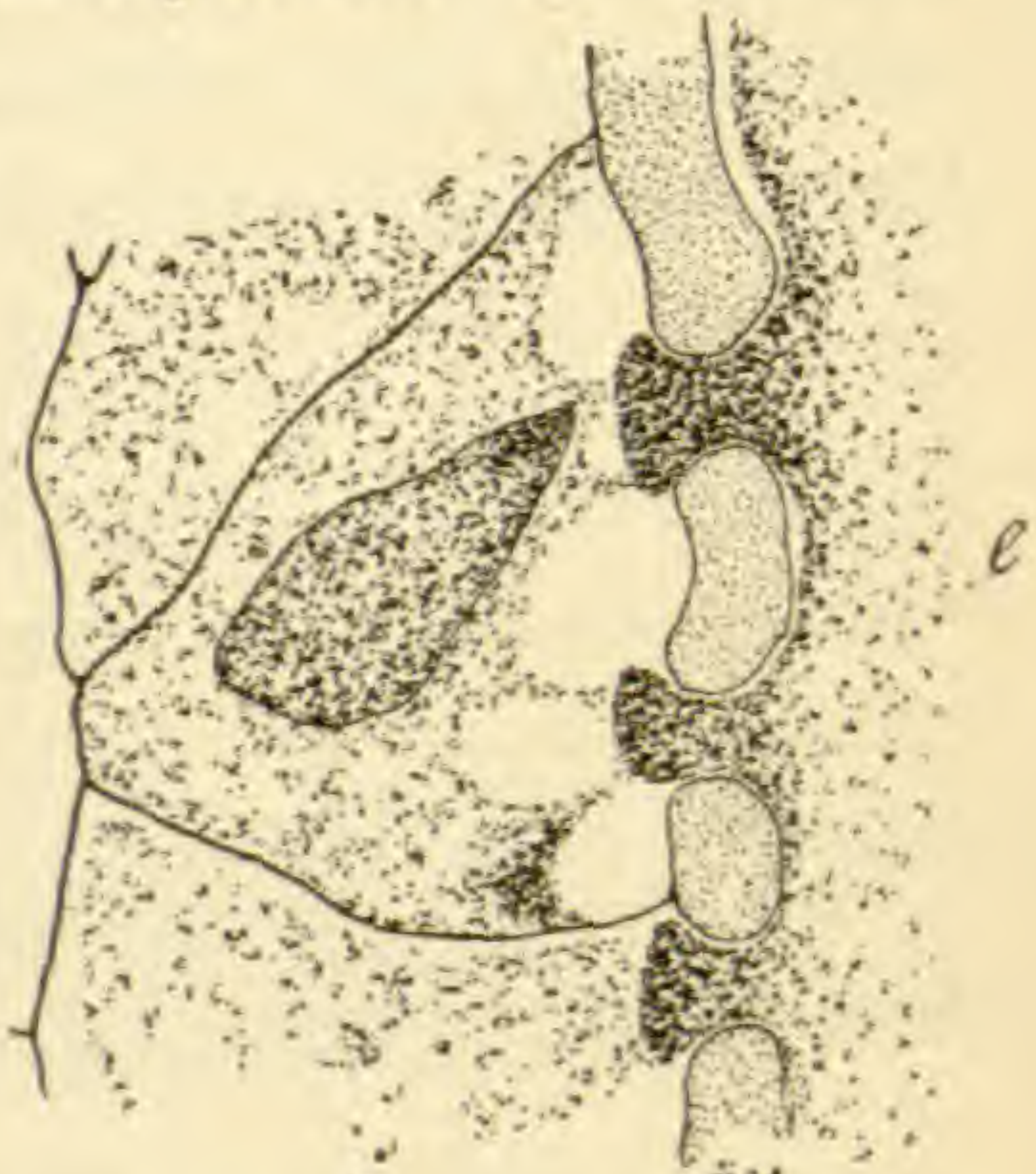

FIG. 4.—*Zamia floridana.* Streaming of cytoplasm toward haustoria; nucleus much drawn out; *e*, peripheral portion of egg; *j*, jacket cells; *w*, thick inner walls of jacket cells.

In no case was there any indication of the passage of nuclei or nucleoli from the jacket cells into the egg, and in no case did we find a jacket cell without a nucleus. However, that material is probably drawn from the nuclei as well as from the cytoplasm may be seen by comparing the nuclei of *figs. 1* and *6* with those of *fig. 3*, the former showing the active condition and the latter the exhausted condition following the discharge.

In preparations the haustoria are often broken off (*figs. 1* and *6*), and in this condition they might be mistaken for material passing in large masses from the jacket cells into the egg. This condition resembles that shown by Ikeno for *Cycas revoluta*. Possibly his figures may bear this interpretation; at least it would be worth while to re-examine Cycas with this in mind.

It often happens that the knob-like ends of haustoria are cut in a longitudinal tangential plane. In such cases they closely resemble nuclei (*figs. 3* and *5*, *h'*), and then they might be mistaken for nuclei passing bodily into the egg. Whether such a mistake would be sufficient to explain Arnoldi's account still remains to be seen.

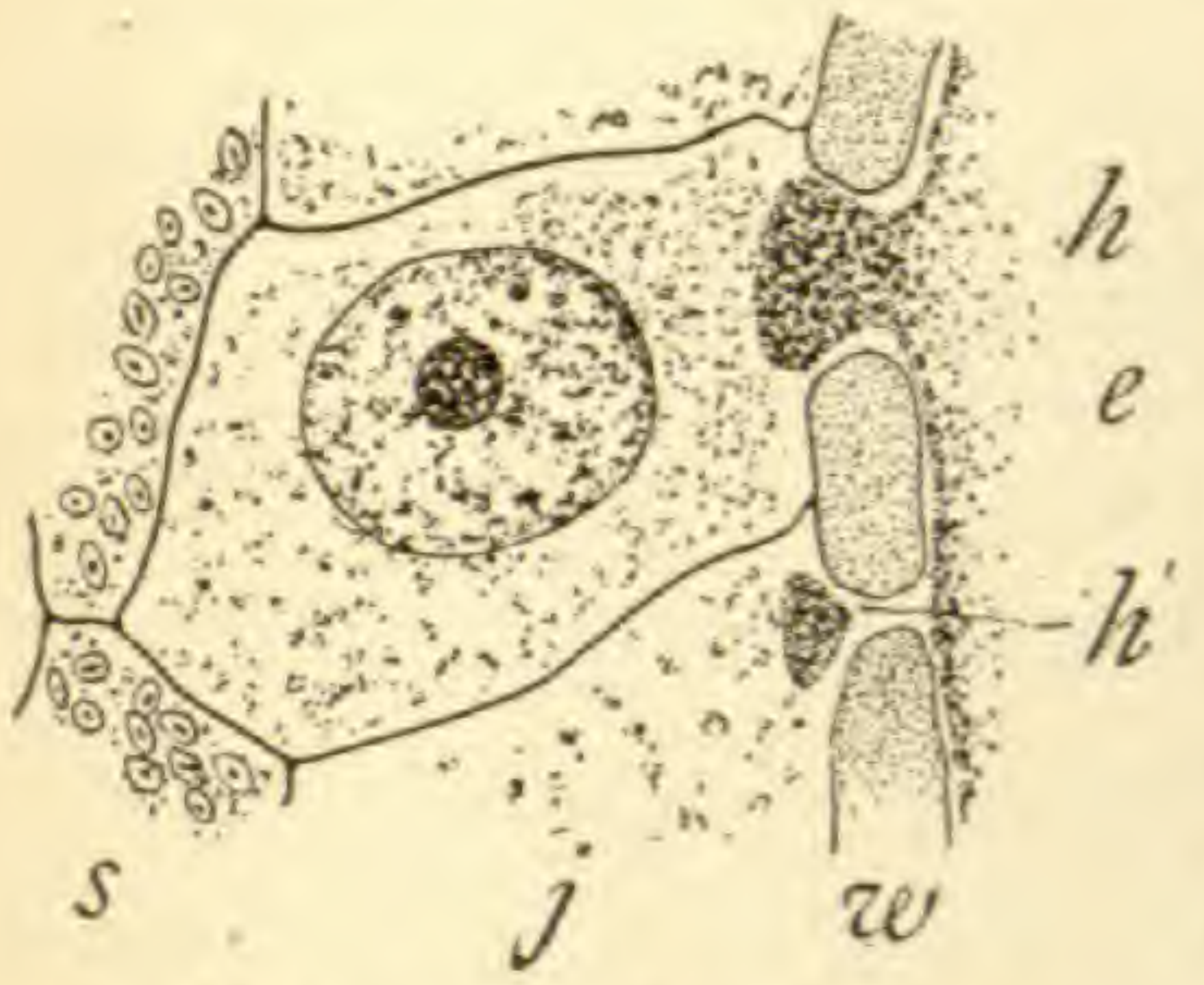

FIG. 5.—*Zamia floridana; e*, peripheral portion of egg; *h*, *h'*, haustoria, the lower a tangential section of the knob-like end which might be taken for a nucleolus; *j*, jacket cells; *s*, starch-containing cells outside jacket; *w*, thick inner walls of jacket cells.

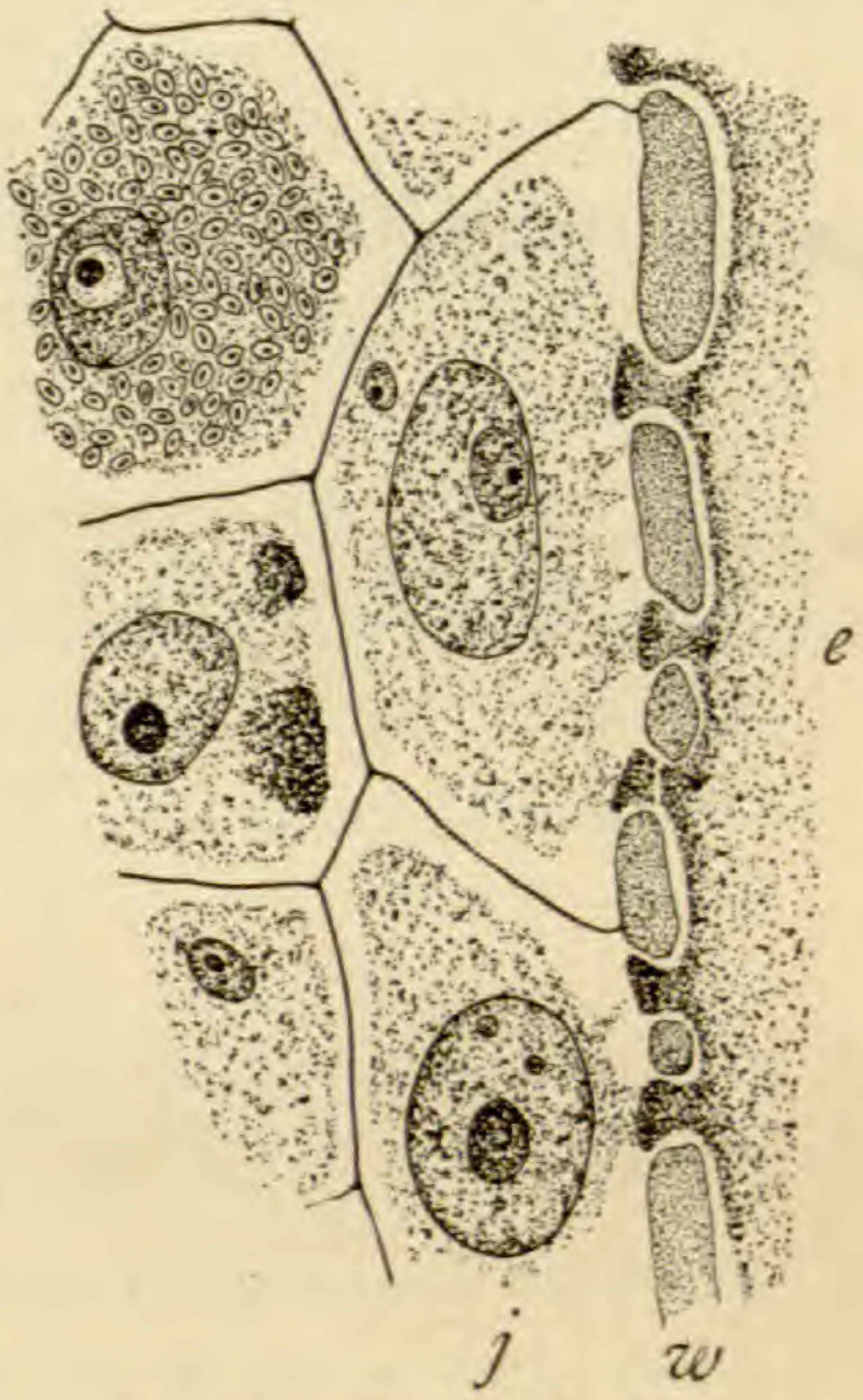

FIG. 6.—*Zamia floridana.* Streaming of cytoplasm toward haustoria; *e*, peripheral portion of egg; *j*, jacket cells; *w*, thick inner walls of jacket cells.

No sieve plates or similar structures, as described by Goroschankin, were observed in any of the preparations.

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A CONTRIBUTION TO THE LIFE HISTORY OF ASTER.

MARIE OPPERMAN.

(WITH PLATES XIV AND XV)

MATERIALS AND METHODS.

THIS study is based upon an investigation of *Aster undulatus*, *A. multiflorus*, *A. Novi-Belgii*, and *A. Novae-Angliae*. Flowers in various stages of development were collected. The buds were halved, the smaller heads were cut into thirds, and the larger into quarters. The upper portion of the floral envelopes together with the inclosed styles and stamens were cut away, great care being exercised not to injure the ovules. Two fixing fluids were used, Flemming's chrom-osmo-acetic acid mixture and chrom-acetic acid, both giving good results. After dehydration the material was brought gradually, through ascending grades, into either cedar oil or chloroform before infiltration with the paraffin. So far as a study of my material goes, it is a mere matter of convenience whether cedar oil or chloroform be used in the process of imbedding, as the results obtained by either method were equally satisfactory. Sections were cut 10 μ thick and stained in Flemming's safranin, gentian-violet, and orange combination, or in Heidenhain's iron-haematoxylin. When Flemming's triple stain was used, it was necessary to allow the slides to remain for several hours in the gentian-violet, since this stain is rapidly removed during the process of dehydration in Aster. It was found advantageous to place the slides in xylol before mounting in balsam. With this treatment the sections cleared more quickly, and were therefore ready for study in a shorter time than when mounted directly from the bergamot oil.

This investigation was carried on in the Botanical Laboratory of Wellesley College, under the direction of Dr. Margaret C. Ferguson, to whom I desire to express my gratitude for her invaluable counsel and unceasing interest and encouragement.

THE DEVELOPMENT OF THE EMBRYO SAC.

The embryo sac arises from the lowest cell of an axial row of four cells, that is, from the cell most distant from the micropyle. The mother-cell of the embryo sac grows rapidly, soon becoming strongly differentiated from the surrounding cells. At some time during the early stages of development, the nucleus of the macrospore moves to the micropylar end of the spore and there divides. The embryo sac contains very little cytoplasm at this stage, with the exception of the dense mass around its nucleus (*fig. 1*). It agrees in this respect with the young embryo sac of Silphium, as described by Merrell (1900), and differs from Lilium and some other plants in which the embryo sac is densely filled with cytoplasm at the time of the first nuclear division.

In *A. multiflorus* the young embryo sac reaches an advanced stage of growth at the time of the first division of its nucleus, and does not show a very great increase in size subsequent to its binucleate stage. In the other species studied, however, the embryo sac does not assume its ultimate form until about the time of the fusion of the polar nuclei. After the division of the macrospore nucleus, one of the resulting nuclei moves toward the opposite or lower pole. In the meantime the embryo sac continues to grow in length, but increases very little, if any, in breadth. At the time of the second nuclear division, the embryo sac is long and somewhat cylindrical in outline. Here, as in other angiosperms, the two nuclei divide simultaneously, the division occurring, in some cases at least, before the lower nucleus has reached the antipodal end of the sac (*figs. 2, 3*). In the embryo sac shown in *fig. 2* the second nuclear division is just completed, and the nuclei have not as yet separated. The four nuclei enter the complete resting stage, as shown in *fig. 3*, and then immediately divide again, giving rise to a typical eight-nucleate embryo sac.

At the time when the eight nuclei are formed, the embryo sac, as seen in vertical section, is more or less rectangular in outline, but from this stage on the two poles of the embryo sac may become strongly differentiated. The antipodal end shows little or no increase in breadth, but elongates rapidly, pushing down for a considerable distance into the nucellus, while the upper and central region of the embryo sac ceases to elongate, but grows to several times its original breadth.

Considerable variation has been noted in the shape and size of the mature embryo sac, not only in the different species, but also in different ovules of the same species. These irregularities may be apparent at an early stage, as is shown in *figs. 2* and *3*. The embryo sac represented in *fig. 3*, although of the same species as the one represented in *fig. 2* and of a later stage of development, has grown much less in length. It is also apparent from a comparison of *figs. 6* and *7* that, while the embryo sac of *A. undulatus* shows a remarkable growth in breadth near the micropylar end, the embryo sac of *A. multiflorus*, though slightly older than the former, has broadened very little in that region. The upper portion of the embryo sac of *A. Novi-Belgii*, like that of *A. multiflorus*, grows little in breadth, while the form of the embryo sac in *A. Novae-Angliae* (*fig. 8*) resembles very much that of *A. undulatus*.

Soon after the embryo sac has reached the eight-nucleate stage of development, three of the nuclei in the lower end of the embryo sac move downward to form the cells of the elongated antipodal region. The four nuclei in the micropylar end assume their characteristic arrangement and give rise to the egg apparatus and to the upper polar nucleus. The egg nucleus rests in the lower oval end of a pear-shaped cell, in a dense mass of cytoplasm. Above the nucleus the usual vacuole is found, which is very large in Aster, often occupying two-thirds of the entire oosphere. The synergids lie one on each side or both on the same side of the oosphere. Each may have the same relative position with reference to the micropyle, or one synergid may extend farther into the micropyle than the other. They are usually densely filled with cytoplasm, but may be somewhat vacuolate. The nucleus of each synergid is much smaller than the egg nucleus or the upper polar nucleus, and may be placed centrally or at a point considerably above or below the middle of its cell.

Immediately after the organization of the egg apparatus, the polar nuclei move toward one another. The lower nucleus travels much faster than the upper one, so that they meet comparatively near the oosphere. The two take a position just beneath the egg, but in contact with it, and there fuse to form the endosperm nucleus. An early stage of fusion is illustrated by *fig. 6*, in which one polar nucleus appears closely pressed against the other. In *fig. 7* the membranes between the two fusing nuclei have already disappeared. The endosperm nucleus is very large, almost spherical in outline, and is furnished with a rather open reticulum and one large densely staining nucleolus. The fusion of the polar nuclei may be delayed, in some instances until the time of fertilization (*fig. 9*), but ordinarily the formation of the endosperm nucleus has taken place before the pollen tube discharges its contents into the embryo sac.

When the embryo sac is mature, it occupies about one-half the entire length of the nucellus. The lower two-thirds of the embryo sac consists of the narrow elongated antipodal cells. As a rule, the cells of the nucellus immediately surrounding the antipodals are empty and more or less irregular in outline. A general conception of the structure and position of the parts of the ovule at the time of the maturity of the embryo sac is given in *fig. 10*.

LATER HISTORY OF THE ANTIPODALS.

The antipodal portion of the embryo sac in dicotyledons has been found to vary greatly in the number, structure, and position of its cells. Chamberlain (1895) finds that the number of antipodals in *A. Novae-Angliae* ranges from two to thirteen, six or seven being the usual number. The lower antipodal was found to differ from the others in size, in the density of its cytoplasm, and in the appearance of its nuclei. He observes, however, that in one instance the contents of this cell bear a superficial resemblance to an egg and believes that it represents an antipodal oosphere. The number of nuclei in an antipodal cell was found to vary from one to over twenty. In my study of Aster I find that the antipodals in the species examined, although showing in no instance as many as thirteen cells, agree closely, as to their structure, with Chamberlain's description, but they do not confirm the observations made by Martin (1892), who found only four antipodals. These four cells were never arranged in a single longitudinal row, and he did not figure them as separated by cell walls.

Definite cells appear in the antipodal region very early in the development of the embryo sac. As a rule, these cells have reached their greatest development when the embryo sac is ready for fertilization, but occasionally they continue to grow for some time after fertilization. It often occurs in *A. Novae-Angliae* and in *A. undulatus* that the lowest of the antipodal cells becomes very much enlarged (*figs. 11, 14, 16*). The nuclei of this cell were found in a few cases to be somewhat larger than the nuclei of the other antipodals, but in no instance was I able to find in this lowest cell an antipodal oosphere as described by Chamberlain (1895). However, an egg, doubtless derived from one of the upper antipodal nuclei, was observed and will be described later. In one preparation an embryo sac was found in which the lowest antipodal exceeded in width the expanded upper portion of the embryo sac, but there was nothing in the character of its nuclei to indicate the presence of an antipodal egg (*fig. 16*).

There seems to be no limit to the number of antipodal nuclei in Aster. Cells which contained only one nucleus were found in only a few cases. *Figs. 14* and *15* illustrate two antipodal cells, one of which contains fourteen nuclei of various sizes and the other nineteen small nuclei.

The antipodals persist until the embryo sac is in an advanced stage of development, and their function is probably that of conveying nutrition to the developing embryo. In several instances two or three cells just below the antipodals were observed to retain their normal appearance, containing cytoplasm and nucleus (*fig. 5*). It may be that these cells are active in supplying food to the developing embryo, as described by Ferguson (1901) in Pinus and confirmed by Coker (1902) in Taxodium.

FERTILIZATION.

Double fertilization has been found to occur in several Compositae and, judging from some of my preparations, it occurs also in Aster; but my material has yielded so few stages just before and including the fusion of the sexual nuclei that I do not wish to speak unqualifiedly regarding this point at present. In *fig. 9* we have an instance of the delayed fusion of the polar nuclei, and apparently an example of double fertilization in *A. undulatus*. The polar nuclei are in an early stage of fusion, and the sperm nucleus is pressed against the lower polar nucleus. The fusion of the sperm with the egg nucleus is nearly completed, so that the two appear almost as one nucleus with two nucleoli.

A most interesting embryo sac is illustrated in *fig. 18, a–b*. There can be no doubt that we have in this instance the occurrence of two oospheres and two endosperm nuclei in the same embryo sac. The upper part of the embryo sac resembles all normal embryo sacs at a similar stage of development; but in the lower portion, just above the first antipodal cell, there is a cell and a large nucleus which have the same structure and the same relative position as that of the egg and the endosperm nucleus at the micropylar end. These clearly represent, so far as position is concerned, an antipodal oosphere and a definitive nucleus.

No positive statement regarding the origin of this extra egg and endosperm nucleus can be made, but several theories as to their probable derivation may be suggested. It is possible that the lower polar nucleus did not fuse with the upper polar nucleus, but that each has taken on the appearance of an endosperm nucleus, and that the lower oospere has arisen directly from an antipodal; it may be that the normal egg has wandered to the antipodal region of the embryo sac, and that the upper egg has been derived from one of the synergids; or it is possible that the lower egg has developed from one of the synergids which had become displaced. In order to explain satisfactorily the structure of this embryo sac on the basis that one of the eggs has been derived from a synergid, it is necessary to assume that at least three irregularities have occurred in its development.

Moreover, the two small nuclei at the micropylar end of the embryo sac doubtless represent the synergids, now in a state of disintegration. Therefore, it seems to the writer most improbable that either egg had its origin in a synergid. I am aware that one of the two nuclei just above and at one side of the upper egg may represent the tube nucleus, but we have no direct evidence that such is the case, and it has not yet been demonstrated that the tube nucleus enters the embryo sac in Aster. Judging from the structure of the micropylar end of this embryo sac and from the position of the unusual nuclei, the most probable, and also the most simple interpretation of this phenomenon is that the upper egg apparatus was formed in the usual way, and that the lower egg and the endosperm nucleus associated with it were derived from one of the three original antipodal cells.

We have here not only the remarkable occurrence of a distinctly outlined egg associated with a large definitive nucleus in the antipodal region of the embryo sac, but also the interesting phenomenon of the fertilization of that egg. Whether a sperm nucleus has already fused with the upper egg or with the endosperm nucleus cannot be ascertained. One of the sperm nuclei, however, has passed to the lower part of the embryo sac to fuse with the lower oosphere. The sperm is more or less banana-shaped and is just pressing itself against the cytoplasm of the egg. It has somewhat the appearance of the sperm nuclei of *Paris quadrifolia*, as described in the recent paper of Ernst (1902).

This discovery of an antipodal functioning as an egg and about to be fertilized is a very significant fact, and has an important bearing on the problem of the homologies of the antipodals. It has been shown by different investigators that all the nuclei of the embryo sac except the antipodals are capable of being fertilized and may therefore be considered as potential eggs. As already stated, Chamberlain (1895) reports the occurrence of a nucleus in the enlarged end cell of the antipodals, which he believes to be an oosphere, formed by one of the nuclei of the antipodal region surrounding itself with cytoplasm, and he suggests that we need only to observe an actual case of fertilization in this region to demonstrate the egg-like nature of these cells. Tretjakow (1895) reports an instance in which he finds an embryo in the antipodal region, but as he did not find fertilization he believed the embryo to have arisen apogamously.

Of the two views held as to the homologies of the antipodals, namely, that they represent either a vegetative prothallus or that they are potential eggs, the discovery of the fertilization of an antipodal egg adds substantial evidence to the theory that all the cells of the embryo sac are potential eggs. If the antipodals are potential eggs, then it would seem that the fusion of one sperm nucleus with the two polar nuclei is, as Nawaschin and some other investigators believe, a true act of fertilization.

After fertilization the egg nucleus becomes spherical but does not divide until sometime subsequent to the first division of the endosperm nucleus. The first division of the egg is transverse, as usual, and the subsequent development of the embryo differs little from that of other Compositae.

SUMMARY.

The embryo sac arises from the lowest cell of an axial row of four cells.

The eight-nucleate embryo sac is formed in the usual manner.

Great variation is shown in the form of embryo sacs, both in different species and in the same species.

The polar nuclei fuse ordinarily before fertilization, but may fuse after it.

The endosperm nucleus is marked by its very large size, its almost spherical shape, its large nucleolus, and its position below and in contact with the oosphere.

The antipodals show a remarkable growth before the time of fertilization and persist very late in the development of the embryo.

From one to nineteen nuclei were found in a single antipodal cell.

The lowest antipodal cell in *A. undulatus* and *A. Novae-Angliae* is often very much enlarged.

The fertilization of an antipodal egg is clearly demonstrated in Aster.

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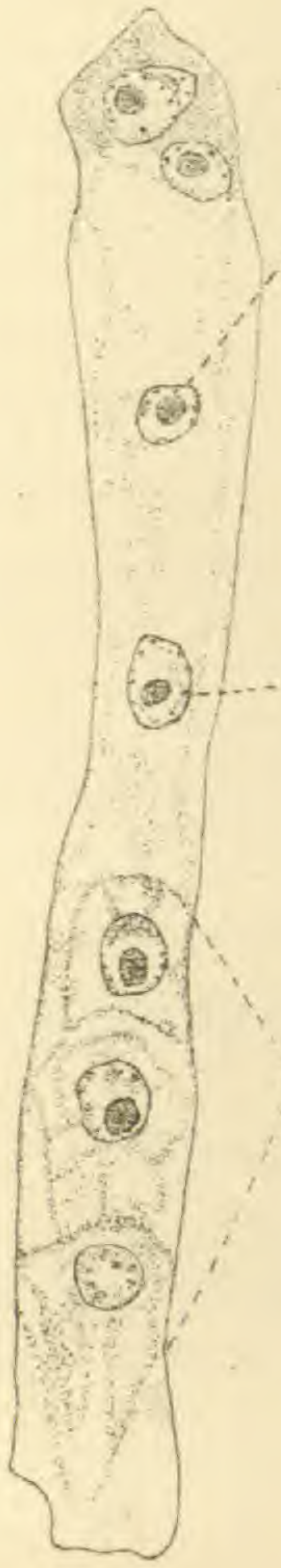

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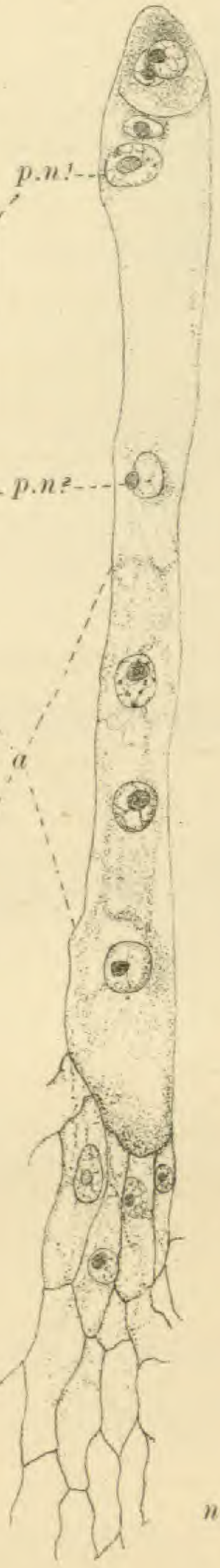

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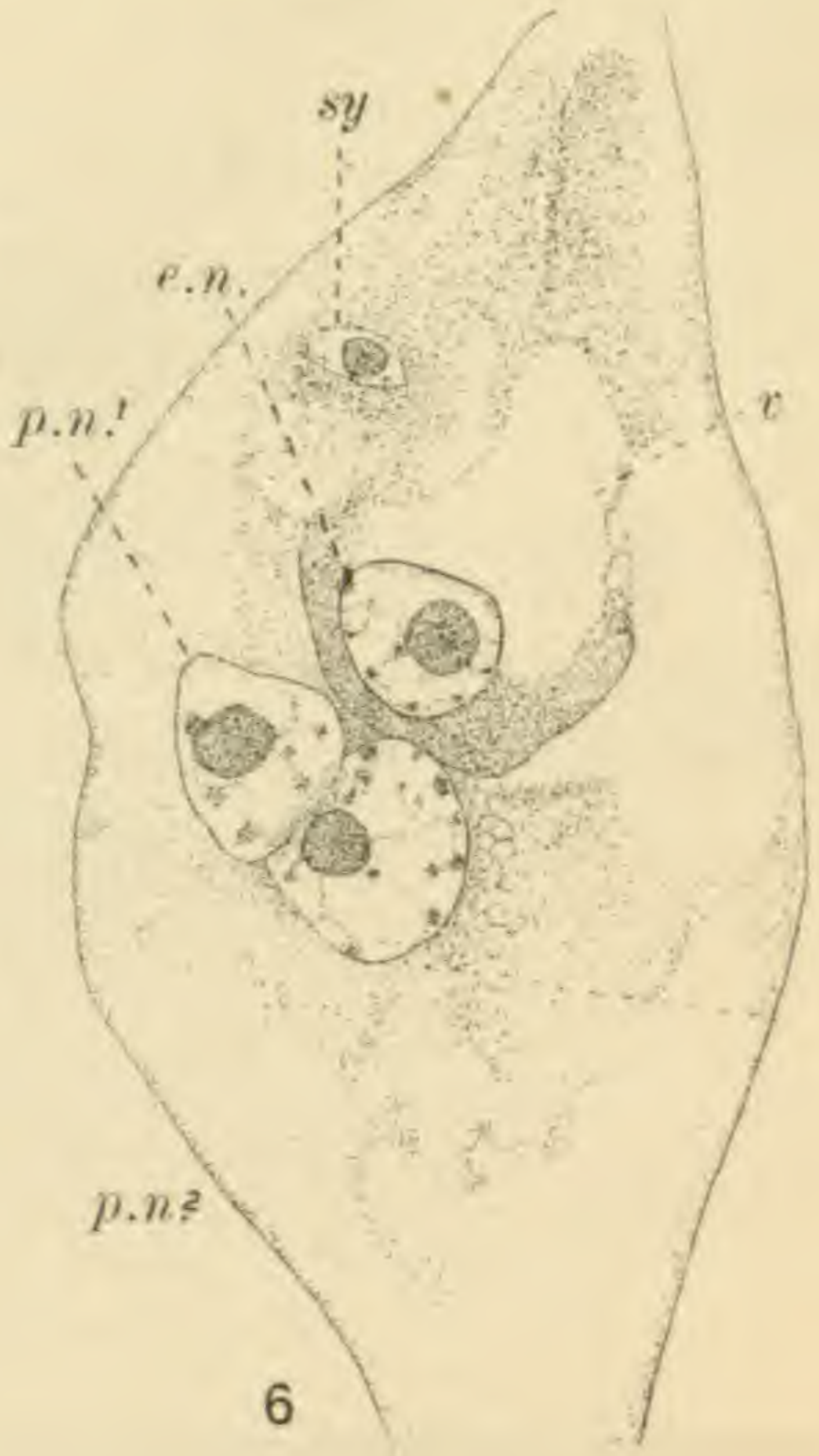

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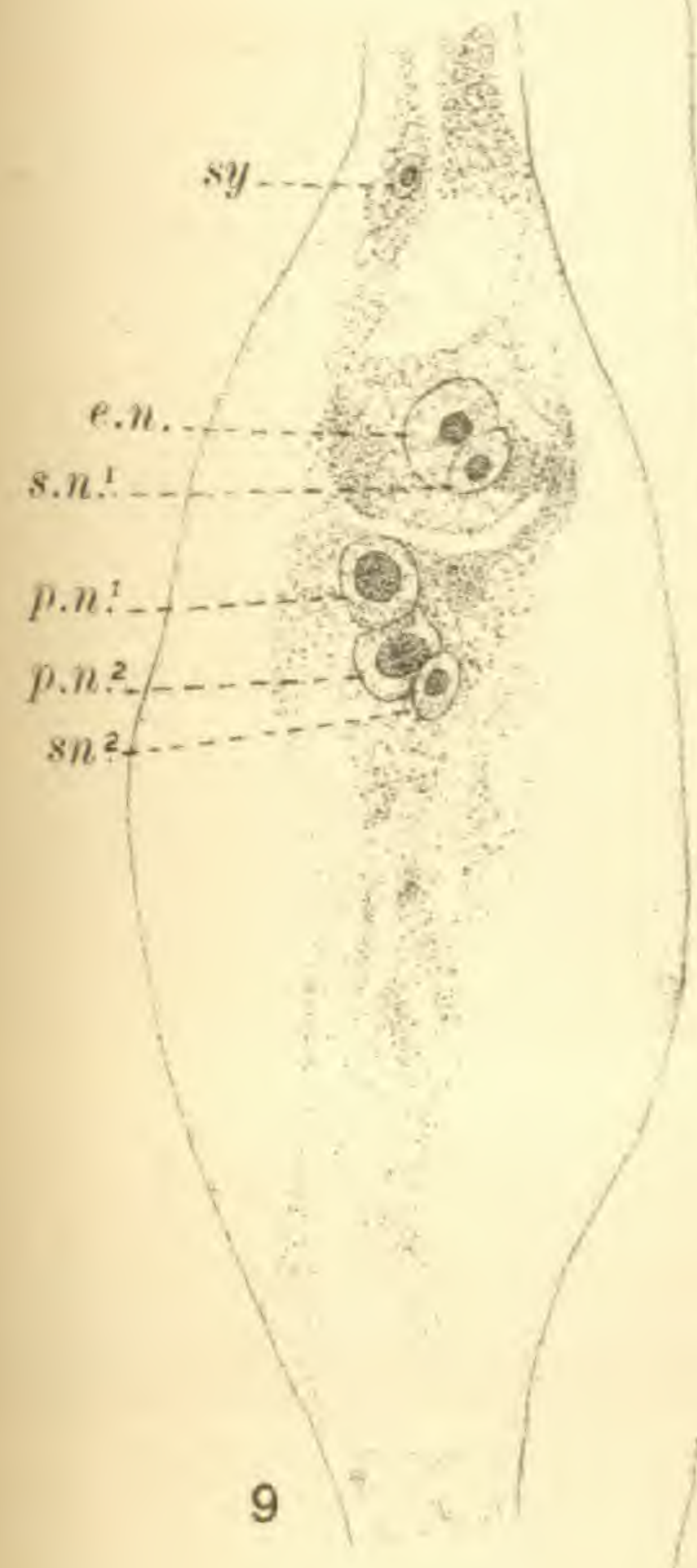

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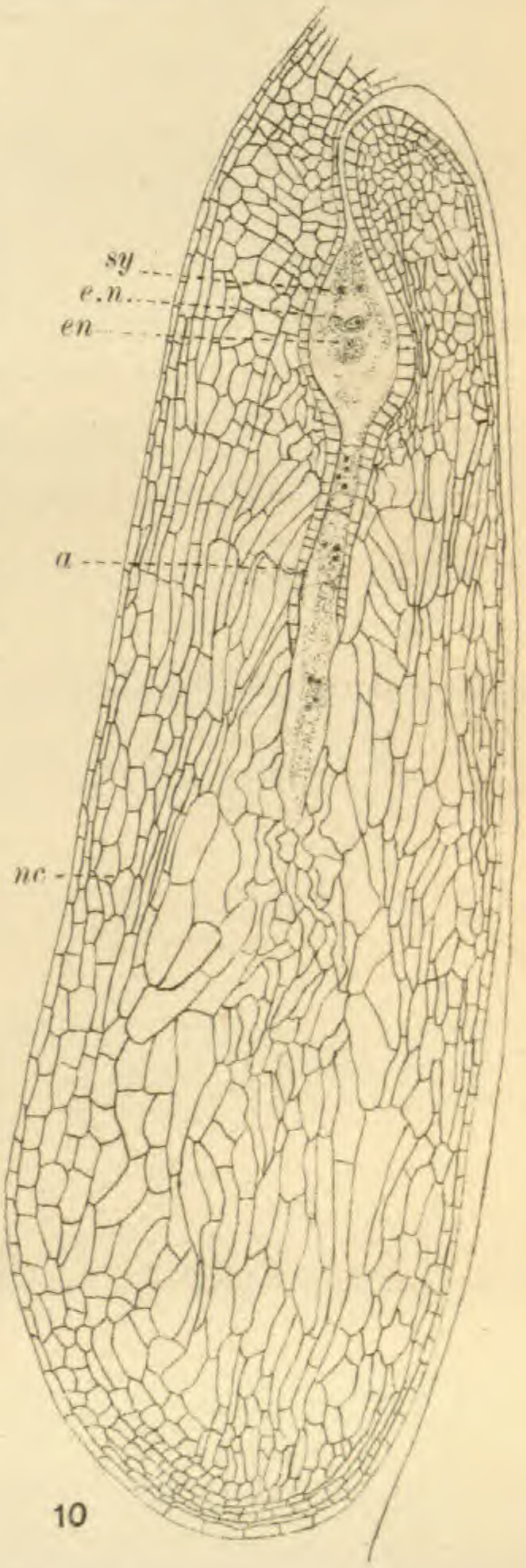

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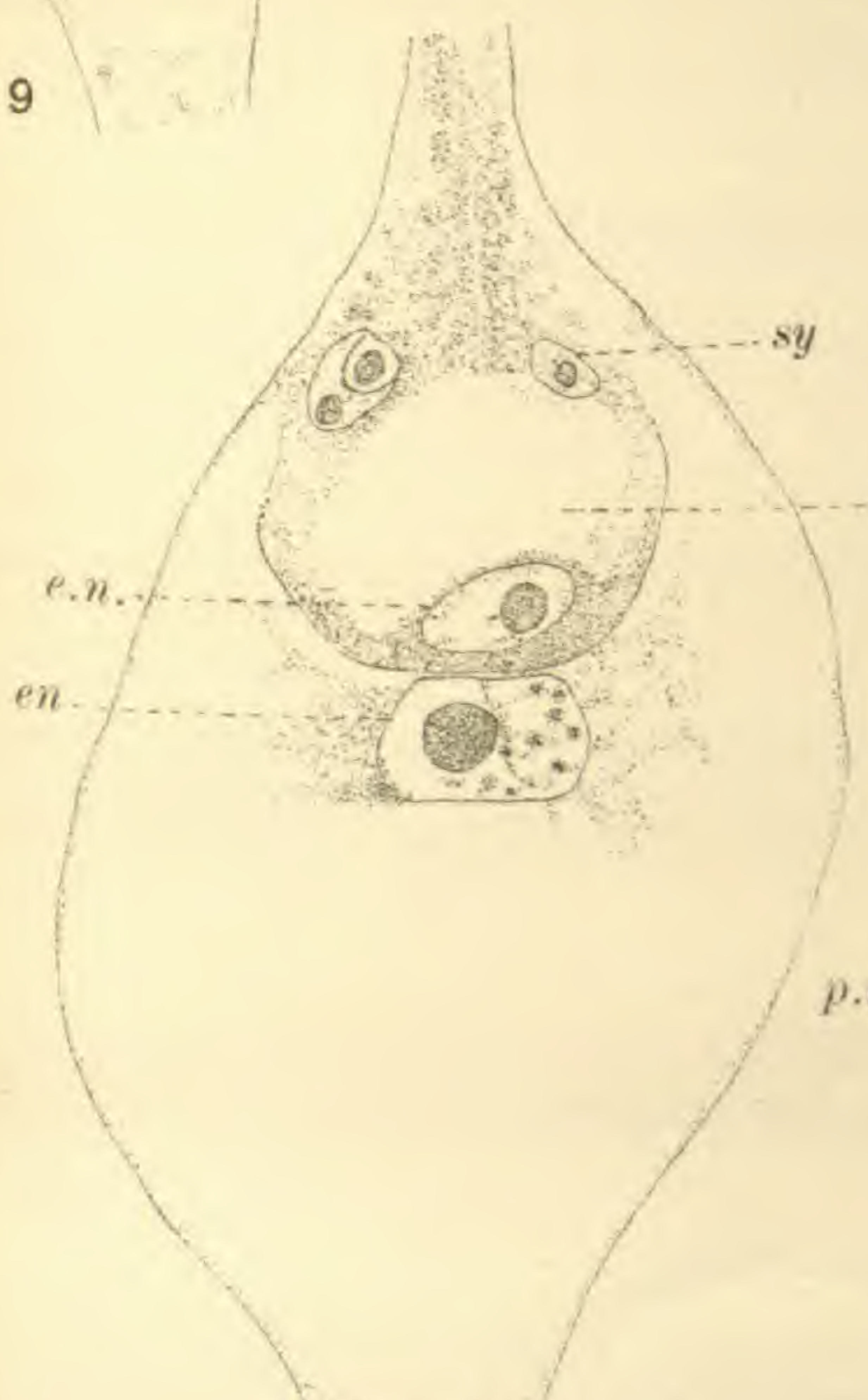

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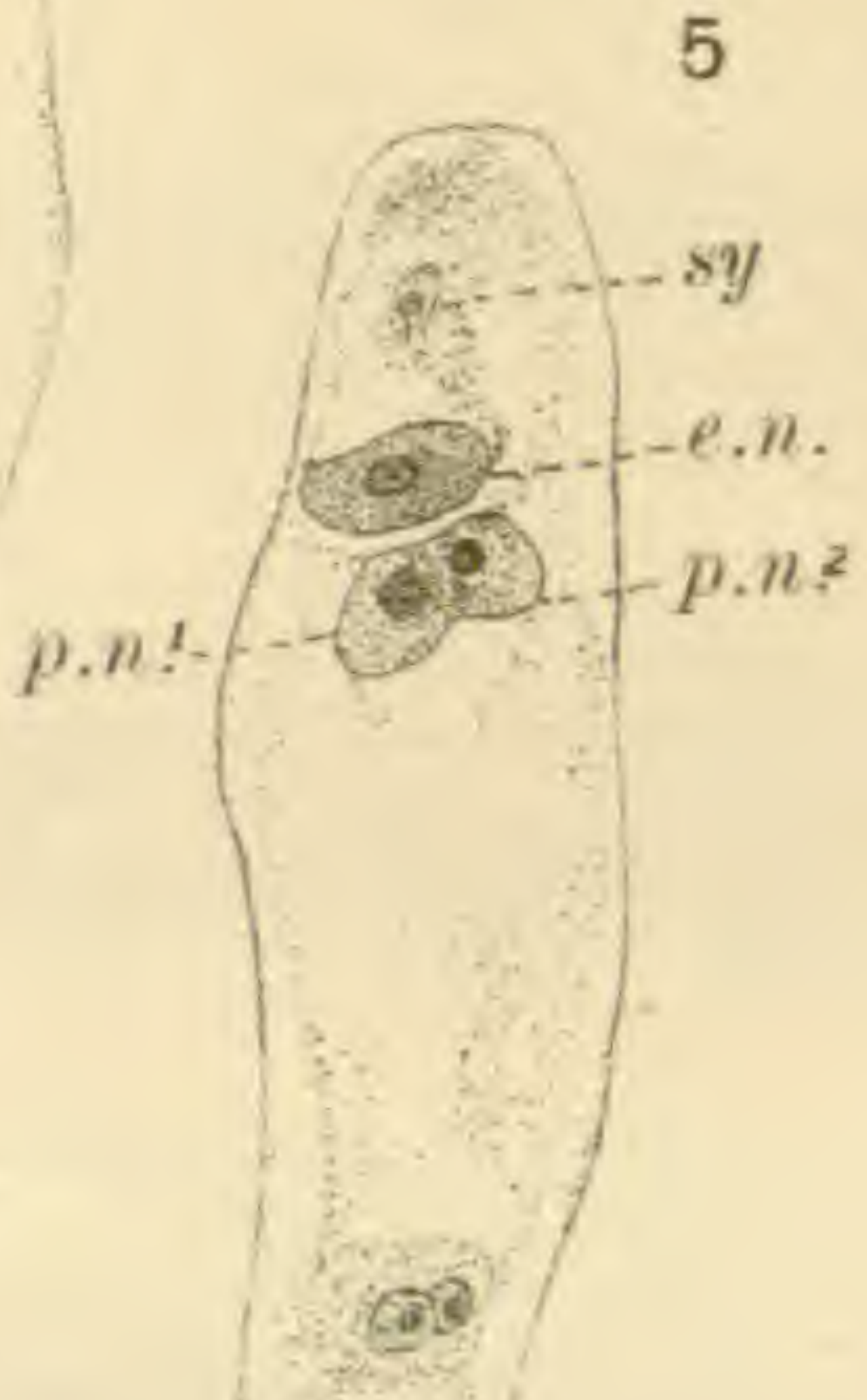

7

OPPERMAN DEL.

OPPERMAN on ASTER.

OPPERMAN DEL.

OPPERMAN on ASTER.

Double fertilization was observed in *A. undulatus*.

The sperm nuclei assume the structure of ordinary nuclei at the time of their fusion with the egg and the endosperm nucleus.

The development of the embryo follows the type described for other Compositae.

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EXPLANATION OF PLATES *XIV AND XV.*

All figures were drawn with a Nachet camera lucida and are reduced one-fourth in reproduction. The portion of a figure nearest to the micropylar end of the ovule is always toward the top of the plate. The lettering of the figures is to be interpreted as follows: *e.n.* egg nucleus; *o*, oosphere; *sy*, synergids; *p.n.*[1] upper polar nucleus; *p.n.*[2] lower polar nucleus; *nu*, nucleolus; *en*, endosperm nucleus; *s.n.*[1], *s.n.*[2] sperm nuclei; *a*, antipodals; *nc*, nucellus; *v*, vacuole.

FIG. 1. *A. multiflorus*. A young embryo sac with its nucleus in the metaphase of division. × 600.

FIG. 2. *A. undulatus*. A young embryo sac in the two-nucleate stage; the nuclei are in the telophase of division. × 600.

FIG. 3. *A. undulatus*. A four-nucleate embryo sac just after the second nuclear division. × 600.

FIG. 4. *A. Novae-Angliae*. An eight-nucleate embryo sac; the three antipodal cells have just been laid down; the egg apparatus is being formed

in the micropylar end; the polar nuclei are moving toward one another. × 600.

FIG. 5. *A. Novae-Angliae.* An eight-nucleate embryo sac; the egg apparatus is not yet formed; the polar nuclei are some distance apart; three active nuclei lie in the nucellus below the antipodal region. × 600.

FIG. 6. *A. undulatus.* The polar nuclei in the first stage of fusion. × 600.

FIG. 7. *A. multiflorus.* The polar nuclei in a more advanced stage of fusion. × 600.

FIG. 8. *A. Novae-Angliae.* A mature embryo sac. × 600.

FIG. 9. *A. undulatus.* An embryo sac in which the fusion of the polar nuclei has been delayed and double fertilization is taking place. × 600.

FIG. 10. *A. undulatus.* A mature embryo sac showing the structure of the surrounding nucellar tissue. × 140.

FIG. 11. *A. Novae-Angliae.* The antipodal region of a mature embryo sac, showing a long somewhat enlarged lower cell with two large nuclei. × 600.

FIG. 12. *A. multiflorus.* The antipodal region of a young embryo sac, showing six cells. × 600.

FIG. 13. *A. multiflorus.* The antipodal region of a young embryo sac, showing two of its cells lying side by side. × 600.

FIG. 14. *A. undulatus.* The antipodal region of an older embryo sac; the lowest cell is enlarged and contains nineteen small nuclei. × 600.

FIG. 15. *A. Novae-Angliae.* The antipodal region of a mature embryo sac showing multinucleate cells. × 600.

FIG. 16. *A. undulatus.* An embryo sac with an enlarged antipodal cell. × 600.

FIG. 17. *A. undulatus.* A normal mature embryo sac. × 600.

FIG. 18, *a. A. undulatus.* An abnormal mature embryo sac, containing an antipodal endosperm nucleus and also an antipodal oosphere which is about to be fertilized by a banana-shaped sperm. × 600.

FIG. 18, *b.* The antipodal cells of the embryo sac in *fig. 18, a.*

NEW OR UNRECORDED MOSSES OF NORTH AMERICA. II.[1]

J. CARDOT and I. THÉRIOT.

(WITH PLATES XVI–XXV)

Phascum hyalinotrichum Card. & Thér., *sp. nova*.—Plantulae minimae, pusillae, gemmaceae, solitariae vel gregariae, pallide virides. Folia imbricata, inferiora brevia, superne majora, media superioraque ovata, 0.8–1^{mm} longa et 0.6^{mm} lata, concava, acuminata, integra vel subintegra, *marginibus undique* planis vel inferne leniter reflexis, costa angusta, 24μ in medio folii crana, inferne attenuata, in cuspidem piliformem, flexuosam, hyalinam, tertiam vel dimidiam partem folii aequantem excurrente, rete laxo, omnino-laevi, parum chlorophylloso, pallide viridi, superne hyalino, cellulis mediis irregularibus, quadratis, breviter rectangulis vel subhexagonis, long. 18–30μ, lat. 12–18μ, parietibus crassiusculis, inferioribus majoribus, parietibus tenerrimis, superioribus longioribus, parietibus incrassatis. Capsula in pedicello perbrevi, 0.2^{mm} longo, geniculato, immersa, *globosa*, apiculata, diam. 0.7^{mm}. Calyptra cucullata, dimidiam partem capsulae obtegens. Sporae maturae ignotae. *Plate XVI.*

California: Soldier's Home, Los Angeles county (Dr. Hasse, 1902; herb. C. F. Baker).

A quite peculiar species, very distinct by its habit, which recalls that of an Acaulon, its puliform excurrent nerve, and its loose smooth areolation, a little chlorophyllose below and hyaline above.

Pleuridium Bakeri Card. & Thér., sp. nova.—Humile, laxiuscule cespitosum, viridi-lutescens. Caulis 2–4^{mm} altus, erectus, simplex. Folia erecta, inferiora minuta, remota, brevia, superiora longiora, lanceolato-subulata, acuta, integra, rarius apice subdenticulata, marginibus inflexis subcanaliculata, 1.3^{mm} longa, 0.35^{mm} lata; perichaetialia duplo longiora, sensim subulata; costa lata (80–100μ), percurrens, in foliis perichaetialibus paululum angustior; cellulae inferiores pellucidae, subrectangulae, 24μ longae,

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[1] See for No. I, BOT. GAZ. 30: 12. 1900.

12 μ latae, mediae superioresque angustiores, 29–30 μ longae, 5 μ latae, opacae, parietibus incrassatis. Capsula in pedicello erecto, brevi, 0.4^{mm} longo, immersa, ovata, leniter gibbosa, obtusissime apiculata, laevis, matura fusco-lutescens, 1^{mm} longa, 0.6^{mm} crassa. Calyptra cucullata, tertiam dimidiamve partem capsulae obtegens. Sporae elliptico-subglobosae, minutissime papillosae, 24–30 μ crassae. Dioicum videtur (floribus masculis ignotis). *Plate XVI.*

California: on ground in old pastures, foothills near Stanford University (C. F. Baker, 1902).

Var. **elongatum** Card. & Thér., var. nova.—A forma typica differt caulibus altioribus foliisque superioribus longioribus et magis flexuosis.

California: on wet clay soil, foothills near Palo Alto (C. F. Baker, 1902).

Distinguished from *P. subulatum* Br. Eur. by the shorter and less finely subulate leaves, with a broader costa. The latter character also separates our species from *P. Bolanderi* C. Müll., which, besides, has the leaves distinctly denticulate on the margins from the middle upward. *P. Ravenelii* Aust., of which we have seen no authentic specimen, according to the description has carinate leaves, excurrent costa, and synoicous inflorescence. If the inflorescence of *P. Bakeri* is, as we think, really dioicous, this character would distinguish it from all the other North American and European species of Pleuridium.

DICRANELLA CURVATA Sch. var. **missourica** Card. & Thér., var. nova.—A forma typica differt capsula minus distincte striata et areolatione foliorum e cellulis latioribus brevioribusque composita.

Missouri: Seligman, on ground (B. F. Bush, 1898).

Dicranum alatum (Barnes) Card. & Thér., sp. nova. (*D. Bonjeani* de Not. var. *alatum* Barnes, Bot. Centralbl. **44**: 386. 1890).—Atroviride, dense cespitosum, intus tomentosum, 4–6^{cm} altum. Folia falcato-secunda, 3–5^{mm} longa, 1^{mm} lata, lanceolata, acuta, superne carinata, haud vel vix undulata, in tertia parte superiore acute dentata, dentibus in foliis superioribus longioribus et magis numerosis, costa basi 120 μ, medio circa 100 μ lata, in dimidio superiore dorso duabus alis altis dentatis ornata, cellulis inferioribus rectangulis, hyalinis, haud porosis, mediis 40–50 μ longis, 12–15 μ latis, valde porosis, superioribus brevioribus latioribusque, 30–36 μ longis, 18 μ latis, valde chlorophyllosis, alaribus breviter rectangulis, inflatis, lutescentibus. Caetera ignota. *Plate XVII.*

Illinois: Chicago (Dr. J. Röll, 1888). Wisconsin: Madison (Cheney and True). W. Minnesota: Cedar Lake, near Montevideo, Chippewa county (J. M. Holzinger, 1901).

The nerve bearing on the back two high, serrate lamellae, and the shorter, thinner-walled cells of the areolation, seem characters of sufficient value to separate this moss from *D. Bonjeani*.

Fissidens Bushii (Card. & Thér.) Card. & Thér. sp. nova. (*F. subbasilaris* var. *Bushii* Card. & Thér. in BOT. GAZETTE **30**: 16. 1900).—Monoicus, laxe cespitosus, pallide vel lutescenti-viridis. Caulis brevis, $5-8^{mm}$ longus, divisus. Folia oblongo-lanceolata, obtusa, abrupte apiculata, toto ambitu minute denticulata, $1.2-1.4^{mm}$ longa, 0.45^{mm} lata, lamina dorsali basi rotundata, haud undulata, costa percurrente, basi 40μ crassa, rete opaco e cellulis minutis, angulosis subrotundatisve, $6-7\mu$ latis, parietibus incrassatis, marginalibus haud vel parum translucentibus. Flores feminei in ramulis brevibus basalibus. Caetera ignota. *Plate XVII.*

Missouri: Eagle Rock, on gravelly ground (B. F. Bush, 1897). Texas (Elsa Baumann; herb. Dr. Zickendrath).

At first we considered this moss as a variety of *F. subbasilaris* Hedw., but further observations led us to a different conclusion, and now we think it preferable, on account of the inflorescence and the costa reaching the apex, to place it near *F. taxifolius* Hedw., of which it may be a subspecies, characterized by the nearly twice smaller size, the obtuse abruptly apiculate leaves with the dorsal wing not undulate at base and with smaller cells. From *F. subbasilaris* it is easily distinguished by the inflorescence and the costa reaching the apex.

FISSIDENS PUSILLUS Wils. var. **brevifolius** Card. & Thér., var. nova.—A forma typica differt foliis innovationum sterilium multo brevioribus, magis abrupte et brevius acuminatis.

California: Soldier's Home, Los Angeles county (Dr. Hasse, 1902; herb. C. F. Baker).

Pottia nevadensis Card & Thér., sp. nova.—Monoica? viridis, densiuscule cespitosa. Caulis erectus, brevis, $1-2^{mm}$ altus. Folia erecta, ovata, concava, media 1^{mm} longa, 0.6^{mm} lata, inferiora minora, omnia laevia, marginibus integris, saltem uno latere parce revolutis, costa angusta, in cuspidem subpiliformem abrupte excurrente, cellulis mediis hexagonis rhomboidalibusve, parce chlorophyllosis, circa 18 μ longis, 15 μ latis, superioribus paululum minoribus, basilaribus elongato-rectangulis, 40 μ longis, 18 μ latis, omnibus perfecte laevibus. Folia perichaetialia multo majora et latiora, valde concava, usque 2^{mm} longa. Capsula in pedicello pallido, flexuoso, $10-15^{mm}$ longo, erecta, oblonga, basi attenuata, ore truncata, pallida, gymnostoma, $1.5-2^{mm}$ longa, 0.75^{mm} crassa, operculo depresso, longe tenuirostro, 1.2^{mm} longo, columellae parum adhaerente. Sporae dense papillosae, 24–30 μ crassae. *Plate XVIII.*

Nevada: Kings Cañon, near Carson, on ground about willow thickets (C. F. Baker, 1902).

This species seems very distinct from any other European or North American Pottia.

DIDYMODON TOPHACEUS Jur. var. **decurrens** Card & Thér., var. nova.—Var. *elatae* similis. Folia remota, madida recurva, longe decurrentia, dorso valde papillosa, costa scabra.

Texas: Shovel Mt., Burnet county (Rev. Franciscus Ebeling; herb. Dr. E. Zickendrath).

Desmatodon Bushii Card & Thér., sp. nova.—Laxiuscule cespitosus, olivaceo-viridis. Caulis erectus, $5-15^{mm}$ altus, simplex vel divisus. Folia sicca crispatula, madida erecto-patentia, $1-1.5^{mm}$ longa, 0.4^{mm} lata, oblongo-lanceolata, plerumque obtusa, costa breviter excurrente mucronata, marginibus integris longe revolutis, cellulis inferioribus rectangulis, hyalinis vel paululum lutescentibus, 35–40 μ longis, 9 μ latis, caeteris quadrato-rotundatis, valde papillosis, opacis, diam. 7–8 μ, costa basi 60 μ crassa. Folia perichaetialia majora, in tertia vel dimidia parte inferiore hyalina, magis acuminata, marginibus tantum superne revolutis. Capsula in pedicello pallide rubello, circa 10^{mm} longo, erecta, subcylindrica, cum operculo 2^{mm} longa, 0.44^{mm} crassa, operculo conico, breviusculo, 0.5^{mm} longo. Calyptra dimidiam partem capsulae obtegens. Peristomium 0.35^{mm} altum, purpureum, membrana basilari brevi, dentibus leniter contortis, usque ad basin in 2 crura filiformia, papillosa, saepissime inferne 2 vel 3 trabeculis coalita divisis. Sporae laeves, variabiles, globulosae vel ellipticae, diam. 20–30μ. Dioicum videtur (floribus masculis ignotis). *Plate XVII.*

Missouri: Courtney, on wet rocks (B. F. Bush, 1898).

Much resembling *Barbula unguiculata* Hedw. by the habit and the shape and areolation of the leaves, but readily distinguished from it by the peculiar structure of the peristome, which is hardly twisted, and by the spores twice larger. C. Müller described a *B. cancellata*, the peristome of which according to the description must have a similar structure to that of our *D. Bushii*, but the teeth are smooth (likely twisted), and the lid is as long as the capsule.

DESMATODON SYSTILIOIDES Ren. & Card., BOT. GAZETTE 30:16. 1900 is not a *Desmatodon* but a new *Pottia* of the group *Heimii.*

Barbula macrotricha Card & Thér., sp. nova.— Pulvini compacti, superne grisei. Caulis brevissimus, 1–2$^{\mathrm{mm}}$ altus. Folia madida erecta, gemmatim conferta, sicca contortula, 1–1.5$^{\mathrm{mm}}$ longa, 0.6–0.8$^{\mathrm{mm}}$ lata, ovata vel breviter subspathulata, apice late obtuso, praecipue in foliis inferioribus saepe emarginato, aetate eroso, marginibus integerrimis, basi planis, deinde usque apicem versus revolutis, costa angusta, 4–8μ crassa, in pilo laevi, hyalino, in foliis inferioribus brevi, in superioribus limbo aequilongo, imo longiore excurrente, cellulis inferioribus quadratis vel breviter rectangulis, 18μ latis, hyalinis vel vix chlorophyllosis, sublaevibus, caeteris minoribus, circa 12μ latis, quadratis subrotundatisve, valde chlorophyllosis et grosse papillosis inde obscuris, indistinctis. Capsula in pedicello basi rubello, superne pallidiore, brevi, 6–8$^{\mathrm{mm}}$ longo, erecta, subcylindrica, curvatula, unacum operculo conico-elongato 2.5$^{\mathrm{mm}}$ longa. Ob capsulas immaturas caetera ignota. Dioica videtur (floribus masculis in planta fructifera non visis). *Plate XVIII.*

California: Soldier's Home, Los Angeles county (Dr. Hasse, 1902; herb. C. F. Baker).

In general appearance resembling the smallest forms of *B. muralis* Timm., from which it differs by the smaller size, the short pedicel, the much shorter leaves obtuse or emarginate and finally eroded at the apex, the hair of the upper leaves as long as or even longer than the lamina, etc.

Barbula Bakeri Card & Thér., sp. nova.—Dioica, laxiuscule cespitosa, olivaceo- vel lurido-viridis, 3–8$^{\mathrm{mm}}$ alta. Folia sicca erecta, contortula vel crispatula, madida patulo-squarrosa, 1.4–1.5$^{\mathrm{mm}}$ longa, 0.6–0.7$^{\mathrm{mm}}$ lata, e basi ovata longiuscule acuminata, carinata, marginibus integris e basi usque apicem versus valde revolutis, costa percurrente, basi 60 μ crassa, rete laevi vel vix papilloso, cellulis subuniformibus, quadrato-rotundatis, 6 μ latis, nonnullis ad basin folii juxta costam breviter rectangulis, 9 μ longis. Folia perichaetialia caulinis subsimilia, tamen paululum, longius acuminata. Capsula in pedicello rubello, circa 10^{mm} longo, erecta, oblonga subcylindricave, unacum operculo conico-rostrato $2.5-3^{mm}$ longa. Calyptra dimidiam partem capsulae obtegens. Annulus distinctus, persistens. Peristomium purpureum, 0.6^{mm} altum, dentibus semicontortis. Sporae laeves, pallidae, diam. 8–9 μ. *Plate XVIII.*

California: Stanford University, on stones bordering flower beds (C. F. Baker, 1901); foothills near Palo Alto, on ground (C. F. Baker, 1902); Alma, Santa Clara county, on bowlder (C. F. Baker, 1902); Soldier's Home, Los Angeles county (Dr. Hasse, 1902; herb. C. F. Baker).

A species belonging to the perplexing group of *B. fallax* Hedw., differing from this species by its smooth or very slightly papillose leaves with margins more broadly revolute, and by its shorter, slightly twisted peristome. From *B. virescens* Lesq. it is distinguishable by its shorter leaves, broader at base, its almost uniform areolation, and its lower cells small, quadrate, chlorophyllose, with thinner walls.

BARBULA HUMILIS Hedw., Sp. Musc. 116, tab. XXV, *figs. 1–4.*

Missouri: Swan, on rocks (B. F. Bush. 1899).

A reduced form of *B. caespitosa* Schw. (See: Cardot, Revision des types d'Hedwig et de Schwaegrichen, in Bull. Herb. Boiss. 7: 304. 1899).

Grimmia cognata Card. & Thér., sp. nova.—Verisimiliter dioica, densiuscules cespitosa, superne lutescenti-viridis, inferne fusca. Caulis pro more basi longe denudatus, ascendens arcuatusve, parce ramosus, $2-5^{cm}$ longus. Folia sicca erecto-flexuosa, madida erecto-patentia, $2.5-3.5^{mm}$ longa, 0.7^{mm} lata, lanceolata, sensim et longe acuminata, carinata, pilo hyalino integro praedita, marginibus uno latere parce revolutis, rete opaco, cellulis inferioribus linearibus, 30–40 μ longis, 6–8 μ latis, parietibus valde incrassatis et sinuosis, caeteris quadrato-rotundatis vel breviter rectangulis, in dimidio superiore bistratosis. Caetera ignota. *Plate XIX.*

Colorado: along the Cogwheel Railway to Pike's Peak, alt. $2100-3000^{m}$ (J. M. Holzinger, 1896).

Closely allied to *G. trichophylla* Grev., of which it may be considered as a subspecies; differing from it in its more robust size, recalling that of *G. elatior* Br. Eur., its stems naked below, and the basal areolation with much thicker and more sinuate walls.

GRIMMIA HENDERSONI Ren. & Card., Rev. Bryol. **19**: 86. 1892. —A *G. decipienti* Lindb. proxima differt caulibus brevioribus, 10–15^{mm} altis, foliis minoribus, 2.5^{mm} longis, 0.8^{mm} latis, costa angustiore, 65μ basi crassa, cellulis mediis minoribus, 6–8μ latis, inferioribus laxioribus, 24–35μ longis, 10–14μ latis, pedicello breviore, 4–5^{mm} longo, capsula angustiore, subcylindrica, 1.6^{mm} longa, 0.7^{mm} crassa, minus profunde sulcata, operculo longius rostrato, 1^{mm} longo, peristomii dentibus minus profunde fissis, 0.36^{mm} altis, denique sporis laevibus, multo minoribus, 9μ crassis. *Plate XX.*

Oregon: sunny dry rocks in rill bed, Hood River (L. F. Henderson, 1889).

BARTRAMIA ITHYPHYLLA Brid. var. **fragilifolia** Card. & Thér., var. nova.—A forma typica differt foliis rigidis, fragilibus, plerumque effractis.

Colorado: along the Cogwheel Railway to Pike's Peak, 2100–3000^{m} alt. (J. M. Holzinger, 1896).

By its brittle and usually broken leaves, this form much resembles *B. breviseta* Lindb.; but in the latter the leaf base is hardly glossy and less abruptly contracted to the subula.

Webera chlorocarpa Card. & Thér., sp. nova.—Densiuscule cespitosa, basi terra obruta, inferne fusco-viridis, superne lutescens. Caulis 1–2^{cm} altus, erectus, simplex divisusve. Folia erecto-appressa, 2^{mm} longa, 1^{mm} lata, ovato-lanceolata, acute acuminata, basi paulo decurrente, marginibus planis integris, costa inferne 80μ crassa breviter excurrente, cellulis basilaribus quadratis vel breviter rectangulis, subinflatis, 40–60μ longis, 25–40μ latis, mediis hexagono-rhomboidalibus, 40μ longis, 18–20μ latis, marginalibus e tertia parte inferiore angustis, linearibus, 4–5-seriatis quemdam limbum lutescentem subefformantibus. Capsula in pedicello rubello, superne pallido, plus minus flexuoso, 2–2.5^{cm} longo, nutans vel pendula, ovato-pyriformis, collo sporangio aequilongo attenuata, pallide flavescens, aetate plicata, sub ore haud constricta, parietibus mollibus, stomatibus numerosis, emersis, 2–2.5^{mm} longa, 0.75^{mm} crassa, operculo convexo, obtuse apiculato. Annulus latus. Exostomii dentes 0.44^{mm} alti, 20–25 lamellis praediti; endostomii membrana praealta, ultra medium dentium producta, processus in carina late hiantes, cilia solitaria vel bina, plus minus elongata, ut processus subtiliter granulosa. Sporae 18–20μ crassae. Dioica videtur (floribus masculis in planta fructifera non visis). *Plate XX.*

Nevada: Marlette Lake, Washoe county, on stream bank (C. F. Baker, 1902).

Resembles in habit *W. gracilis* De Not., but much stronger, with a very different areolation of broad and short cells. The leaf areolation recalls that of the genus *Mniobryum* Limpr., but the stomata of the capsule are superficial and the annulus is quite distinct.

Webera Debati Card. & Thér., sp. nova — Laxe cespitosa, lutescenti-viridis, habitu philonotideo. Caulis 1.5–2.5^{cm} altus, inferne dense radiculosus, inde tomentosus, innovationibus gracilibus erectis. Folia inferiora sat remota, erecto-patentia, superiora magis conferta, appressa, circa 1.3^{mm} longa, 0.33^{mm} lata, lanceolata, acuta, basi haud decurrentia, marginibus planis toto fere ambitu denticulatis, costa basi 40μ crassa, sub summo apice evanida, cellulis mediis linearibus, 140–170μ longis, 28–30μ latis, inferioribus latioribus brevioribusque, rectangulis vel subhexagonis, marginalibus longioribus, anguste linearibus. Caetera ignota. *Plate XX.*

N. America: Alexander county (Herb. L. Debat, without name of collector.)

This species seems closely connected with *W. annotina* Bruch, from which it is distinguished by the larger size, the habit resembling that of a small Philonotis, the tomentose stems and the leaves plane on the margins.

BRYUM PENDULUM Sch. var. **nevadense** Card. & Thér., var. nova.—A forma typica differt capsula angustiore, illae varietatis *angustatum* Ren. simili sed majore, operculo convexo-apiculato, haud conico, denique foliis costaque basi viridibus, nec rubentibus.

Nevada: King's Cañon, near Carson, along stream (C. F. Baker, 1902).

Bryum polycladum Card. & Thér., sp. nova.—Synoicum dense lateque cespitosum, intus fuscum, superne laete viride. Caulis brevis, 3–5 mm altus, ramis gracilibus, erectis, numerosis, sub perichaetio nascentibus. Folia erecto-appressa, conferta, inferiora brevia, 1 mm longa, 0.5 mm lata, media superioraque paulo majora, 1.5 mm longa, 0.5–0.6 mm lata, basi haud decurrentia, ovata vel ovato-oblonga, breviter acuminata, marginibus e basi usque apicem versus anguste revolutis, superne denticulatis, costa valida, rubente, basi 60–65 μ crassa, in foliis mediis et superioribus brevissime excurrente, in inferioribus apicem vix excedente, cellulis mediis et superioribus breviter subhexagonis, 30–35 μ longis, 12 μ latis, parietibus incrassatis, marginalibus linearibus, 2–3-seriatis, inferioribus majoribus, laxioribus, rectangulis, 35–50 μ longis, 12–18 μ latis. Capsula in pedicello rubello flexuoso, elongato, 4–6 cm alto, nutans vel pendula, oblonga, 4–4.5 mm longa, 1–1.2 mm crassa, collo madore in pedicello abrupte contracto, operculo convexo-apiculato. Annulus latus. Exostomii dentes angusti, pallidi, inferne rubelli, 18–22 lamellis instructi, 0.35–0.4 mm alti, basi 50 μ lati. Endostomium exostomio adhaerens, membrana ad ⅓ dentium producta, processibus linearibus, in carina fissis, ciliis brevissimis obsoletisve. Sporae minutae, pallidae, diam. 12 μ. *Plate XXI.*

Nevada: Spooner, Douglas county, in large mats on moist banks (C. F. Baker, 1902).

This moss can be placed near *B. longisetum* Bland., but it is easily distinguished from it by the numerous sterile branches arising from below the perichaetium, the smaller leaves with a shorter acumen, the peristomial teeth, which are narrower and paler, and have more numerous lamellae, and finally the much smaller spores.

Bryum anceps Card. & Thér., sp. nova.—Dense cespitosum, lutescenti-viride. Caulis simplex vel parce ramosus, 5–10 mm altus, interrupte foliosus. Folia ad apicem innovationum in comam congesta, circa 1.5 mm longa, 0.8 mm lata, concava, e basi paulo decurrente late ovata, brevissime acuminata, inferiora mediaque obtusa, superiora subobtusa vel subacuta, apice integro subdenticulatove, marginibus saltem uno latere in dimidio superiore revolutis, costa valida, basi dilatata, 100 μ crassa, sensim attenuata et sub apice evanida, rete perlaxo, cellulis inferioribus quadratis vel rectangulis, caeteris hexagonis, circiter 50 μ longis, 20 μ latis, omnibus parietibus mollibus, angustis. Caetera ignota. *Plate XIX.*

N. W. Montana: in the vicinity of Lake MacDonald, Flathead county, 1000–2100 m alt. (J. M. Holzinger and J. B. Blake, 1898).

The relationship of this moss is rather doubtful; it seems, however, to have some affinity with *B. capitellatum* C. Müll. & Kindb., which it resembles in habit and form of the leaves, but it has more slender stems, the leaves somewhat decurrent, revolute in the lower part at least on one side, a looser areolation formed of much wider and softer cells with thinner walls, and a much broader nerve (100 μ wide at base, instead of 60), ending at a little distance below the apex.

BRYUM SANGUILENTUM Ren. & Card. Rev. Bryol. **20**: 31. 1893; Bull. Herb. Boissier **4**: 17. 1896. (*B. occidentale* var. Sulliv. & Lesq. Musci Bor.-Amer. exsicc., ed. 2, nos. 283 and 284).—Dioicum, dense cespitosum, superne viride, inferne fuscum. Caulis 10–15 mm altus, radiculosus, innovationibus gracilibus. Folia conferta, madida erecto-imbricata, concava, sicca plus minus flexuosa, haud vel vix spiraliter torta, circa 3 mm longa et 1 mm lata, subspathulato-oblonga, marginibus integris vel apice minute denticulatis, e basi longe revolutis, superne planis, costa basi 90 μ crassa, sensim angustata, longiuscule et tenuiter excurrente, rete laxo, cellulis basilaribus rectangulis, 60–120 μ longis, 24–30 μ latis, mediis hexagonis rhomboidalibusve, 40–50 μ longis, 15 μ latis, superioribus brevioribus, marginalibus 1–2-seriatis, angustioribus, limbum parum distinctum saepe subnullum efformantibus. Capsula in pedicello pallide rubello, flexuoso, 1.5–3 cm longo, nutans pendulave, anguste subcylindrica, basi attenuata, arcuatula, 5 mm longa, 0.9 mm crassa, matura in dimidio superiore plerumque sanguinea, basin versus pallidiore, operculo nitido, convexo. Annulus latus, triplex. Endostomii membrana elata, usque ad ⅔ dentium producta, ciliis appendiculatis. Sporae laeves, diam. 12–15 μ. *Plate XXIII.*

California: "in truncis emortuis et deustis Californiae (Bigelow et Bolander comm.)." Sulliv. et Lesq. Musci Bor.-Amer. Exsicc. ed. 2, no. 284, as *B. occidentale* var.; Mill Valley, Marin county, on old stumps of *Sequoia sempervirens* (Marshall A. Howe, 1892 and 1894; Ren. & Card. Musci Amer. Sept. Exsicc. no 223); Sonoma county (Miss Martha R. Mann, 1886); foothills near Palo Alto, on old logs (C. F. Baker, 1902). We have a specimen from Sonoma county labeled "*Bryum arenarium* Hpe.," sent by the Königl. Bot. Museum in Berlin.

Differs from the small forms of *B. capillare* L. by its capsule generally narrower, light red in the upper part when ripe, and by the less distinct border of its leaves. *B. torquescens* Br. Eur. is a more robust plant, with the leaves generally strongly twisted when dry, distinctly bordered, and a synoicous inflorescence.

Bryum brevicuspis Card. & Thér., sp. nova. — Synoicum, dense cespitosum lurido-viride. Caulis 1–2^{cm} altus, radiculosus, sub perichaetio innovans. Folia madida erecto-patentia, sicca spiraliter contorta, circiter 1.5^{mm} longa et 0.65^{mm} lata, ovato oblonga, breviter acuminata, marginibus e basi usque apicem versus revolutis, superne denticulatis, costa inferne rubella, 72–82μ crassa, percurrente vel saepius brevissime excurrente, cellulis mediis hexagonis vel rhomboidalibus, 30–35μ longis, 12μ latis, valde chlorophyllosis, parietibus angustis, superioribus longioribus, inferioribus majoribus, laxioribus, breviter rectangulis, hyalinis, marginalibus angustis, 2–3-seriatis, limbum sat distinctum efformantibus. Capsula in pedicello flexuoso, circa 1.5^{cm} longo, pendula, brevis, matura et sicca sub ore paulo constricta, 1.6^{mm} longa, 0.9^{mm} crassa, operculo convexo-apiculato. Peristomium perfectum, ciliis appendiculatis. Sporae laeves, diam. 13–15μ. *Plate XXII.*

Missouri: Eagle Rock, on tree (B. F. Bush, 1898).

Easily distinguished from *B. capillare* L. by its synoicous flowers, very briefly excurrent costa and shorter capsule. Differs from *B. provinciale* Philib. by its smaller leaves, more narrowly revolute, with a shorter point, not so much denticulate in the upper part, and also by its shorter capsule. It seems more closely connected with *B. oreganum* Sulliv.; but from Sullivant's description and drawings (Exped. Wilkes, Musci, 10, *pl.* 7, B) the latter has shorter stems, more serrate leaves, not twisted when dry, and a longer capsule.

Bryum distantifolium Card. & Thér., sp. nova.— Cespites molli, luridi, circa 5^{cm} alti. Caulis erectus, parce radiculosus, simplex vel superne 3–5 innovationes graciles emittens. Folia dimorpha, omnia integra, anguste sed distincte decurrentia, marginibus planis vel basi tantum subrevolutis: inferiora remota, parva, breviter acuminata, saepe obtusa subobtusave, 0.9^{mm} longa, 0.5^{mm} lata, limbo nullo vel indistincto, costa haud excurrente; media superioraque minus remota, majora, 2–2.4^{mm} longa et 0.9^{mm} lata, lanceolata, longe acuminata, costa basi 70μ crassa in cuspidem rubentem breviter excurrente, cellulis mediis rectangulis, 60–80 μ longis, 15 μ latis, marginalibus 2–3-seriatis angustis, linearibus, limbum distinctum efformantibus. Caetera ignota. *Plate XXI.*

Assiniboia: Wood Mountains (Macoun, 1895. Sent as *B. erythrophylloides* Kindb.).

Somewhat recalling the slender forms of *B. pallens* Sw., but differing by its dimorphous leaves, which are plane on the margins or nearly so. The leaves decurrent at base, the upper distinctly limbate, at once distinguish this moss from Kindberg's *B. erythrophyllum* and *B. erythrophylloides*.

Bryum subdrepanocarpum Card. & Thér., sp. nova.—Dioicum, laxe cespitosum, viride. Caulis brevis, 5–7^{mm} altus, inferne radiculosus, sub perichaetio innovans, innovationibus gracilibus, laxe foliosis. Folia inferiora remota, superiora in rosulam congesta, 1–1.5^{mm} longa, 0.6–0.75^{mm} lata, ovato-oblonga, breviter acuminata, marginibus longe revolutis, superne planis et denticulatis, costa basi 80 μ crassa, pro more infra apicem evanida, rete laxo, cellulis basilaribus rectangulis, mediis superioribusque oblongo-hexagonis, 60 μ longis, 18–20 μ latis, marginalibus angustis, linearibus, lutescentibus, 1–2-seriatis. Capsula in pedicello inferne rubello, superne pallido, 1.5–2^{cm} longo, pendula vel nutans, oblonga, arcuata, longicollis, operculo convexo-apiculato. Annulus latus. Peristomium perfectum, ciliis appendiculatis. Sporae 8–12 μ crassae. *Plate XXII.*

California: Soldier's Home, Los Angeles county (Dr. Hasse, 1902; herb. C. F. Baker).

This moss is very near *B. drepanocarpum* Philib., from which it differs by its shorter and broader leaves, denticulate in the upper part, and forming a small rosette or bud at the top of each stem, and by its costa generally vanishing below the apex.

Bryum camptocarpum Card. & Thér., sp. nova.—Monoicum, laxiuscule cespitosum, lutescenti-viride. Caulis brevis, circa 5^{mm} altus, radiculosus, simplex ramosusve. Folia erecta, sat conferta, oblongo-lanceolata, acuminata, media superioraque 2^{mm} longa, 0.6–0.7^{mm} lata, inferiora breviora, marginibus incrassatis, planis vel inferne vix reflexis, apicem versus subdenticulatis, costa rubente, basi 80–90 μ crassa, in foliis inferioribus breviter, in superioribus longius excurrente, cellulis mediis superioribusque hexagonis rhomboidalibusque, 54–70 μ longis, 18–24 μ latis, basilaribus rectangulis, 80–90μ longis, 25–30μ latis, marginalibus linearibus, limbum pulchre distinctum lutescentem, incrassatum, 2–3-stratosum efformantibus. Flos masculus in ramo proprio terminalis. Capsula in pedicello rubello, 1.5–3^{cm} longo, nutans, oblonga, arcuata, 4–4.5^{mm} longa, 1^{mm} crassa, collo attenuato sporangio aequilongo, operculo convexo, breviter apiculato. Annulus duplex et triplex. Peristomium perfectum, 0.48^{mm} altum; endostomii membrana ultra medium dentium producta, processus in carina anguste et parce fissi, cilia 1–3, appendiculata. Sporae papillosae, diam. 24μ. *Plate XXII.*

Newfoundland: John's Beach, wet places (Rev. Arthur C. Waghorne, 1895).

Allied to *B. meeseoides* Kindb., *B. drepanocarpum* Philib., and *B. subdrepanocarpum* Card. & Thér. by the form of the capsule, but distinct from these species by the monoicous inflorescence and by the leaves plane on the margins, or nearly so, with a very distinct and thickened border. It also much resembles *B. pallens* Sw. var. *arcuatum* Sch., from which, however, it differs by the shorter leaves, with margins plane or scarcely reflexed at base and denticulate or sinuate at apex.

Bryum dimorphophyllum Card. & Thér., sp. nova.—Verisimiliter dioicum, sat robustum. Cespites compacti, cohaerentes, superne lutescenti-virides, intus dense rufo-tomentosi. Caulis erectus, 4–5^{cm} altus, pluries divisus. Folia sicca erecta, ramea contorta, madida erecto-patentia, dimorpha: inferiora valde concava, e basi longe decurrente ovata vel oblonga, 1.5^{mm} longa, 1^{mm} lata, apice cucullato obtusissimo, costa sub apice evanida, superiora majora et angustiora, 2.2^{mm} longa, 0.8^{mm} lata, lanceolata, acuminata, acuta, minus decurrentia, costa percurrente vel breviter excurrente; omnia marginibus integris, e basi usque apicem versus revolutis, cellulis quadratis, breviter rectangulis vel rhomboidalibus, 30μ longis, 14μ latis, parce chlorophyllosis, parietibus crassis, marginalibus angustioribus, linearibus. Folia perichaetialia minora, angustiora, acuta, costa breviter excurrente. Capsula in pedicello purpurascente circa 2^{cm} longo nutans pendulave, anguste subpyriformis, 3^{mm} longa, 0.9^{mm} crassa, sicca et matura sub orificio paulisper constricta, operculo convexo-conico. Annulus latus, triplex. Endostomii membrana elata, ciliis 2–3, appendiculatis. Sporae laeves, inaequales, aliae, magis numerosae, minores, diam. 11 μ, aliae, rariores, majores, diam. 18 μ. Planta mascula ignota. *Plate XIX.*

N. W. Montana: Mt. Lottie Stanton and Mt. Trilby, in the vicinity of Lake MacDonald, Flathead county, 1100–1800^{m} alt. (J. M. Holzinger and J. B. Blake, 1898).

Belongs to the group of *B. pseudotriquetrum* Schw., but is at first sight distinguished from all the other species of this group by its dimorphous leaves.

AULACOMNIUM PALUSTRE Schw. var. **dimorphum** Card. & Thér., var. nova.—Caulis superne innovationibus numerosis ramosissimus. Folia dimorpha, caulina elongata, acute acuminata, apice sinuato-subdenticulata, valde papillosa, ramea multo breviora, obtusa, integerrima, minus papillosa, interdum laevia.

Colorado: near Breckenridge, 175^{km} from Denver, alt. 3000^{m} (J. M. Holzinger, 1896).

A similar form is recorded by Mr. Dixon in his admirable *Handbook of British Mosses* 282.

AULACOMNIUM PALUSTRE Schw. var. **lingulatum** Card. & Thér, var. nova.—Gracile, formis majoribus *A. androgyni* simile. Folia lingulata, omnia obtusa, integra apiceve sinuolata.

Colorado: bog near Chamber's Lake (C. S. Crandall, 1894; herb. J. M. Holzinger).

Distinguished from the var. *imbricatum* Br. Eur. by its smaller size and its longer, not imbricated leaves.

Fontinalis subcarinata Card., sp. nova.—Mollis, lutescenti vel lurido-viridis. Caulis 15–20^{cm} longus, inferne denudatus, ramis elongatis, gracilibus, erectis, attenuatis, subcuspidatis. Folia mollia, quadrifaria, erecta, 4–5^{mm} longa, 1–2^{mm} lata, anguste lanceolata, longe acuminata, integerrima apiceve subdenticulata, plerumque sulco longitudinali medio distincte notata, lateralia subconduplicata, cellulis angustissimis longissimisque, alaribus paucis, parvis, parum distinctis, saepe subnullis. Caetera ignota. *Plate XXIII.*

Assiniboia: Cypress Hills, Battle Creek (Macoun, 1895. Sent as *F. Lescurii*).

This species belongs to the sect. MALACOPHYLLAE, and is closely allied to *F. seriata* Lindb., but differs from it by its plicate leaves, with less distinct alar cells.

FONTINALIS OBSCURA Card. Minn. Bot. Stud. **3**: 120. 1903.—In the note following the description of this species, the phrase: "It belongs to the section HETEROPHYLLAE" should be stricken out.

CLIMACIUM AMERICANUM Brid. var. **pseudo-Kindbergii** Card. & Thér., var. nova.—Habitu *C. Kindbergii* omnino simile, sed areolatione cum *C. americano* exacte congruit.

Missouri: Paw Paw Junction, on old log; Pleasant Grove, on wet bank (C. F. Bush, 1897 and 1899).

Contrary to the opinion of Dr. A. J. Grout, we think that *C. Kindbergii* cannot be distinguished specifically from *C. americanum*. We have specimens on which the distinctive characters become attenuated. The plant of which we make the var. *pseudo-Kindbergii* is just one of these forms.

LESCURAEA STRIATA Br. Eur. fasc. 46–47.

Labrador: Lack Harbour, on rocks (Rev. Arthur C. Waghorne).

This specimen, sent by Waghorne as *L. saxicola* Milde seems to us nearer to *L. striata*, on account of its leaves less imbricate and not homomallous; yet it differs from the European type by the shorter acumen of the leaves, distinctly denticulate towards the apex. *Pseudoleskea substriata* Best has much smaller leaves, but is also merely a form of *L. striata*.

Brachythecium subasperrimum Card. & Thér., sp. nova.—Laxe intricato-cespitosum, lutescenti-viride, nitidulum. Caulis gracilis, 3–6^{cm} longus, prostratus, radicosus, ramis inaequalibus attenuatis, ascendentibus irregulariter pinnatus. Folia caulina erecto-patentia, e basi decurrente deltoidea, sensim longe et anguste acuminata, vix plicatula, sublaevia, 1.8–2^{mm} longa, 0.75^{mm} lata, marginibus basi leniter reflexis, subintegris vel inferne parce denticulatis, costa angusta, 36μ basi crassa, medium versus evanida, cellulis mediis linearibus, angustis, 60–85μ longis, 6μ latis, basilaribus laxioribus, hyalinis, rectangulis vel subhexagonis; folia ramea oblonga, longe et anguste acuminata, nec deltoidea, nec decurrentia, distinctius plicatula, 1.6^{mm} longa, 0.5^{mm} lata, marginibus plus minus longe revolutis, superne minute denticulatis. Folia perichaetialia enervia, e basi ovata amplexicauli in acumen patulum vel reflexum, angustum, elongatum, integrum abrupte constricta. Capsula in pedicello purpureo scaberrimo, papillis altis dense obtecto, 1.5^{cm} longo, inclinata vel subhorizontalis, ovata, gibbosa, sicca sub ore leniter constricta, 1.7^{mm} longa, 0.8 mm crassa, operculo ignoto. Peristomium perfectum, ciliis appendiculatis. Sporae 15 μ crassae. Dioicum videtur (floribus masculis ignotis). *Plate XXIV.*

British Columbia: New Westminster (A. J. Hill, 1902; herb. C. F. Baker).

By the habit, dioicous inflorescence and very rough pedicel this moss stands near *B. asperrimum* (Mitt.) Kindb. and *B. Washingtonianum* Eaton, differing from both in having the leaves scarcely plicate, almost smooth, with the acumen much longer and narrower, and the borders very slightly denticulate or subentire and partly revolute.

Plagiothecium sulcatum Card. & Thér., sp. nova.—Monoicum, laxiuscule depresso-cespitosum, nitidulum. Caulis gracilis, repens, ramis ascendentibus, subarcuatis, circa 1 cm longis, compressulis. Folia ramea laxe subdisticho-homomalla, 1.2–1.5 mm longa, 0.4–0.5 mm lata, haud decurrentia, lanceolata, sensim longe acuminata, marginibus planis, e medio, nonnunquam e basi serrulatis, costa gemella, nunc brevi, nunc longiore et uno crure fere ad medium producta, cellulis anguste linearibus, 70–90 μ longis, 6 μ latis, inferioribus brevioribus, laxioribus, non porosis, 20–40 μ longis, 12–15 μ latis. Flores masculi prope femineos nascentes. Folia perichaetialia erecta, appressa, enervia, breviter ovata, apice rotundata, apiculo erecto brevi abrupto. Capsula in pedicello pallide purpurascente, tenui, flexuoso, 2 cm longo, subhorizontalis inclinatave, 2 mm longa, 0.7 mm crassa, subcylindrico-arcuata, vacua infra orificium contractula, tam juvenilis quam matura profunde sulcata, operculo obtuse conico. Annulus duplex. Peristomium perfectum, 0.42 mm altum, ciliis nodulosis, minute papillosis. Sporae laeves, diam. 12 μ. *Plate XXIV.*

N. Minnesota: on Fall Lake, near the foot of Kawasatchong Falls, 11 km north of Ely (J. M. Holzinger, 1897. Sent as *P. Muehlenbeckii* Br. Eur.).

This moss seems somewhat intermediate between *P. striatellum* Lindb. (*P. Muehlenbeckii* Br. Eur.) and *P. silesiacum* Br. Eur., differing from the former by its non-decurrent leaves, narrower at base, with a more distinct costa, its much longer cells, the basilar ones not porose, its more arcuate capsule, and the form of its perichaetial bracts; and from the latter by its capsule being deeply sulcate, even when young, and its more compressed branches. According to the description, *P. pseudosilesiacum* Sch. differs from our species by its much shorter pedicel (1 cm), and its ecostate leaves.

Plagiothecium Groutii Card. & Thér., sp. nova.—Monoicum, tenellum, nitidum, densiuscule depresso-cespitosum. Caulis tenuis, prostratus, ramis brevibus numerosis complanatis. Folia minuta, compressa, disticha erecto-patentia, 0.7–0.8^{mm} longa, 0.3–0.35^{mm} lata, haud decurrentia, oblongo-lanceolata, lateralia subcultriformia, breviter et latiuscule acuminata, margine plana, enervia, caulina subintegra vel obsolete denticulata, ramea in tertia parte superiore vel fere e medio minute sed distincte serrulata, cellulis mediis linearibus, angustissimis, 60–90μ longis, 6μ latis, superioribus brevioribus, inferioribus rectangulis, infimis majoribus subdilatatis. Folia perichaetialia oblonga, subito breviter cuspidata, subintegra vel ad basin acuminis sinuolata. Capsula in pedicello tenui, erecto, rubello, 1–1.5^{cm} longo, horizontalis, inclinata suberectave, minuta, ovata, vix 1^{mm} longa, 0.5–0.7^{mm} crassa, laevis, sicca sub orificio non constricta, collo brevi, operculo rostrato. Sporae irregulares, diam. 8–20μ. *Plate XXIV.*

Delaware: Hampstead, depression in base of a chestnut tree (A. J. Grout, 1899).

Allied to *P. elegans* Sch., but easily distinguished from it by the shorter leaves, more abruptly and broadly acuminate, the rameal rather strongly denticulate in the upper third, the perichaetial bracts subentire, with a shorter acumen, the smaller capsule, the beak of the lid thinner, and the monoicous inflorescence.

Amblystegium laxirete Card. & Thér., sp. nova.—E sectione *A. riparii*, sat robustum, fluitans, sordide viride, usque 10^{cm} longum, vage pinnatum, ramis inaequalibus patulis, attenuatis, laxe foliosis. Folia compressa, disticha patula, ovato-lanceolata, breviuscule acuminata, circiter 3^{mm} longa, 1^{mm} lata, marginibus planis integris, costa valida, 100μ basi crassa, longe ultra medium evanida, rete laxo, cellulis 60–80μ longis, 12μ latis, parietibus angustis, mollibus. Caetera ignota. *Plate XXV.*

Missouri: Monteer, in spring (B. F. Bush, 1899).

The leaves shorter acuminate, the longer and thicker costa, and chiefly the loose areolation, at first sight distinguish this moss from *A. riparium.* The last character also separates it from *A. vacillans* Sulliv. From *A. Kochii* Br. Eur. it differs by its larger leaves and its much stronger and longer nerve.

Amblystegium brevipes Card. & Thér., Minn. Bot. Stud.

3:124. 1903.—In the note following the description of this species, this phrase has been omitted in the printing: "Differs from *A. Kochii* Br. Eur. by its leaves much more shortly and less narrowly acuminate and by the short pedicel."

Hypnum malacocladum Card & Thér., sp. nova.—Monoicum, tenellum, molle, laxiusculum, lutescenti-viride. Caulis filiformis, prostratus, denudatus, ramis ascendentibus, circa 1^{cm} longis. Folia sat remota, mollia, concava, patentia, $0.8-1.1^{mm}$ longa, $0.4-0.5^{mm}$ lata, e basi valde constricta ovata vel oblonga, latissime et brevissime acuminata, apice rotundato vel subacuto, marginibus planis integris, costa tenui simplici ad medium vel ultra producta, interdum superne subfurcata, $35-40\mu$ basi crassa, cellulis alaribus rectangulis vel subhexagonis, hyalinis, sed auriculas distinctas non efformantibus, mediis sublinearibus, $35-70\mu$ longis, 7μ latis, superioribus brevioribus, rhomboidalibus, parietibus crassioribus. Folia perichaetialia erecta, longius acuminata, costata. Capsula in pedicello brevi crassiusculo purpurascente, $8-10^{mm}$ longo, horizontalis vel oblique erecta, brevis, gibbosa, $1-1.5^{mm}$ longa, 0.75^{mm} crassa, operculo convexo-apiculato. Annulus simplex, distinctus. Peristomium 0.4^{mm} altum, processus in carina anguste fissi, superne papillosuli; cilia 1–2. Sporae 12μ crassae. *Plate XXV.*

North America: Without locality or name of collector, in herb. L. Debat.

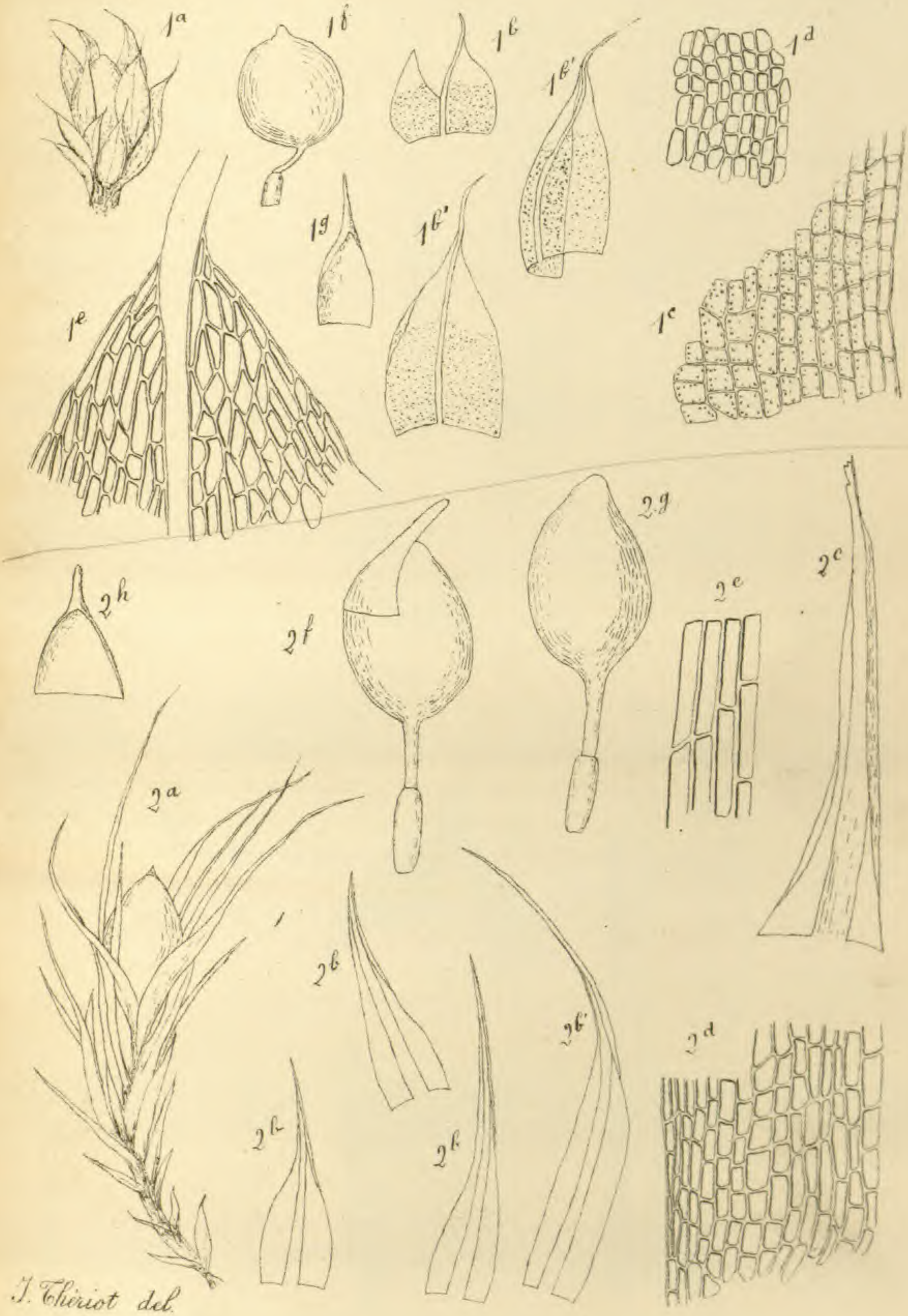
This species somewhat resembles *H. Goulardi* Sch., from which it differs by its longer leaves with a single long costa. It is also distinguished from *H. Closteri* Aust. (*Amblystegium Holzingeri* Ren. & Card.) by its greater size and longer costa.

CHARLEVILLE AND LE HÂVRE, FRANCE.

EXPLANATION OF PLATES XVI–XXV.

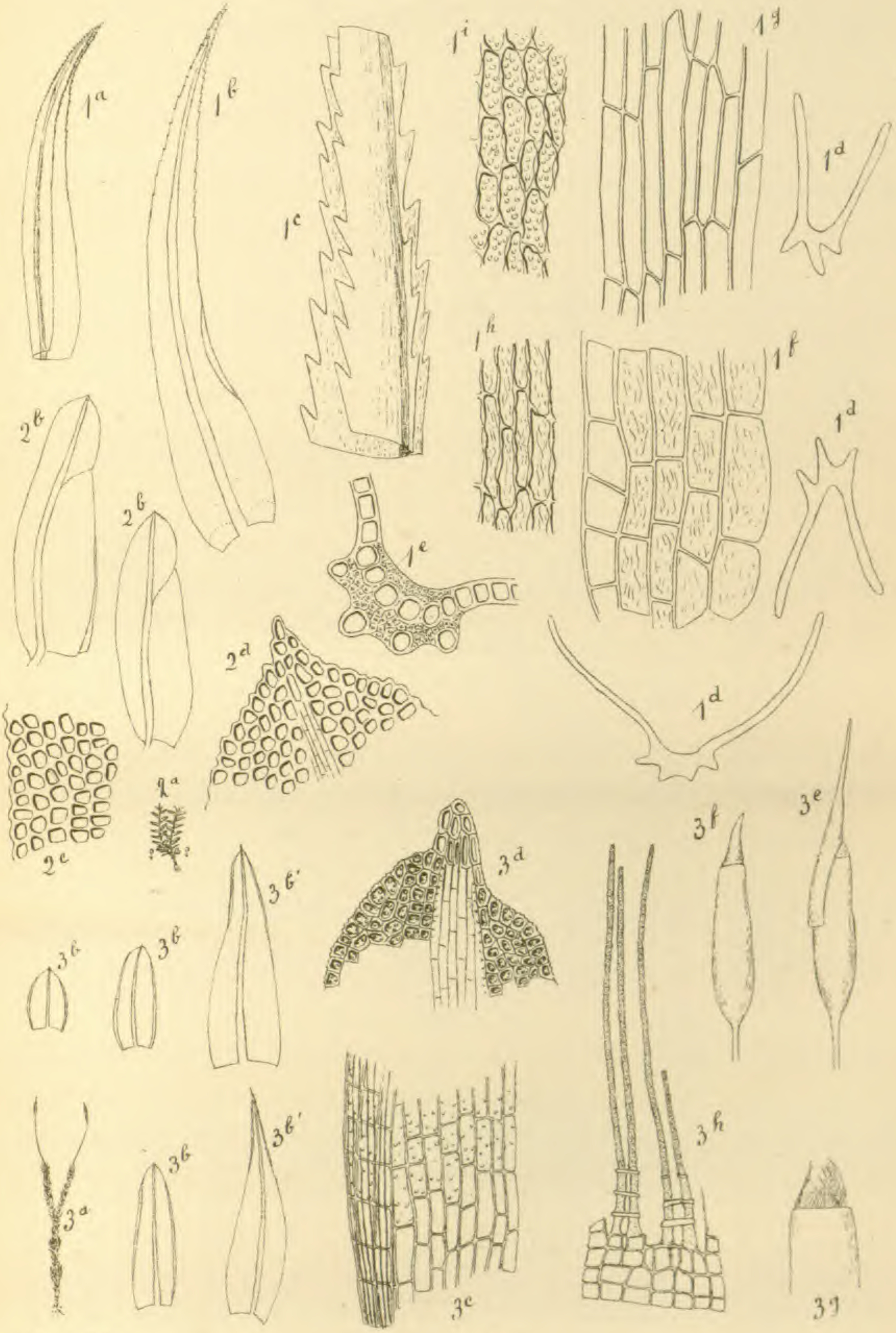
Plate XVI.—1. *Phascum hyalinotrichum.* *a*, entire plant × 17; *b*, lower leaf × 26; *b'*, *b'*, upper leaves × 26; *c*, basal areolation × 135; *d*, areolation in the middle × 135; *e*, areolation in the upper part × 135; *f*, capsule unripe × 26; *g*, calyptra × 26.—2. *Pleuridium Bakeri.* *a*, entire plant × 17; *b, b, b*, leaves × 26; *b'*, perichaetial leaf × 26; *c*, apex of a leaf × 90; *d*, basal areolation × 200; *e*, areolation in the middle × 270; *f*, capsule with calyptra, in moist state × 26; *g*, capsule in moist state × 26; *h*, calyptra × 26.

Plate XVII.—1. *Dicranum alatum.* *a, b*, leaves × 13; *c*, part of a leaf



J. Thériot del.

CARDOT & THÉRIOT on MOSSES.



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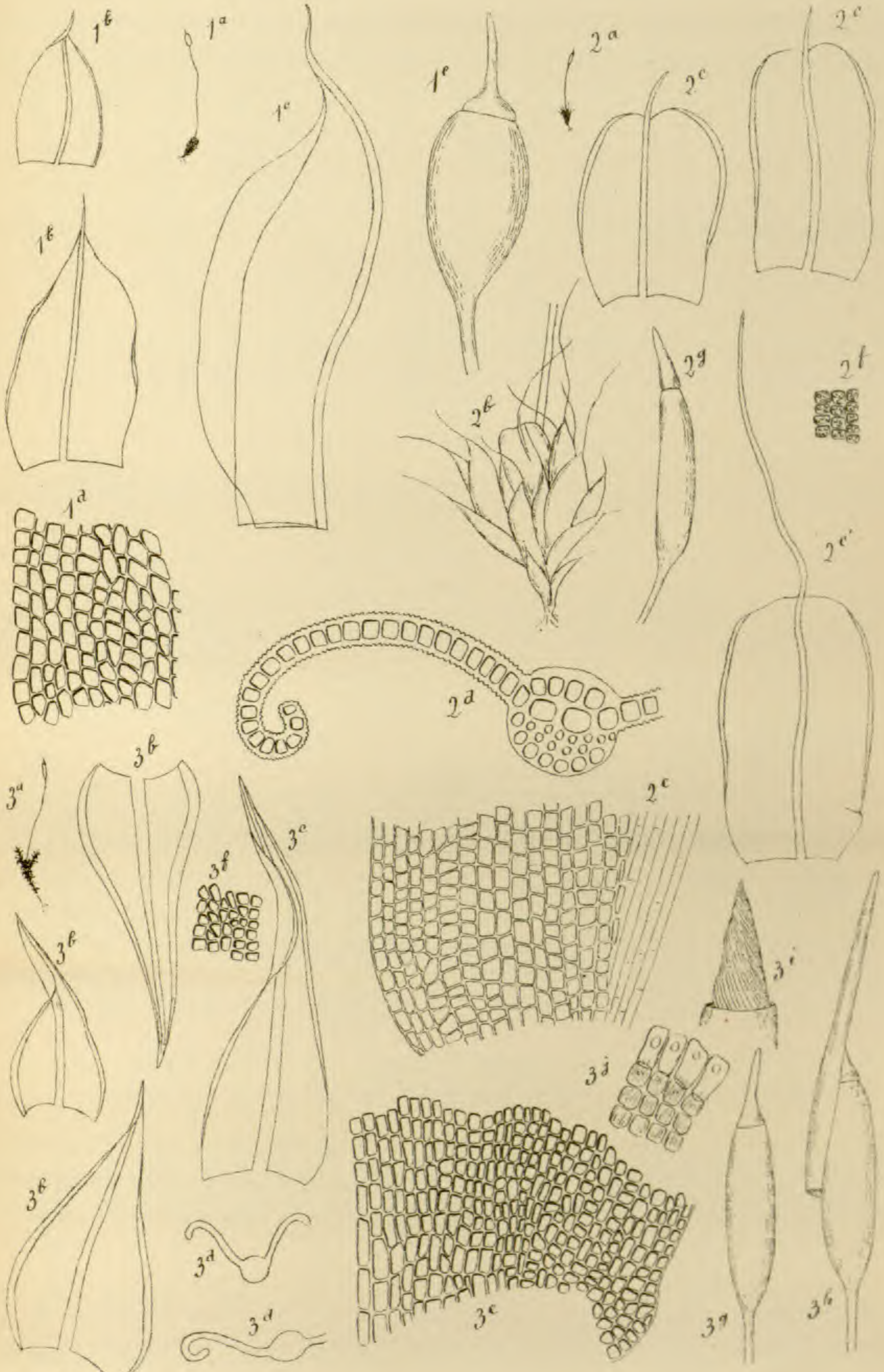

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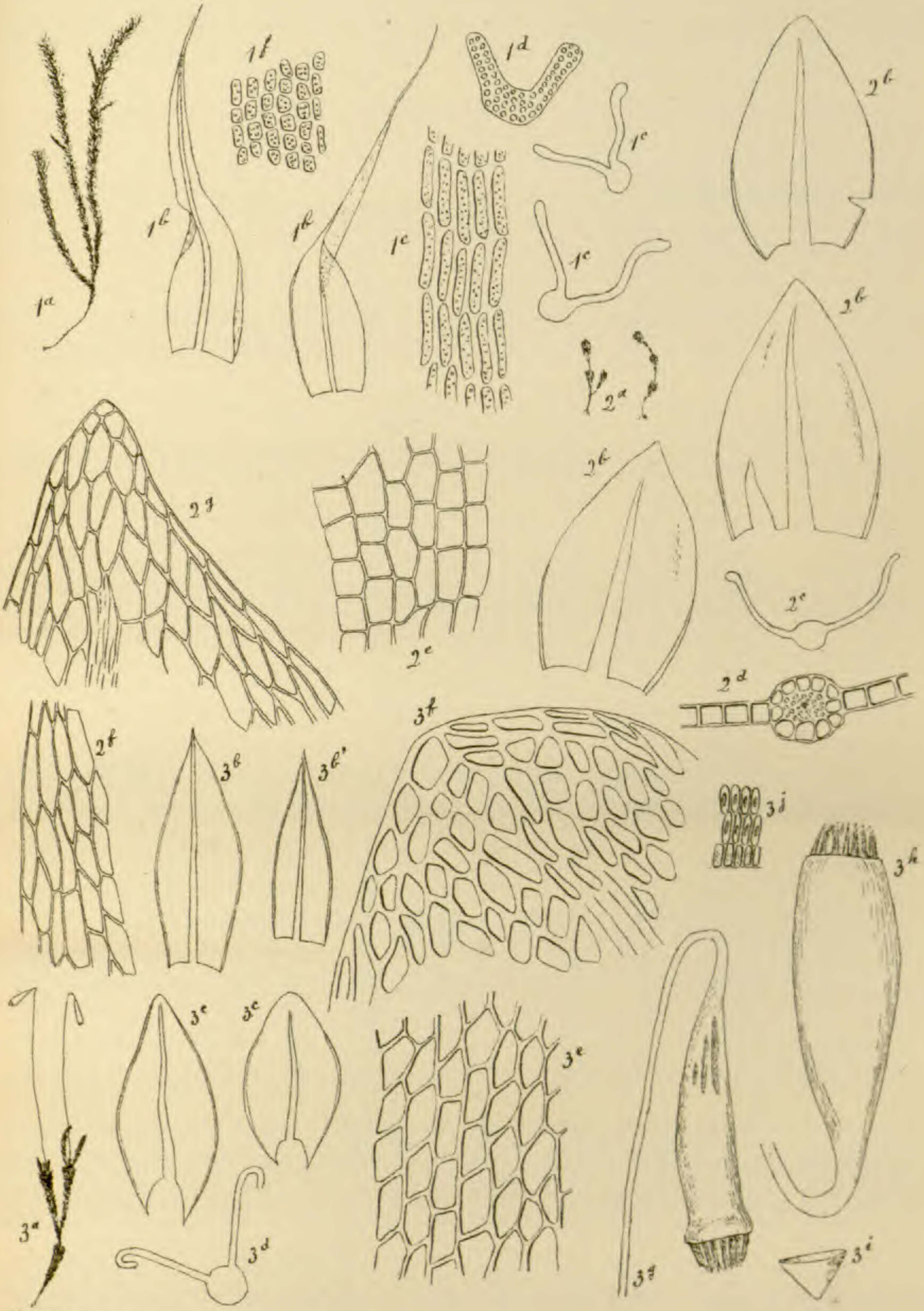

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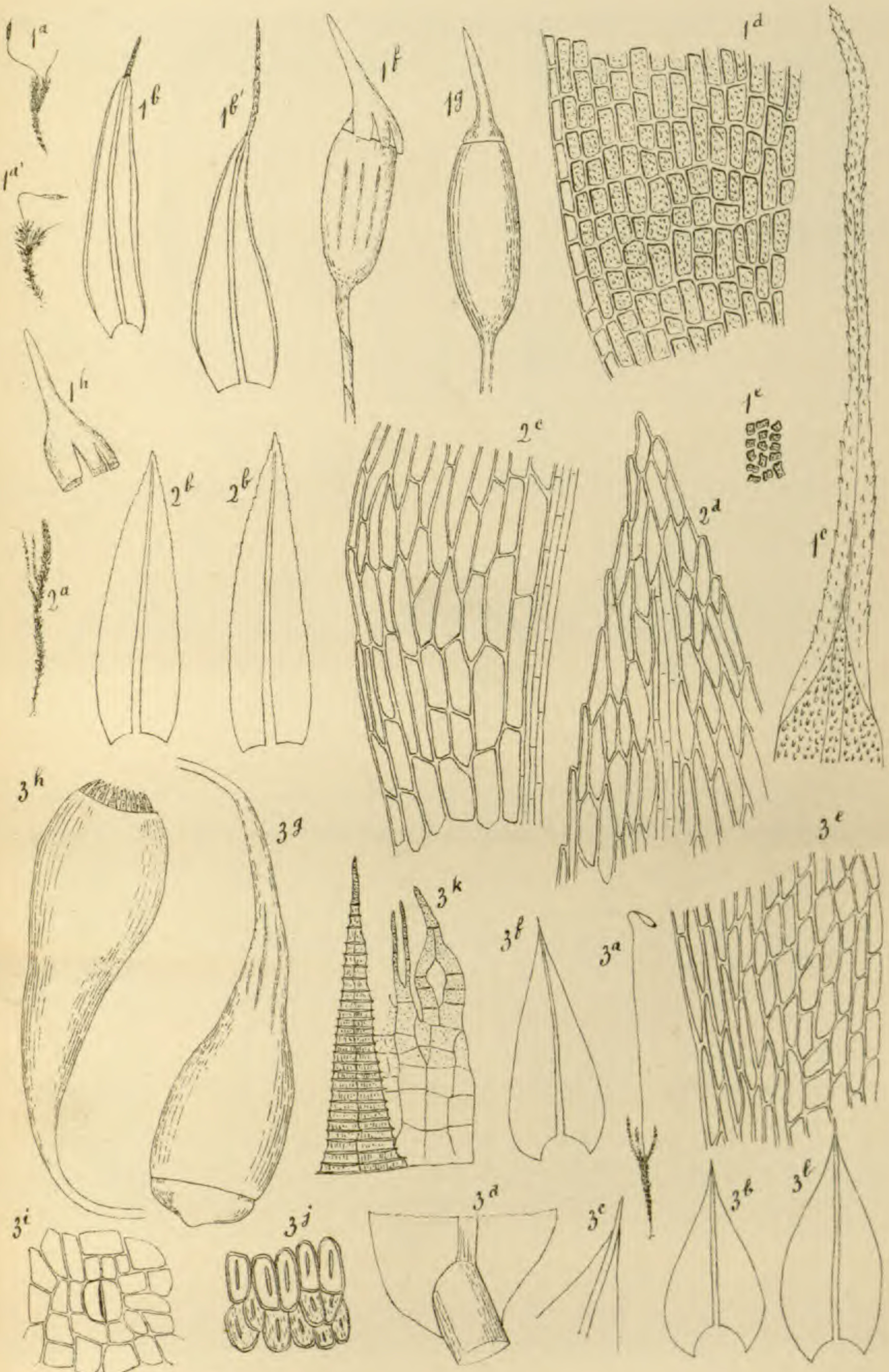

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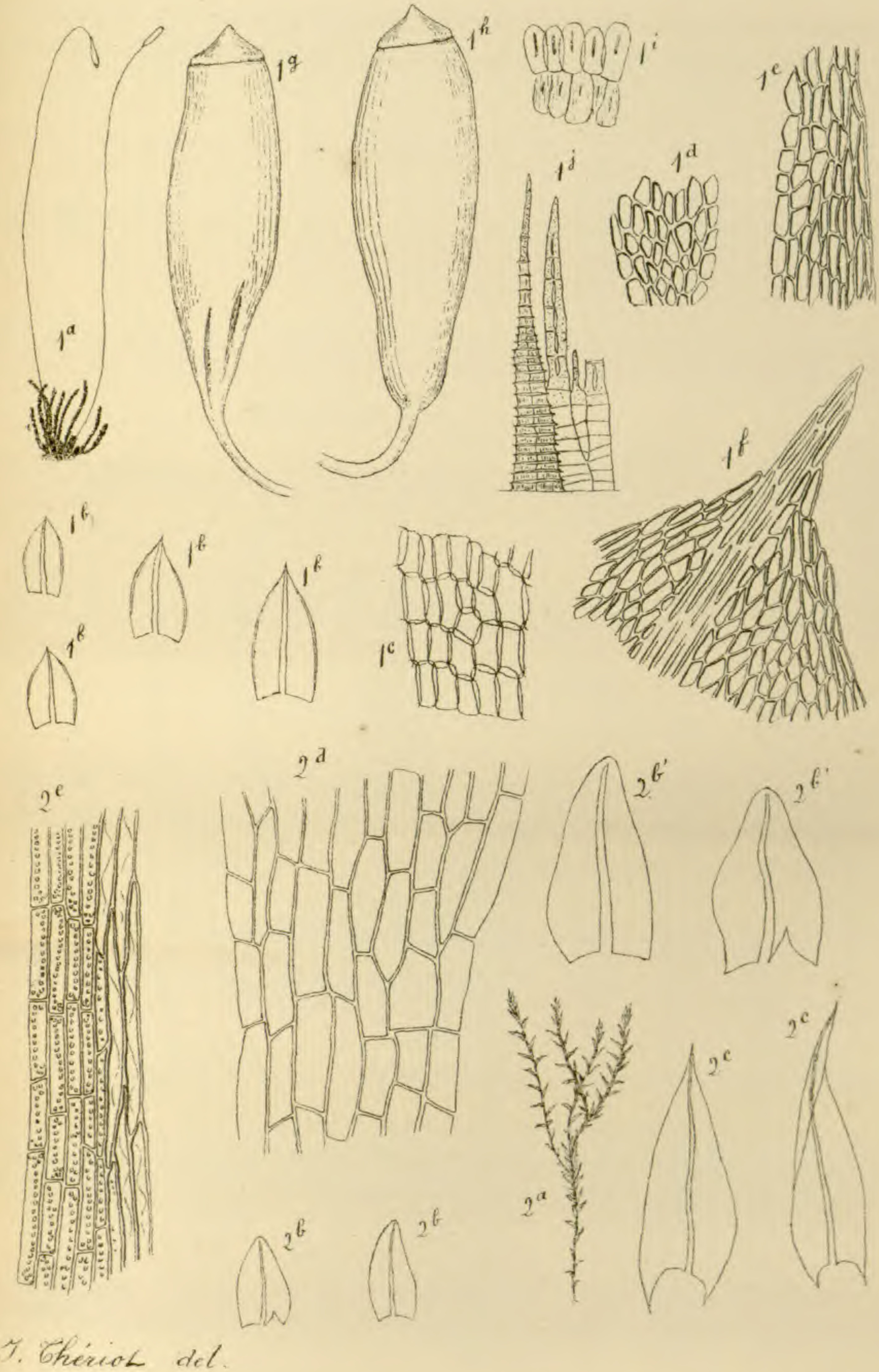

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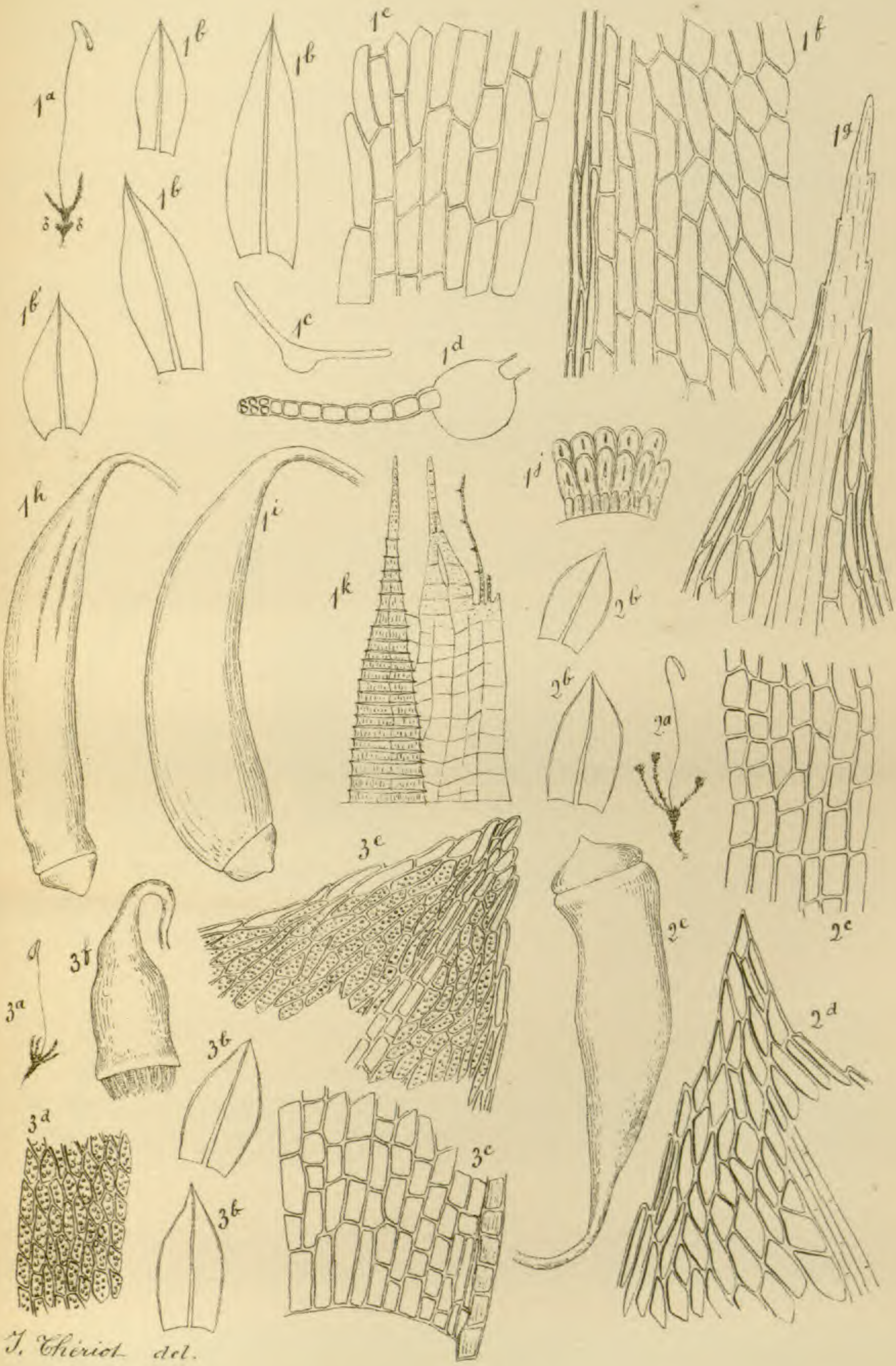

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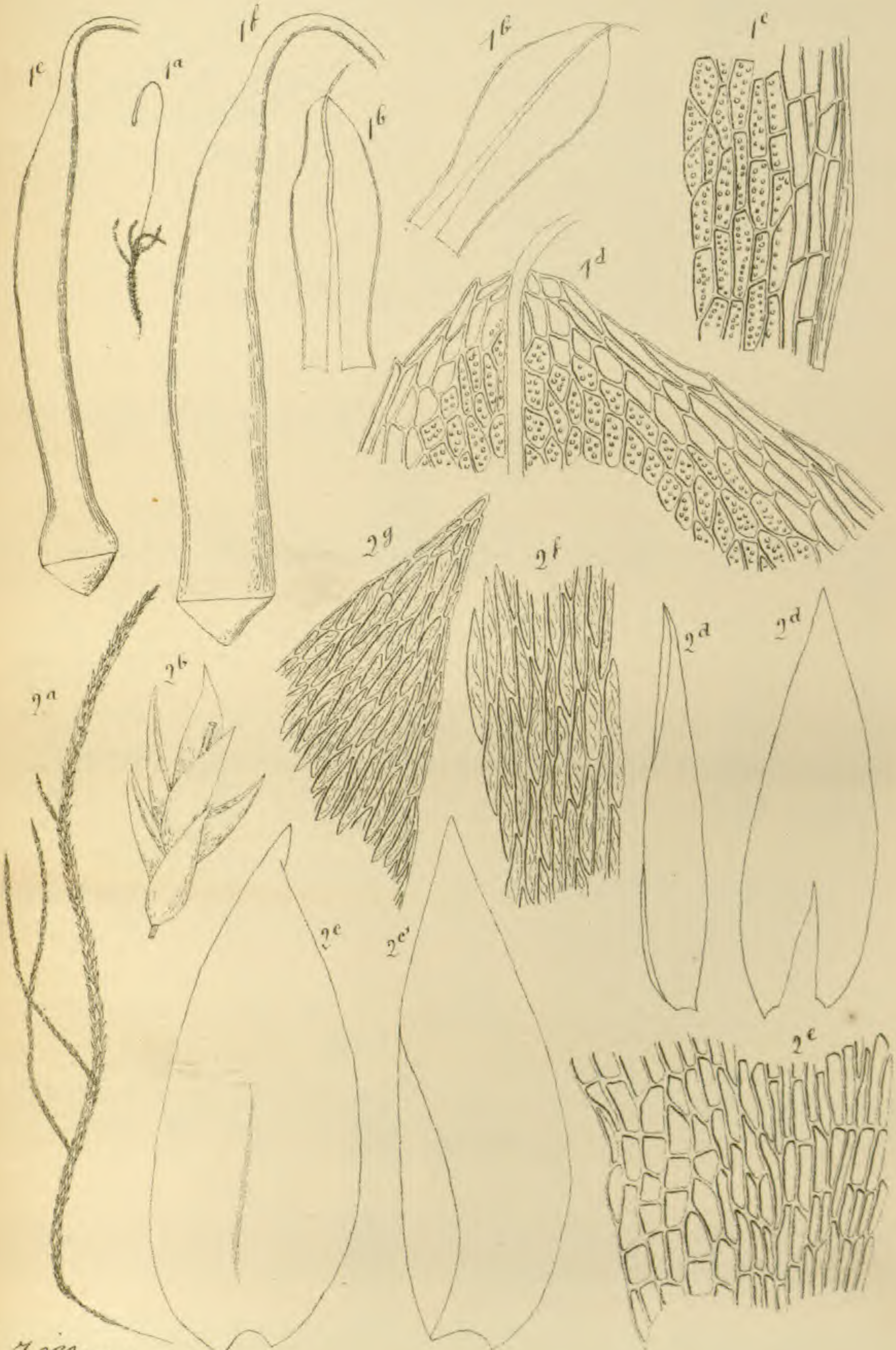

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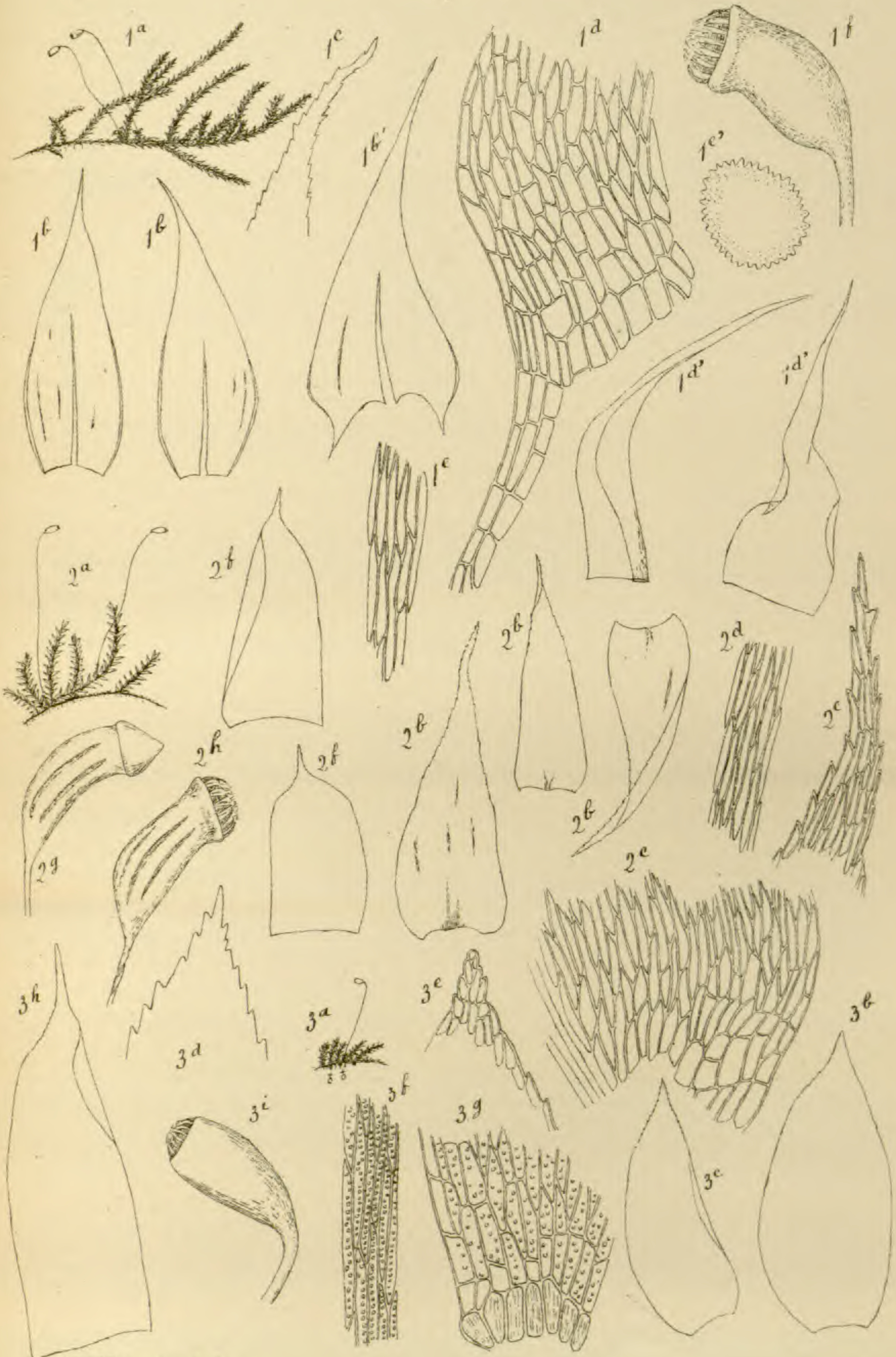

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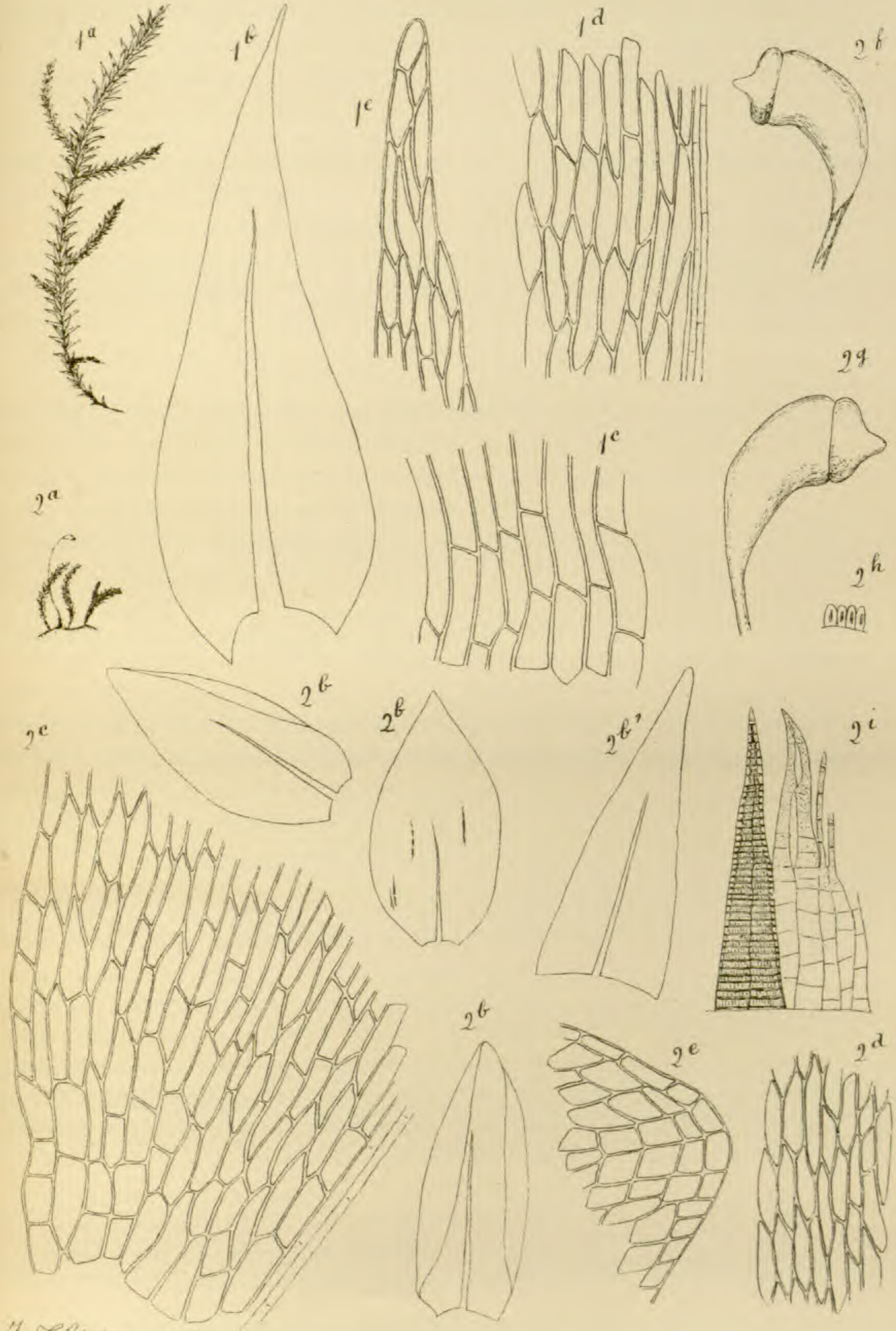

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CARDOT & THÉRIOT on MOSSES.

× 90; *d, d, d*, transverse sections of a leaf × 90; *e*, transverse section of the costa × 200; *f*, alar cells × 200; *g*, basal areolation × 200; *h*, middle cells × 200; *i*, areolation in the upper part × 200.—2. *Fissidens Bushii.* *a*, entire plant, nat. size; *b, b*, leaves × 26; *c*, marginal areolation in the middle × 270; *d*, areolation in the upper part × 270.—3. *Desmatodon Bushii.* *a*, entire plant, nat. size; *b, b, b*, leaves × 13; *b′, b′*, perichaetial leaves × 13; *c*, basal areolation × 200; *d*, areolation in the upper part × 200; *e*, capsule with calyptra × 13; *f*, capsule in dry state × 13; *g*, peristome × 26; *h*, portion of the peristome × 200.

Plate XVIII.—1. *Pottia nevadensis.* *a*, entire plant, nat. size; *b, b*, leaves × 26; *c*, perichaetial leaf × 26; *d*, areolation in the middle of a leaf × 135; *e*, capsule in moist state × 13.—2. *Barbula macrotricha.* *a*, entire plant, nat. size; *b*, lower part of the same × 13; *c, c*, lower leaves × 26; *c′*, upper leaf × 26; *d*, transverse section of a leaf × 200; *e*, basal areolation × 135; *f*, middle cells × 135; *g*, capsule × 13.—3. *Barbula Bakeri.* *a*. entire plant, nat. size; *b, b, b*, leaves × 13; *c*, perichaetial leaf × 13; *d, d*, transverse section of the leaf × 90; *e*, basal areolation × 200; *f*, middle cells × 200; *g*, capsule in moist state × 13; *h*, capsule with calyptra × 13; *i*, peristome × 30; *j*, portion of the persistent annulus × 200.

Plate XIX.—1. *Grimmia cognata.* *a*, entire plant, nat. size; *b, b*, leaves × 13; *c, c*, transverse sections of the leaf × 60; *d*, transverse section of the leaf in the upper part × 80; *e*, basal areolation × 270; *f*, areolation in the upper part × 270.—2. *Bryum anceps.* *a*, entire plant, nat. size; *b, b, b*, leaves × 26; *c*, transverse section of the leaf × 26; *d*, transverse section of the nerve × 195; *e*, basal areolation × 135; *f*, marginal areolation in the middle × 135; *g*, areolation in the upper part × 135.—3. *Bryum dimorphophyllum.* *a*, entire plant, nat. size; *c, c*, lower leaves × 13; *b*, upper leaf × 13; *b′*, perichaetial leaf × 13; *d*, transverse section of the leaf × 60; *e*, areolation in the middle × 270; *f*, areolation of the upper part × 270; *g*, capsule ripe and deoperculate, in dry state × 73; *h*, the same in moist state × 13; *i*, lid × 13; *j*, portion of the annulus × 135.

Plate XX.—1. *Grimmia Hendersoni.* *a*, entire plant, in dry state, nat. size; *a′*, the same, in moist state, nat. size; *b*, lower leaf × 13; *b′*, upper leaf × 13; *c*, point of the same × 60; *d*, basal areolation × 200; *e*, middle cells × 200; *f*, capsule with calyptra, in dry state × 13; *g*, capsule operculate, in moist state × 13.—2. *Webera Debati.* *a*, entire plant, nat. size; *b, b*, leaves × 32; *c*, basal areolation × 135; *d*, areolation of the upper part × 135.—3. *Webera chlorocarpa.* *a*. entire plant, nat. size; *b, b*, leaves × 13; *c*, apex of a leaf × 32; *d*, base of a leaf × 32; *e*, marginal areolation in the middle × 135; *f*, perichaetial leaf × 13; *g*, capsule in dry state × 13; *h*, capsule deoperculate, in moist state × 13; *i*, capsular membrane with a stomata × 135; *j*, portion of the annulus × 135; *k*, portion of the peristome × 90.

Plate XXI.—1. *Bryum polycladum.* *a*, entire plant, nat. size; *b, b, b, b*, leaves × 13; *c*, basal areolation × 135; *d*, middle cells × 135; *e*, marginal areolation in the middle × 135; *f*, areolation of the apex × 135; *g*, capsule in dry state × 13; *h*, the same in moist state × 13; *i*, portion of the annulus × 135; *j*, portion of the peristome × 90.—2. *Bryum distantifolium.* *a*, entire plant, nat. size; *b, b*, lower leaves × 13; *b', b'*, the same × 26; *c, c*, upper leaves × 13; *d*, basal areolation × 135; *e*, marginal areolation in the middle × 135.

Plate XXII.—1. *Bryum camptocarpum.* *a*, entire plant, nat. size; *b, b, b*, stem-leaves × 13; *b'*, branch-leaf × 13; *c*, transverse section of a leaf × 60; *d*, the same × 135; *e*, basal areolation × 135; *f*, marginal areolation in the middle × 135; *g*, apex of the leaf × 135; *h*, capsule in dry state × 13; *i*, the same, in moist state × 13; *j*, portion of the annulus × 135; *k*, portion of the peristome × 90.—2. *Bryum subdrepanocarpum.* *a*, entire plant, nat. size; *b, b*, leaves × 13; *c*, basal areolation × 135; *d*, areolation of the upper part × 135; *e*, capsule in dry state × 13.—3. *Bryum brevicuspis.* *a*, entire plant, nat. size; *b, b*, leaves × 13; *c*, basal areolation × 135; *d*, middle cells × 135; *e*, areolation of the apex × 135; *f*, capsule in dry state × 13.

Plate XXIII.—1. *Bryum sanguilentum.* *a*, entire plant, nat. size; *b, b*, leaves × 13; *c*, marginal areolation in the middle × 135; *d*, areolation of the apex × 135; *e*, capsule in dry state × 13; *f*, the same in moist state × 13.—2. *Fontinalis subcarinata.* *a*, entire plant, nat. size; *b*, portion of the stem × 4; *c*, stem-leaf × 13; *c'*, lateral stem-leaf × 13; *d, d*, branch leaves × 13; *e*, basal areolation × 135; *f*, areolation in the middle × 135; *g*, areolation of the apex × 135.

Plate XXIV.—1. *Brachythecium subasperrimum.* *a*, entire plant, nat. size; *b, b*, branch-leaves × 26; *b'*, stem-leaf × 26; *c*, apex of a branch-leaf × 60; *d*, basal areolation of a stem-leaf × 200; *e*, middle cells × 200; *d', d'*, perichaetial leaves × 26; *e'*, transverse section of the pedicel × 60; *f*, capsule ripe × 13.—2. *Plagiothecium sulcatum.* *a*, entire plant, nat. size; *b, b, b*, leaves × 26; *c*, basal areolation × 135: *d*, middle cells × 135; *e*, apex of a leaf × 135; *f, f*, perichaetial leaves × 26; *g*, capsule unripe in dry state × 13; *h*, capsule ripe, in dry state × 13.—3. *Plagiothecium Groutii.* *a*, entire plant, nat. size; *b*, stem-leaf × 26; *e*, apex of a stem-leaf × 135; *c*, branch-leaf × 26; *d*, apex of a branch-leaf × 135; *f*, middle cells × 200; *g*, basal areolation × 200; *h*, perichaetial leaf × 26, *i*, capsule ripe, in moist state × 13.

Plate XXV.—1. *Amblystegium laxirete.* *a*, entire plant, nat. size; *b*, leaf × 26; *c*, basal areolation × 200; *d*, areolation in the middle × 200; *e*, areolation of the apex × 200.—2. *Hypnum malacocladum.* *a*, entire plant, nat. size; *b, b, b*, leaves × 32; *b'*, perichaetial leaf × 32; *c*, basal areolation of a leaf × 270; *d*, areolation in the middle × 270; *e*, areolation of the apex × 270; *f*, capsule unripe, in dry state × 15; *g*, the same, in moist state × 15; *h*, portion of the annulus × 90; *i*, portion of the peristome × 90.

BRIEFER ARTICLES.

PHYSICAL PROPERTIES OF BOG WATER.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LVII.

THAT many plants growing typically in the peat bogs of the northern United States and Canada exhibit the same structural characters as do those occurring in very dry soils of the same region has long been known by students of plant distribution. But the question why these so-called xerophytic swamps differ so entirely in the nature of their vegetation from the drained or river swamps near by has never received a decisive answer. The idea is generally current among workers in this field that the factor determining the nature of the vegetation in bog areas lies, somehow, in the nature of the soil. Schimper states clearly that only xerophytes thrive in peat bogs, "because of the humous acids in the soil."[1] In another place (*l. c.*, p. 4) he says that a soil may be "physiologically dry" for various reasons, among which are (1) "abundance of soluble salts" and (2) "richness of the soil in humous acids." In still another place (*l. c.*, p. 657) the same writer describes the sphagnum bog ("high moor") as having a soil solution which "contains humates of alkalis in solution besides the humous acids," in which character these bogs differ from the "meadow moors," or grassy marshes.

It becomes evident immediately that if the "physiological dryness" of the bog be due to humous acids or humous salts, these substances may check absorption of water by plants either physically—by high osmotic pressure—or chemically—by toxic or stimulation effects. The question as to whether or not bog waters have a concentration appreciably higher than those of river and lake swamps near by should be easy of answer. Therefore, in 1901, the writer began a series of determinations of the osmotic pressure of the bog waters which were available. By the well-known Beckmann apparatus, determinations of the lowering of the freezing point were made, and from the data thus obtained the approximate osmotic pressure of the solution at 25° C. was calculated.[2]

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[1] SCHIMPER, A. F. W., Plant geography upon a physiological basis. Translated by W. R. Fisher. Oxford. 1903. P. 8.

[2] For methods of procedure see LIVINGSTON, B. E., The rôle of diffusion and osmotic pressure in plants, part I, chap. VI. Chicago. 1903.

Bog water has now been studied from a number of widely distant localities, namely: from Aetna and Millers, Ind. (at the southern end of Lake Michigan); from Oconomowoc, Wis.; from Grand Rapids, Mich.; from Ann Arbor, Mich.; from Toms River, N. J.; and from near Port Jervis, N. J. The results obtained are tabulated below, together with a brief characterization of the flora of the bogs. Data for $\frac{1}{100}$ sea water are given for comparison. In the table, lowering of the freezing point, due to dissolved substances, is given in degrees centigrade. The osmotic pressure is given in millimeters of a mercury column and also in terms of M, which represents the pressure developed in a molecular solution of any non-electrolyte.

TABLE OF PHYSICAL PROPERTIES OF NATURAL WATERS.

SOURCE OF WATER	NATURE OF VEGETATION	LOWERING OF FREEZING POINT (degrees C.)	CALCULATED OSMOTIC PRESSURE	
			Mm. of Hg	M
Drained swamps of Hackensack River, N. J.	....	0.005	50.075	$\frac{29}{10000}$
New York city supply (Croton and Bronx Rivers)	....	0.005	50.075	$\frac{29}{10000}$
Chicago city supply (Lake Michigan).	....	0.01	100.15	$\frac{58}{10000}$
Grand River, Grand Rapids, Mich.	....	0.01	100.15	$\frac{58}{10000}$
Aetna, Ind.	Rhus Vernix, Drosera.	0.01	100.15	$\frac{58}{10000}$
Millers, Ind.	Larix, Rhus Vernix.	0.005	50.075	$\frac{29}{10000}$
Oconomowoc, Wis.[3]	Typical Larix swamp.	0.02	200.30	$\frac{117}{10000}$
Grand Rapids, Mich.	Larix, Sphagnum, Eriophorum, Oxycoccus.	0.015	150.225	$\frac{187}{10000}$
Ann Arbor, Mich.:				
First Lake Bog[4]	Larix, Chamaedaphne, Sphagnum, Aronia.	0.005	50.075	$\frac{29}{10000}$
West Lake Bog[5]	Sphagnum, Chamaedaphne, Potentilla palustris, Salix.	0.0125	125.188	$\frac{73}{10000}$
Toms River, N. J.	Chamaecyparis, Sphagnum, Chamaedaphne, Sarracenia. Oxycoccus.	Average of 13 tests, 0.0057 Max., 0.017 Min., 0.0025	57.086 170.26 25.038	$\frac{33}{10000}$ $\frac{99}{10000}$ $\frac{15}{10000}$
Port Jervis. N. J.[6]	Aronia, Chamaedaphne.	0.006	60.090	$\frac{35}{10000}$
$\frac{1}{100}$ sea water	....	0.0225	250.075	$\frac{146}{10000}$

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[3] This water was obtained for me by Dr. H. C. Cowles.

[4] This lake and its bog are described in detail by WELD, L. H., Botanical survey of the Huron River Valley. II. A peat bog and morainal lake. BOT. GAZ. **37**: 36–52. 1904.

[5] This lake and bog are described by REED, H. S., A botanical survey of the Huron River Valley. I. The ecology of a glacial lake. BOT. GAZ. **34**: 125–139. 1902. These Ann Arbor waters were obtained by the kindness of Mr. E. N. Transeau.

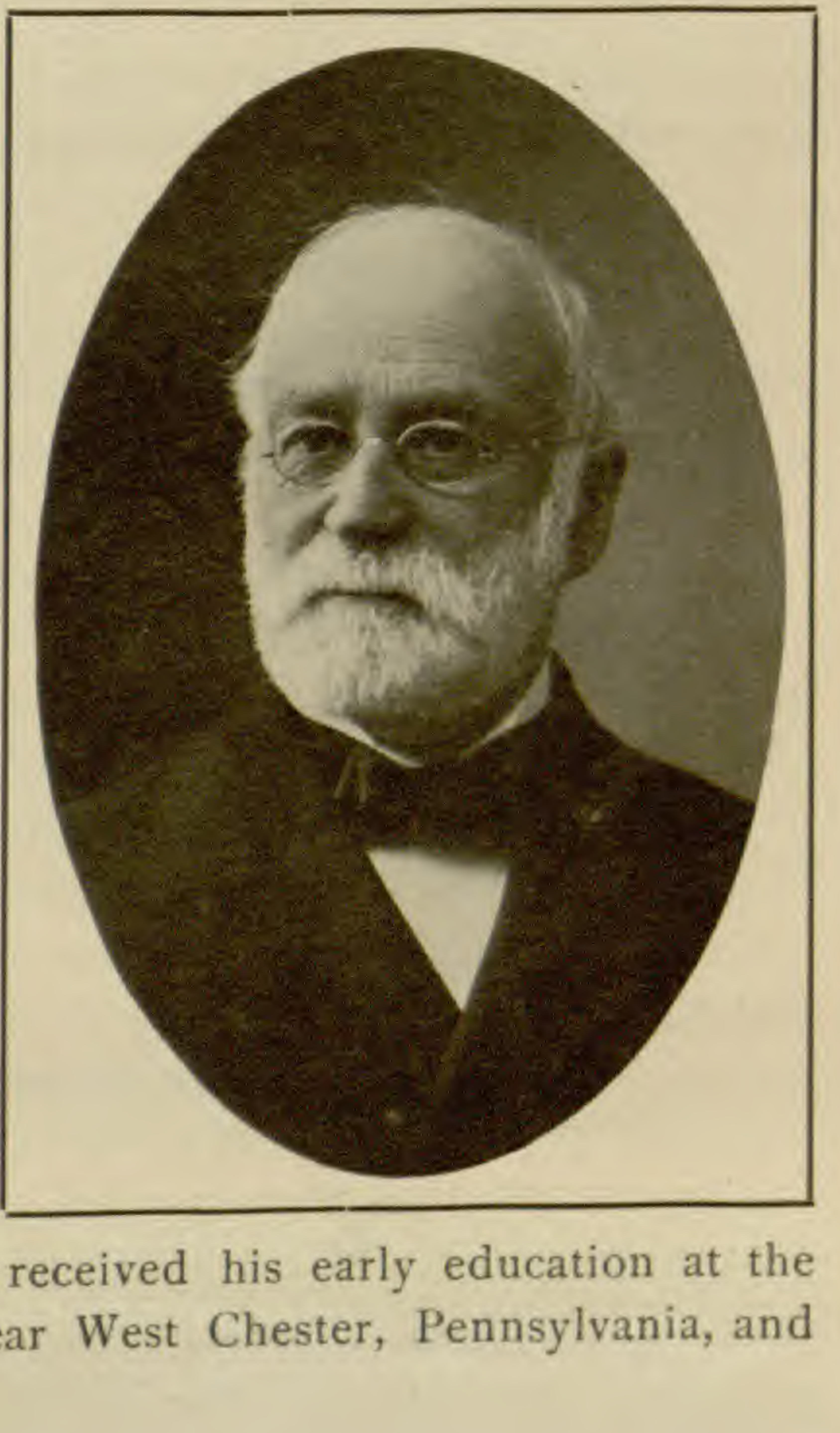
[6] This water was obtained through the kindness of Dr. C. C. Curtis, of Columbia University.

The tests here recorded were made in the summer, autumn, and winter, several bogs being studied both in the dryest part of the former season and in the middle part of the latter. These last-named tests showed practically no difference in osmotic pressure corresponding to the season. Keeping the bottled water for months and even years does not alter its osmotic pressure appreciably.

The conclusion to be drawn from the material just presented is simply that *bog waters do not have an appreciably higher concentration of dissolved substances than do the streams and lakes of the same region.* Thus we are driven to the idea that if there is any property of bog water which prevents ordinary swamp plants from growing therein, this property must rest upon the chemical nature of the very small amounts of dissolved substances present. The nature and physiological properties of these bodies the writer is now studying.—BURTON EDWARD LIVINGSTON, *Hull Botanical Laboratory, The University of Chicago.*

WILLIAM M. CANBY.

(WITH PORTRAIT)



THE announcement of the death of Mr. William M. Canby, of Wilmington, Delaware, will come as a personal loss to botanists throughout the country, for he has been as well the intimate friend of many of them as a most generous contributor to all our public and private herbaria. Although Mr. Canby had not been in the best of health for some time, his condition was not such as to cause any serious alarm to his friends. On February 23 he went south for rest and change, but he contracted a severe cold, which was followed by a chill, and died very suddenly March 10, at North Augusta, South Carolina.

William Marriott Canby was born in Philadelphia, Pennsylvania, March 17, 1831, thus being nearly 73 years of age at the time of his death. He received his early education at the Friends School at Westtown, near West Chester, Pennsylvania, and from private tutors.

Although to most readers of this sketch Mr. Canby is known only as a botanist or as a collector, he was all his life a most industrious business man. The mere mention of the various enterprises in which he was engaged shows that he was a man of much importance in his community. For many years he was engaged in railroad business as receiver, president, or director, holding the last position in connection with one of the branches of the B. & O. Railway at the time of his death. He was also a director in various banking and trust companies, and for twenty-four years had been president of the Wilmington Savings Fund Society, one of the most substantial institutions of his home city. As a member and president of the Park Commission of Wilmington for more than twenty years, he rendered most valuable service to the community, and the beautiful park system of Wilmington is said to be largely due to his efforts. In politics he was a Republican, but was elected to the city council as an independent for the purpose of doing away with public graft and a corrupt political ring.

Mr. Canby early developed a love for botany, and as long ago as 1858 began collecting plants, and for the remainder of his life was an enthusiastic collector, distributing his material with a lavish hand to those who showed even the least interest in it. He traveled extensively, and always went prepared to care for rare or strange plants which he might find. His knowledge of the plant life of his own state and the "eastern shore" region of Maryland was very great. One of my pleasantest recollections of him is in connection with an excursion of several days in this region. His knowledge of the plants, their haunts, their names, their peculiarities, astonished me. His method of work was that of an enthusiast. Stopping at some good collecting ground, he would spend several hours gathering specimens, reaching the station just in time to make his train, spending the next hour or so in putting away his plants, and ready to repeat the operation at the next station.

His most important work of this kind was that as botanist in charge of the Northern Transcontinental Survey of 1882-3. This was a survey undertaken by the Northern Pacific Railway Company, which planned a most extensive study of the natural history resources of the region through which the road passes. The railway company, however, finally withdrew its support, and the survey was never completed. In the meantime a great mass of material was collected containing many new species, and the specimens were afterwards freely distributed to all the large private and public herbaria.

The Canby herbarium was for many years one of the most important herbaria in the country and was always placed at the service of monographers who wished to study it. It not only represented the forty-five years of collecting of its founder, but was increased through extensive exchanges and purchases. For years Mr. Canby bought every collection offered for sale. It was largely through the efforts of a few men, one of whom was Mr. Canby, that Parry and Palmer made their trip to San Luis Potosi, Mexico, in 1877, which yielded such an astonishing number of new plants. He also aided Mr. Pringle in his early struggles in Mexico.

In 1893 his herbarium numbered some 30,000 specimens, and was about this time sold to the College of Pharmacy of New York city, where it now remains. He had no sooner disposed of his herbarium than he began, with all the enthusiasm of a young man, to build up a new one, giving it to the Natural History Society of Delaware at Wilmington. This herbarium contains about 15,000 species at the present time. Although Mr. Canby was a very keen and able botanist, he rarely described new plants, usually contenting himself with pointing out differences and permitting specialists to publish the results of his discoveries.

Quite a number of plants have been named in his honor. The genus Canbya, though named by Dr. C. C. Parry, was described by Dr. Asa Gray in the Proceedings of the American Academy in 1876. Among the species I recall the following: *Angelica Canbyi* C. & R., *Crataegus Canbyi* Sargent, *Hydrocotyle Canbyi* C. & R., *Ligusticum Canbyi* C. & R., *Lobelia Canbyi* Gray, *Pachystima Canbyi* Gray, *Pedicularis Canbyi* Gray, *Peucedanum Canbyi* C. & R.

Although Mr. Canby never wrote any extensive work, he was an occasional contributor to botanical journals, and some eleven articles in this journal were furnished by him. Mention should be made of his very valuable contributions to the study of insectivorous plants, especially in connection with Dionaea and Darlingtonia. Darwin made free use of his observations and refers to his work in high terms. In his writings he always referred to Mr. Canby as "Dr. Canby," although I belive he never received a degree of any kind. He once told the writer that one of our American colleges had offered him the degree of Ph.D., but he declined it.—J. N. Rose, *U. S. National Herbarium, Washington, D. C.*

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Notes and descriptions of species of Eriogonum. Contr. Nat. Herb. **4**: 185–187. 1893.

George Vasey: a biographical sketch (with J. N. Rose). BOT. GAZ. **18**: 170–176. 1893.

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A new Silphium. BOT. GAZ. **27**: 139–140. 1899.

Coreopsis involucrata on the Atlantic coast. Rhodora **2**: 34. 1900.

ANATOMY OF COTYLEDONS.

LAST year the writer published a short article[1] describing some observations on the anatomy of cotyledons with a comparison of cotyledons and foliage leaves in the Papilionaceae. In that paper it was stated that the study would be continued to other plant families. This has been done in the case of representative species of the Cruciferae and Ranunculaceae by two graduate students, Miss Neata Clark and Miss Martha Phelps. A further investigation will be made in these same families and with other families.

In the Ranunculaceae and Cruciferae studied there is not as great a difference in structure between cotyledons and leaves as was seen in the Papilionaceae. Thus the form of the epidermal cells is frequently the same in the two structures. There are, however, some differences in the arrangement and number of stomata, these being sometimes absent from one surface of the leaf, but present on both surfaces of the cotyledon. The trichome structures are frequently absent from the cotyledon when present on the leaf, and sometimes when present on the cotyledon they are of special form.

[1] University of Colorado Studies **1**: 239–243. 1903.

The stalks of the cotyledon and leaf are quite different in anatomical structure. In all cases the vascular tissue of the cotyledon stalk is placed in the center, and is for the most part organized as a single vascular bundle. In the leaf stalk the vascular tissue has the usual arrangement, the bundles being three or more in number and placed in the form of a circle or a partial circle or ellipse.

In these families, as in the Papilionaceae, there seems to be no relation in external form between the cotyledon and leaf. Whether it will be considered best to continue the use of the name "seed leaf" for cotyledon must depend on other things than mere anatomy of the structures considered, but the writer believes that further study will bring the problem of the cotyledon nearer solution.—FRANCIS RAMALEY, *University of Colorado, Boulder, Colo.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plant physiology.

GERMAN PHYSIOLOGISTS all seem to have been resting on their oars, awaiting the forthcoming volumes of Pfeffer. Not since the publication of Sachs's lectures has a book of any considerable size appeared in Germany, though Detmer's work, a part of Schenck's *Handbuch*, could be purchased separately. Dr. Ludwig Jost[1] of Strassburg has been engaged for several years on a volume intermediate between the monumental work of Pfeffer and the brief treatment of physiology by Noll in the "Bonn" *Lehrbuch.*

As a result of his labors we have a volume of almost 700 pages, treating in a critical and yet synoptic fashion the metabolism, the morphogeny, and the energetics of plants. The work takes the form of lectures, and by this device retains a vigor of phrase and fitness of description that is impossible in a more formal type of composition. The sentences are clear, direct, and forceful, and the style is consequently most attractive. In this it stands in sharp contrast with the work of Pfeffer, whose completion we note below.

Jost gathers up the literature through 1902 and exhibits critical acumen in sifting the mass of data which have accumulated. The section on metabolism treats the usual topics, somewhat more space being given to the ash constituents of plants perhaps than the reliable data will justify. Under the heading carbon and nitrogen the author discusses photosynthesis and proteid making, as well as respiration, digestion, fermentation, and other processes. So general a heading, therefore, is hardly useful, since all the metabolism of plants is connected with these two elements. Unfortunately, the author continues the use of the term "assimilation" for the synthetic processes which really precede true assimilation, and we have such divisions as *Assimilation bei den Autotrophen* and *Assimilation bei den Heterotrophen*, two processes which are so unlike that the identical terminology is sure to be confusing.

A second section of the book treats morphogeny (*Formwechsel*) rather more fully than is usual, but not more so than is desirable; to it almost one-third of the book is devoted. Besides the consideration of growth and development and the influence of external factors thereon, reproduction, heredity, and variation find adequate treatment. The section on reproduction is not a mere description of reproductive organs, as is so commonly the case, but a discussion of the physiological processes that are connected with these organs.

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[1] JOST, LUDWIG, Vorlesungen über Pflanzenphysiologie. Imp. 8vo. pp. xiii + 695. *figs. 172.* Jena: Gustav Fischer. 1904. *M*13; bound *M*15.

In a third section, *Energiewechsel*, the author discusses movements of all kinds, whether due to warping, to growth, or to turgor variations.

The scope of this work, its freshness, conciseness, and not least its clear and pleasing style, will commend it to every reader. It is easily the best work on plant physiology in any language for the general student. We hope that it will be translated promptly into English, though the necessity for this is not so great as in the case of some less readable works.— C. R. B.

THE LAST PART of the second volume of Pfeffer's *Pflanzenphysiologie*[2] has recently made its appearance from the press of Wilhelm Engelmann at Leipzig. Its publication, indeed, is almost simultaneous with the English translation of the first part of the same volume. We may therefore expect that the usual two years will elapse before this final part is translated into English. This portion is devoted entirely to the movements of plants, except a short chapter on the production of heat, light, and electricity, and a synoptical account of the forms and amount of energy exhibited in plants. In the discussion of movement one feels still more strongly the lack of coordination which is a marked characteristic of the whole work. The field in which there was needed the utmost clarity of statement and organization of facts is naturally the one in which the lack of such definite organization and clear presentation is most felt. But in spite of this serious fault one finds the same suggestiveness in the treatment of the various topics that has likewise characterized the preceding portions of the work. The same concise bibliography (notwithstanding the often incomplete citations) puts one into immediate touch with the more important literature. It is as impossible as it is unnecessary to go into detail in reviewing this volume. The mere announcement of its publication is all that is needed to insure its purchase by every institution in which plant physiology has a place and by every student who touches more than the rudiments. And the German original is as important to the investigator as the more easily read translation.— C. R. B.

THE SECOND INSTALLMENT of the English edition of Pfeffer's *Physiology of Plants*[3] has recently appeared. Its sub-title is *Growth, reproduction, and maintenance*. The present volume is both more and less than a translation. Dr. Ewart's aim has been to transfer the meaning into good English without undue regard to the original form, so that many of the involved paragraphs of the author may be said to be interpreted rather than translated. This is usually a distinct improvement, and can cause serious trouble only in those comparatively rare cases where the author's meaning is not quite

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[2] PFEFFER, W., Pflanzenphysiologie: ein Handbuch der Lehre vom Stoffwechsel und Kraftwechsel in der Pflanze. Zweiter Band: Kraftwechsel. 2. Hälfte. Imp. 8vo. pp. xi + 353 to 986. *figs. 60.* Leipzig: Wilhelm Engelmann. 1904. *M*19. Parts 1 and 2 of Vol. II, *M*30; bound *M*33.

[3] EWART, A. J., Pfeffer's Physiology of Plants, Vol. II. Growth, reproduction, and maintenance. 8vo. pp. viii + 296. *figs. 31.* Oxford: The Clarendon Press. 1903

clear. But there are places where certain finer shades of meaning in the original are not reproduced in the translation. These, of course, are the passages wherein Pfeffer's personality and suggestiveness of mind are hinted at by form of statement, and it thus comes about that the English volume contains somewhat less of Pfeffer and more of Ewart, albeit its physiology is more concisely put than in the German edition. Also, while the entire omission in the translation of the author's numerous parenthetical cross references to other sections of the same work makes the text more readable, it cannot but be regretted that the volume has thus been robbed of one of the most characteristic and valuable features which the original possessed for research workers. For the latter class of English readers the German edition will still be in demand, though no place where physiology is studied can afford to be without the translation.

In form, typography, etc., this volume follows the previous English volume and leaves nothing to be desired. The footnotes which cite the literature are usually merely translated, and have all the good and bad qualities of those of the original.— B. E. LIVINGSTON.

Plant geography.

THE appearance of the English edition of Schimper's great masterpiece[4] has been long awaited with impatience by all English and American botanists. During the latter part of 1903 the Clarendon Press issued the translation in instalments, and the completed work has been recently distributed. Every ecologist — one wishes he might say every botanist — has a well-thumbed copy of the original German edition upon his desk, and it has been one of the reference books most consulted during the past five years. Perhaps to such the appearance of a translation is too late to be of the greatest service. But to the reading public and to the students of botany in high schools, colleges, and universities the translation makes readily accessible this indispensable work. There can no longer be any reason for omitting ecological work from the higher botanical curricula.

The translation was prepared by W. R. Fisher, under the efficient supervision of Groom and Balfour. An excellent photogravure portrait of Schimper forms the frontispiece. This is a particularly welcome addition, since it has been very difficult to secure satisfactory portraits of the great ecologist. Another addition in the English edition is a sympathetic appreciation of Schimper, written by Groom.

One cannot praise too highly the laborious faithfulness to the original, which is shown in the translation. No unfortunate attempts are made to

[4] SCHIMPER, A. F. W., Plant geography upon a physiological basis. Authorized English translation by WILLIAM R. FISHER; revised and edited by PERCY GROOM and ISAAC BAYLEY BALFOUR. With a photogravure portrait, five collotypes, four maps, and four hundred and ninety-seven other illustrations. Imp. 8vo. pp. xxx + 839. Oxford: Clarendon Press. 1903. *Sh.* 42.

improve upon Schimper's thought or diction; very few liberties indeed are taken. In isolated cases the text might be clearer to American readers, if other renderings were used. For example, it may be doubted if *guild* is the best equivalent of *Genossenschaft*, or *elfin-tree* of *Krummholz*. The reviewer sees no objection to retaining the word *Krummholz* in English until an equivalent appears.

The presswork is admirable; even the illustrations seem to be quite equal to those of the original. Both the original and the translation are large and bulky volumes, and it would seem that the advantages of a two-volume edition would more than outweigh the obvious disadvantages. We hope and expect that the belief of Groom and Balfour, stated in the preface, will be realized, viz., that this work will have as great an influence upon current botanical movements as was exerted by the translation of Sachs's *Text-book of Botany* thirty years ago.— HENRY C. COWLES.

Paleobotany.

The modern morphologist is always anxious to secure some definite information concerning paleobotanical material and welcomes every new publication that promises to be helpful. Flahault[5] has just published a résumé of certain paleobotanical conferences he has been in the habit of holding with students at Montpellier, as a preliminary to work with living plants. It is really a brief and simple account of our knowledge of fossil plants and of their relation to modern vegetation. The curious autolithographic preparation of the book, including illustrations, gives to it almost the flavor of a long personal letter. The seven chapters deal with the following subjects: (I) Introductory remarks; (II) Thallophytes; (III) Bryophytes, Characeae, Pteridophytes, and groups of doubtful affinity; (IV) Phanerogamic plants—Gymnosperms; (V) Angiosperms; (VI) Differentiation of climates; successive constitution of floras; (VII) General results and conclusions.

The book will doubtless be of great service in many laboratories where a brief and clear account of the paleobotanical evidence is much needed.— J. M. C.

MINOR NOTICES.

DR. JANET PERKINS[6] has begun a series of publications devoted to the investigation of the flora of the Philippine Islands. The author's work is based upon the old and new collections belonging to the Berlin Museum, and other collections that the Museum has been able to call in; and she has also secured special monographers as collaborators. The first fascicle is chiefly

[5] FLAHAULT, CH., La paléobotanique dans ses rapports avec la végétation actuelle. Autolithograph, pp. 217. Paris: Paul Klincksieck, 3 rue Corneille. fr. 7.50.

[6] PERKINS, JANET, Fragmenta florae Philippinae. Contributions to the flora of the Philippine Islands. Fasciculus I. pp. 1–66. Leipzig: Gebrüder Borntraeger. 1904. *M* 4.

made up of the beginning of an enumeration of some of the recently collected plants of Ahern, Jagor, Loher, Merrill, Warburg, and others; and the novelties are very numerous, the region promising to equal any other in the world in this regard. The Leguminosae (7 n. spp.), Dipterocarpaceae (2 n. spp.), Anacardiaceae (8 n. spp.), Meliaceae (4 n. spp.), Pinaceae, and Taxaceae are by Dr. Perkins; Symplocaceae (1 n. sp.) by A. Brand; Acanthaceae by G. Lindau; Fagaceae by O. von Seemen; Typhaceae by P. Graebner; Orchidaceae by R. Schlechter; Palmae (6 n. spp.) by O. Beccari; Myristicaceae (1 n. sp.), Pandanaceae (1 n. sp.), and Begoniaceae (10 n. spp.) by O. Warburg; and Sapindaceae (10 n. spp.) by L. Radlkofer.—J. M. C.

IN A LITTLE WORK intended for beginners, Walmsley[7] gives a detailed account of the processes of elementary photomicrography and lantern-slide making. The book is intended for those who have little or no knowledge of general photography, and presupposes that the learner will have a student microscope and field camera. After chapters on microscopes and optical apparatus, cameras and appliances, and various radiants (among which he justly gives a high place to acetylene), the various processes for medium and low power photography receive minute attention. For work of little amplification the use of short-focus photographic lenses is recommended, but the experienced worker, acquainted with modern lenses, wonders why a "rapid rectilinear" is advocated for such work. A table giving radiant, amplification, time of exposure, etc., is of value to those who have had little experience. —W. J. G. LAND.

THE FIFTH PART OF ROTH'S *Europäischen Laubmoose*, completing the first volume, has appeared.[8] The volume contains 24 families of cleistocarpic and acrocarpic mosses, the Bryaceae beginning the second volume. Corrections and additions occupy 12 pages. The described species and the synonyms are listed, unfortunately, in two indexes, printed alike and with no page heading to distinguish them. These editorial and typographical faults will cause much inconvenience in using the book, partly defeating the author's laudable desire to save his fellows time in determining the mosses. From the preface we learn that in case the work meets the approval of bryologists the author contemplates publishing his labors on exotic species, of which he has already nearly 3000 drawn.—C. R. B.

LEROY ABRAMS, of Leland Stanford Junior University, has published a *Flora of Los Angeles and vicinity*,[9] which includes the coast slope of Los

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[7] WALMSLEY, W. H., The A B C of phto-micrography. 8vo. pp. 155. *pls. 13.* New York: Tennant and Ward. 1902. $1.25.

[8] ROTH, G., Die europäischen Laubmoose. Erster Band. Kleistokarpische und akrokarpische Moose bis zu den Bryaceen. Leipzig: Wilhelm Engelmann. 1904. *M* 25. See BOT. GAZ. 37: 150. 1904.

[9] ABRAMS, LEROY, Flora of Los Angeles and vicinity. pp. xi + 474. Stanford University, California: Stanford University Press. 1904.

Angeles and Orange counties. The wonderful diversity of the flora of California compels separate manuals for different regions of the state, if they are to be kept within convenient compass. No one of these regions seems to have been in greater need of such a manual than the one selected by the author. The usefulness of such a book is to be determined in the using, but the page is clear and attractive, the keys are well organized for convenience, and the specialists called on for assistance are abundantly able to give it. The book should justify fully the evident pains given to its preparation.—J. M. C.

A KEY to the genera of the native and cultivated woody plants of New York state, as they appear in their winter condition, has been issued recently from Cornell University.[10] One hundred and eighty-two genera are considered, including such plants as Epigaea. The distinguishing characters of the deciduous genera are chiefly those of buds, twigs, and leaf scars. The key will be especially helpful in determining the cultivated trees and shrubs of the city parks. The authors intend later to present keys to the species of each genus.—C. D. HOWE.

A CATALOGUE of the bryophytes and pteridophytes of Pennsylvania, prepared by the late Professor Thomas C. Porter[11] and edited by Dr. John K. Small, has just been published. The liverworts number 91 species and varieties, mosses 366, ferns 56, and "fern allies" 29. The catalogue is a bare list, with habitats and stations, but it is especially interesting in that Professor Porter was assisted in its preparation by such men as Thomas P. James, Coe F. Austin, A. P. Garber, and D. A. Burnett.—J. M. C.

THE THIRD VOLUME of Halacsy's[12] *Flora of Greece* begins with Lentibulariaceae, and the first fascicle closes in the midst of Cyperaceae.—J. M. C.

NOTES FOR STUDENTS.

J. H. SCHAFFNER[13] has published a partial list of Ohio plants with extra-floral nectaries and other glands, and has also referred them to eleven types.—J. M. C.

PORSCH finds[14] the study of the finer details as well as the general struc-

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[10] WIEGAND, K. M. and FOXWORTHY, F. W., A key to the genera of woody plants in winter, including those with hardy representatives found growing wild or in cultivation within New York state. Ithaca, N.Y.: Cornell University. 1904. 25 cents.

[11] PORTER, THOMAS C., Catalogue of the Bryophyta and Pteridophyta found in Pennsylvania. 8vo. pp. 66. Boston: Ginn & Company. 1904. $1.10.

[12] HALACSY, E. DE, Conspectus Florae Graecae. Vol. III. fasc. I. pp. 1–320. Leipzig: Wilhelm Engelmann. 1904. *M* 7.50.

[13] SCHAFFNER, J. H., Ohio plants with extra-floral nectaries and other glands. Ohio Nat. 4: 103–106. 1904.

[14] PORSCH, OTTO, Der Spaltöffnungsapparat von Casuarina und seine phyletische Bedeutung. Oesterr. Bot. Zeits. 54: 7– ; 41–51. *pl. 3.* 1904.

ture of the stomata of Casuarina confirm the conclusions of Treub and others as to the phylogeny of this genus; wherefore he concludes that such data constitute a valuable adjunct to the usual phylogenetic criteria.—C. R. B.

W. C. COKER[15] has discovered that no sterile prothallial cell is cut off in the germination of the microspores of Cupressus (4 spp.), *Taxus baccata* and four vars., Juniperus (2 spp.), Chamaecyparis (5 spp.), Callitris (1 sp.), *Cryptomeria japonica*, and *Thuja orientalis*. In Thuja the four megaspores were not found in the usual linear series, but in the regular tetrad arrangement.—J. M. C.

MISS MARGARET BENSON[16] has suggested a possible origin of the angiosperm flower from the "telescoping" of such an "inflorescence" as that of Gnetum, which also suggests angiosperms in its free sporophylls, nucellar structure, embryo sac development, and vegetative characters. It may be that the possible origin of angiosperms from Gnetum-like forms has been recently too lightly considered.—J. M. C.

TWO RECENT PAPERS by Küster[17] recount the author's experiments on regeneration from the hypocotyl of seedlings of *Anagallis coerulea* and *Linaria Cymbalaria*. When the epicotyl was removed, shoots sprang from the hypocotyl, and showed a marked anisophylly. Detached cotyledons of *Cucumis sativa* produced both roots and shoots in a small proportion of cases. It is shown that anisophylly is not due to geotropism.—M. A. CHRYSLER.

W. B. HEMSLEY[18] has published some curious data in reference to Davidia, an endemic and monotypic Chinese genus usually placed in the Cornaceae. The seeds germinate while retained in the fruit, which has dehisced enough to expose them; hence from one to ten seedlings may be emerging simultaneously from a single fruit. Buds were also observed in the axils of the cotyledons.—J. M. C.

F. V. COVILLE[19] has given an account of the preparation of "wokas" by the Klamath Indians, once a staple farinaceous food of the tribe, and obtained from *Nymphaea* (*Nuphar*) *polysepala*, the great yellow water lily. The Klamath reservation is in eastern Oregon, and Klamath Marsh is estimated to contain about 10,000 acres of a solid growth of "wokas." The plant is so

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[15] COKER, W. C., On the spores of certain Coniferae. Science N. S. **19**:424. 1904.

[16] BENSON, MARGARET, The origin of flowering plants. New Phytologist **3**:49–51. 1904.

[17] KÜSTER, E., Beobachtungen über Regenerationserscheinungen an Pflanzen. Beihefte Bot. Centralbl. **14**: 316–326. 1903; **15**: 421–426. 1904.

[18] HEMSLEY, W. BOTTING, On the germination of the seeds of *Davidia involucrata* Baill. Jour. Linn. Soc. London **35**: 556–559. *pl. 19*. 1903.

[19] COVILLE, F. V., Wokas, a primitive food of the Klamath Indians. Rep. U. S. National Museum *1902*: 725–739. *pl. 13*.

vigorous that it completely excludes other characteristic and conspicuous marsh plants, such as the tule and cat-tail.—J. M. C.

RALPH E. SMITH[20] has issued a preliminary report of his investigation of the asparagus rust, a disease which is seriously threatening a great Californian industry. A complete account will be published later, but the interests involved demand such current information as is available. The account is clear and to the point, and the practical suggestions are of great value, but the wretched half-tone illustrations are almost like so much waste space in so far as they are intended to show anything distinctly.—J. M. C.

MARIANI, in a study of the influence of humidity on the development of stomata in the cotyledons,[21] seems to have obtained no very decisive results. He found that in light humidity tends to increase the area of the cotyledonar limb, but to diminish the number of stomata and (rather more) the number of epidermal cells per unit of surface, which is as much as to say that it favors the formation of stomata, but does not augment their number. In darkness the reverse effect appears, but even less distinctly.—C. R. B.

UNTIL VERY recently there has been no evidence that the Carboniferous ferns followed the same course of development as their recent allies. Within a few months a fossil sporangium, collected by Mr. J. Lomax, has been sectioned by D. H. Scott[22] and found to contain germinating spores of a quite modern type. The rhizoids in several specimens are perfectly clear, as are the cell divisions of the young prothalli. The sporangial wall in its multiseriate structure resembles those of the eusporangiate ferns.—FLORENCE LYON.

BRIOSI AND FARNETI[23] have investigated the lemon scab found in Italy, which has recently appeared in Sicily, where the natives call it *ruggine bianca*. They have identified two diseases due to the presence of a polymorphic fungus known variously as Rhynchodiplodia, Cladosporium, Hormodendron, Ovularia, Haplaria, Pseudofumago, and Pseudosaccharomyces. *Cladosporium Citri* Briosi & Farneti is the form that produces the lemon scab. The investigators produced the disease by cultures and suggest a cure.—L. MONTEMARTINI.

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[20] SMITH, RALPH E., Report on asparagus rust investigation. Agricultural Experiment Station, University of California, Circular no 9, January 4, 1904.

[21] MARIANI, GINDITTA, Intorno all, influenza dell' umidità sulla formazione e sullo sviluppo degli stomi nei cotyledoni. Atti Istituto Bot. Univ. Pavia II. 8: 67–98. 1904.

[22] SCOTT, D. H., Germinating spores in a fossil fern sporangium. New Phytologist 3: 18–23. 1904.

[23] BRIOSI, G., and FARNETI, R., Intorno alla ruggine bianca dei limoni, grave malattia manifestatasi in Sicilia. Atti Istituto Bot. Pavia 10:—. 1904.

SCHAFFNER,[24] in continuing his studies among the lower monocotyledons, concludes that the placing of the Nymphaeaceae near the Helobiae is justified. He holds that the embryonal and anatomical characters, as well as the more superficial features of the group, would suggest the Helobiae as near relatives. He opposes the supposition that all so-called cotyledons are homologous, and suggests that instead of having only two general types in angiosperms there are several types which approach each other at various points in widely separated orders.— R. B. WYLIE.

BACHMANN[25] has attempted to summarize our knowledge of phytoplankton, covering the whole subject, from definitions of plankton and descriptions of methods of collection to the distribution of the phytoplankton and its relation to other organisms. This is followed by a bibliography of about ten pages, and hence it cannot be very complete. The paper adds nothing to what has already been published, but gives a very good résumé of what has been done, and perhaps as good a statement of the present state of knowledge as could be expected in a brief article.—C. D. MARSH.

SEVERAL INTERESTING OBSERVATIONS regarding plasmolytic phenomena in the blue-green algae are made by Brand.[26] Among the most striking are these. Thalli of Phormidium, etc., when strongly plasmolyzed by a salt solution and then placed in pure glycerin, are able to absorb this substance much as they might water, and thus return to their normal form. They live thus, filled with glycerin, for a number of hours. Furthermore, if cells so filled with glycerin are placed in water they stretch to beyond their normal size and often burst from the high internal pressure.— B. E. LIVINGSTON.

FROM HIS STUDIES of the foliar bundles of young plants of *Cycas revoluta* and *Zamia integrifolia*, Enrico[27] concludes that, though most of the centrifugal xylem is of secondary origin, a small portion is primary and is derived from the centripetal wood. This implies a near relationship to the distinctly mesarch structure of the vascular strands of ferns. The author considers that the changes seen in a foliar bundle in its ontogeny and in its course from the leaf tip to cortex of the stem represent the phylogenetic development of the bundle of the higher plants. The phloem shows two maxima of development in its young stages; this is interpreted as an ancestral character.— M. A. CHRYSLER.

[24] SCHAFFNER, J. H., Some morphological peculiarities of the Nymphaeaceae and Helobiae. Ohio Naturalist **4**: 83–92. *pls. 5–7*. 1904.

[25] BACHMANN, H., Das Phytoplankton des Süsswassers. Bot. Zeit. **62**^{2}: 81–100. 1904.

[26] BRAND, F., Ueber das osmotische Verhalten der Cyanophyceenzelle. Ber. Deutsch. Bot. Gesell, **21**: 302–309. 1903.

[27] ENRICO, C., V. Contribuzione alla conoscenza della morphologia e dello sviluppo del fascio vascolare delle foglie delle Cicadacee. Annales di Bot. **1**: 109–121. *pls.* 8–9. 1903.

IN A NEW Contribution from the Gray Herbarium, B. L. Robinson[28] publishes under the following titles: "Diagnoses and synonymy of some Mexican and Central American Eupatoriums," nine new species being described; "Synopsis of the Mikanias of Costa Rica," eleven species being recognized, three of which are new; "Notes on the genus Mimosa in Mexico and Central America," six new species being described; "Notes on some Polygonums of western North America," three new species of § Avicularia being described and the diamorphism of *P. longistylum* Small noted; "New spermatophytes of Mexico and Central America," new species being described in Hechtia, Cerastium, Parnassia, Penstemon, Piptothrix, Brickellia (2), Verbesina (2), and Liabum.—J. M. C.

J. C. ARTHUR[29] has pointed out the taxonomic importance of the spermogonium, the common conception that it is an accompaniment of the aecidium, or other spore-forms, being incorrect and misleading. After an interesting discussion of the varying life-cycles of the rusts, the statement is made that a record of the presence of the spermogonium, and the spore-generation with which it is associated, gives valuable information regarding the probable length of the cycle. If spermogonia and uredospores are found arising from the same mycelium, aecidia do not occur in the cycle; and if spermogonia and teleutospores are found arising from the same mycelium, there are neither uredo nor aecidia in the cycle. It is also stated that position, form, color, and size of the spermogonium are characters worth recording for taxonomic purposes.—J. M. C.

GOEBEL'S STUDIES on *Regeneration in Utricularia*[30] show that in the aquatic members of this genus production of adventitious buds occurs in the "leaf" forks and on the stalk of the bladders. In *U. exalata* budding occurs on leaves attached to the plant only when all vegetative points on the shoot axis are removed; hence the author emphasizes the importance of the principle of correlation. Localization of the regenerating region is ascribed not to the embryonic condition of the tissues in the leaf forks, but to the predisposition to building at places where the conducting system branches. In terrestrial species, if the tip of a leaf is cut off, buds appear on the cut surface of the attached part, but the ability to regenerate decreases rapidly as the base of the leaf is approached. Leaves of Pinguicula removed from a plant show regeneration of a more usual type, in that the adventitious buds are produced on the cut surface at base of the leaf.—M. A. CHRYSLER.

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[28] ROBINSON, B. L., Contributions from the Gray Herbarium of Harvard University. New Series. no. XXVII. Proc. Boston Soc. Nat. Hist. 31:247-271. 1904.

[29] ARTHUR, J. C., Taxonomic importance of the spermogonium. Bull. Torr. Bot. Club 31: 113-124. 1904.

[30] GOEBEL, J., Morphologische und biologische Bermerkungen. 15. Regeneration der Utricularia. Flora 93:98-126. *figs. 17.* 1904.

STEINBRINCK proposes[31] an explanation of the osmotic movement of water, which has the merit of substituting definite dynamics for the vague or ambiguous ideas of previous writers. Briefly stated he conceives the internal pressure of water to be reduced through the wedging apart of its molecules by those of the solute; the excess pressure of the pure solvent then determines its movement toward the region of least (internal) water pressure, *i. e.*, to the points where the solution is most concentrated. As the internal pressure of water has been estimated at *ca.* 10,000 atmospheres (5,000 by Tumlirz), the force concerned is entirely adequate to account for any observed movements. The osmotic cell is thus conceived as a mechanism operating by differences in internal water pressure, as the pump operates by differences in external air pressure. The explanation has no immediate relation to the kinetic theory, and Steinbrinck speaks of osmotic suction, not osmotic pressure. This conception he expounds by clear illustrations from the capillary tube and the siphon, both operating on the same principle, though the inequalities in pressure are differently produced. He also applies the idea to the problem of the ascent of sap, evidently holding the cohesion theory as the most likely.—C. R. B.

POLLACCI, who believes himself to have established the presence of formic aldehyde in green leaves (though the available tests are not beyond suspicion), now holds that he has materially strengthened his theory of photosynthesis by finding free hydrogen emitted from leaves.[32] This, he thinks, is set free in its nascent condition, in which it is a powerful reducing agent. The action normally proceeds according to the formulas: (1) $2CO_2 + 2H_2O = 2CH_2O_3$. (2) $2CH_2O_3 + 2H_2 + \text{light} = CH_2O + CH_4 + H_2O + 2O_2$. On the first step, the formation of carbonic acid, he lays considerable stress as an idea proposed by him. But in 1893[33] and repeatedly since I have insisted upon this as the first and fundamental process in photosynthesis. The second formula exhibits the course of events when adequate light and CO_2 are present. But when an excess of CO_2 is available this formula becomes: (3) $2CH_2O_3 + 3H_2 + \text{light} = CH_2O + H_2O + 2O_2 + CH_4 + H_2$. This shows Pollacci's main result in the present memoir. But he also suggests an important rôle for nascent H in the formation of many common plant products. He will continue his researches, especially to determine more accurately the compound which some of the H forms with C (appearing in the formula as "CH_4," but with probability only) and the conditions of light, temperature, electric charge, phase of development, etc., which influence the emission of free H.—C. R. B.

[31] STEINBRINCK, C., Ueber dynamische Wirkungen innerer Spannungsdifferenzen von Flüssigkeiten und ihre Beziehung zum Saftsteigproblem der Bäume. Flora **93**: 127–154. 1904.

[32] POLLACCI, GINO, Intorno all' assimilazione chlorofillina. Memoria II. Atti Istituto Bot. Univ. Pavia II. **8**: 1–66. *pls. 3.* 1904.

[33] BARNES, C. R., On the food of green plants. BOT. GAZ. **18**: 405. 1893.

MATTEI discusses[34] the structure and ecology of a gall produced on *Quercus leptobalanus* Gussone, by *Cynips Mayri* Kieffel. The galls in question are of a brilliant carmine color and give off the odor of hyacinths. Their surfaces are covered with a viscid secretion, in which are usually to be found the more or less dissolved remains of small myriapods, arachnids, microlepidoptera, minute coleoptera and diptera, with a few other forms. Amid these animal remains are found two kinds of trichomes, one set composed of from three to six cells of unequal size, the largest at the distal extremity, all with reddish purple protoplasm, and resembling the secreting hairs of various carnivorous plants. The other set of trichomes consists of slender quadrifid hairs, radiating in the form of a cross and extending outward toward the portion of the viscid coating (the outer part) where there is the most animal matter. Professor Mattei suggests that the function of the stouter, reddish trichomes is to secrete a fluid which serves both to capture and to digest insects, and that the other trichomes are for absorption of the digested products. Whether the nutritive material obtained by the gall from captured insects, etc. is utilized for the growth of the gall in general, for the nourishment of the Cynips larva in particular, or even, in part, for the use of the oak host Professor Mattei leaves for future investigation and discussion. The subject of possible carnivorous habits in galls deserves to be fully investigated and promises to be full of interest.—JOSEPH Y. BERGEN.

BY THE USE of material infiltrated, imbedded, and cut in serial sections, Erwin Baur[35] has been enabled to trace the origin of the ascogenous hyphae in a number of lichen genera not heretofore studied accurately in this respect. From these researches it appears that the ascogenous hyphae have their origin in a well-developed carpogonium in the case of Parmelia, Anaptychia, Endocarpon, Gyrophora, Lecanora, and Cladonia. The carpogonium in these genera resembles that observed in the genus Collema, and Baur infers that it is sexual in its origin. Only in the genera Anaptychia and Endocarpon, however, was a fusion between the spermatia and the trichogyne observed, and even in these cases the result of the "sexual act" could not be further followed. In Solorina, as in Peltigera, Peltidea, and Nephromium, the origin of the carpogonium is stated to be probably apogamous, and this fact is correlated with the absence of spermogonia in these genera.

In view of the difficulty experienced by other observers in securing thorough infiltration of the lichen thallus, Baur's method may be summarized as follows: Damp material is fixed in a saturated solution of sublimate in 5% acetic acid. After thorough washing in water and alcoholic iodine, the

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[34] MATTEI, G. E., Osservazioni biologiche intorno ad una galla. Bull. Orto Bot. Naples 1:—(fasc. 4). *pl. 1.* 1903.

[35] BAUR, E., Untersuchungen über die Entwickelungsgeschichte der Flechtenapothecien, I. Bot Zeit. 62^1: 21–44. *pls. 1–2.* 1904.

specimens are brought gradually into absolute alcohol. They are then slowly infiltrated (8 days) with celloidin, and the blocks hardened in 70% alcohol (one day), and in a mixture of one part 70% alcohol and ten parts glycerin (at least two days). Sections are cut 20–25μ in thickness, stained with "Hämalaun" and mounted in balsam.—W. C. STURGIS.

DURING THE LAST four years contributions to our knowledge of gymnosperms have accumulated remarkably. In 1901 the reviewer had occasion to bring together the literature of the group in his preparation of the *Morphology of gymnosperms* (Morphology of spermatophytes, part I), but the record of that volume is very scanty in comparison with the material now available. This focusing of attention has not been along morphological lines alone, but has included the work of anatomists and paleobotonists as well. The initial part of a series of papers dealing with the comparative anatomy and phylogeny of the Coniferales by E. C. Jeffrey,[36] has just made its appearance, and promises to be of great service in connection with the phylogeny of a group whose relationships are very obscure. The genus Sequoia was chosen for the first memoir both because it is the sole survivor of a group once extensively displayed, and also because of its possible transition characters. One of the recognized peculiarities of the genus is the absence of resin ducts, but they have now been found in *S. gigantea* in all parts of the ovulate shoot, in the first annual ring of vigorous branches of adult trees, and in the leaf traces of very vigorous leaves of adult trees. In *S. sempervirens* resin ducts are entirely absent from these regions as well as all others; but in both species resin ducts appear in tangential rows in the wood of root and shoot as a result of injury to the tissues. The conclusion is reached that these resin ducts are an ancestral feature of Sequoia, and point strongly to the derivation of the genus from an abietineous stock, a stock which may have been ancestral to the living genera of the Abietineae as well. Morphologists have regarded the Abietineae as a relatively modern group of Coniferales, with Pinus as probably the most modern genus; but now the evidence of paleobotany and of anatomy is against this view, and morphologists are called upon to change their conceptions. The evidence is becoming increasingly clear that purely morphological systems of phylogeny are extremely uncertain.—J. M. C.

ITEMS OF TAXONOMIC INTEREST are as follows: M. L. FERNALD (Rhodora **6**: 34–41. 1904), in presenting a list of New England Juncaceae, has established two new species and a variety, and has discussed *J. bufonius* and its representatives in America.—OAKES AMES (*idem* 27–31. *pl. 51*) has described a new Spiranthes of rather extensive range in the Atlantic region, often confused with *S. praecox* Watson of the southern states; and has also

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[36] JEFFREY, EDWARD C., The comparative anatomy and phylogeny of the Coniferales. Parl I.—The genus Sequoia. Mem. Boston Soc. Nat. Hist. **5**: 441–459. *pls. 68–71.* 1903.

(p. 44) substituted the name *S. Grayi* for *S. simplex* of Gray's *Manual* (5th ed.), the latter name being preoccupied by a West Indian species.— A. A. HELLER (Muhlenbergia 1:47–62. 1904) has published as new genera *Europhyton* (*Cephalanthera oregana* Reich.) and *Polemoniella* (*Polemonium micranthum* Benth.), and new species of Sisyrinchium, Ranunculus, Erysimum (2). Rosa, Lathyrus, Trifolium, Gilia, Heliotropium, Orthocarpus, Valeriana, and Achillea.— E. L. GREENE (Ottawa Nat. 17:201–203. 1904) has described three new Canadian species of Antennaria.— R. CHODAT (Bull. Herb. Boiss. II. 4:285. 1904) has described a new genus (*Hassleropsis*) of Scrophulariaceae from Paraguay.— B. L. ROBINSON (Rhodora 6:50–53. 1904) has shown that two common species of Anychia have been confused, and that the *A. dichotoma* of Gray's *Manual* is *A. polygonoides* Raf., and that *A. capillacea* of the same book is *A. dichotoma* Mx.— In Ann. Mycologici for January (1904) the following new genera appear: *Oncopodium* Sacc. (Deuteromycetae), *Klastopsora* Dietel (Melampsoraceae), *Sirozythia* v. Höhnel (Nectrioideaceae), and *Conioscypha* v. Höhnel (Dematicae).— In the first part of his *Flora Manshuriae* (Acta. Hort. Petrop. 22:1–452. 1903), V. KOMAROV presents the Archichlamydeae through Saxifragaceae, describing only three new species (Aristolochia, Ranunculus, and Deutzia).— E. L. GREENE (Leaflets 1:33–48. 1904), in continuing his studies of "Polygonaceous genera," has described 26 new species of Polygonum.— FINET and GAGNEPAIN (Bull. Soc. Bot. France 50:517–557. *pls. 16–17*. 1904) have begun a series of contribution to the flora of eastern Asia, the first dealing mostly with a synopsis of Clematis (73 spp.) and the second (*idem* 601–627. *pl. 19*) presenting a synopsis of Thalictrum (51 spp.).—EM. BOUDIER (Bull. Soc. Mycol. France 20:19–22. *pl. 1*. 1904) has described a new genus (*Guilliermondia*) of Myriangiaceae, and PAUL VUILLEMIN (*idem* 26–33. *pl. 2*) a new genus (*Spinalia*) of Dispireae parasitic on Mucor.—OAKES AMES (Contrib. Ames Bot. Lab. 1) has published an account of the orchid flora of Southern Florida, including critical notes, a few novelties, and 12 plates.—E. D. MERRILL (Publ. 6. Bur. Gov't Labs. Depart. Interior, P. I.) has described some new or noteworthy Philippine plants, and has also discussed the American element in the Philippine flora.—N. L. BRITTON (Bull. Torr. Bot. Club 31:165–166. 1904) has described four new North American species of Betula. —WILLARD N. CLUTE (Fern Bull. 13:20–23. 1904) has described a new Equisetum from northern Illinois.—THEO. HOLM (Am. Jour. Sci. IV. 17:301–317. 1904), in his 21st "Studies in the Cyperaceae," has described 17 new species and 5 new varieties of Carex, and has discussed 10 noteworthy species. —ROBERT KELLER (Bot. Jahrb. 33:547–554. 1904) has described 12 new forms of Hypericum from eastern Asia.—SPENCER LE M. MOORE (Jour. Bot. 42:100–110. 1904), in describing Mons. A. Robert's Matto Grosso Plants, has described *Salpingacanthus* as a new genus of Acanthaceae (Ruellieae).—AGNES CHASE (Rhodora 6:65–71. *pls. 52–53*. 1904), in presenting the N. Am. allies of *Scirpus lacustris*, recognizes four species, one of which is new.—J. M. C.

NEWS.

PROFESSOR E. WARMING, of Copenhagen, has been elected a member of the Paris Academy of Sciences.

DR. CARL VON MARCHESETTI, director of the Museum of Natural History at Trieste, has been appointed director of the Botanical Gardens.

DR. B. E. LIVINGSTON, of the University of Chicago, has been awarded the Walker prize by the Boston Society of Natural History for a paper on *Ionic stimulation in plants.*

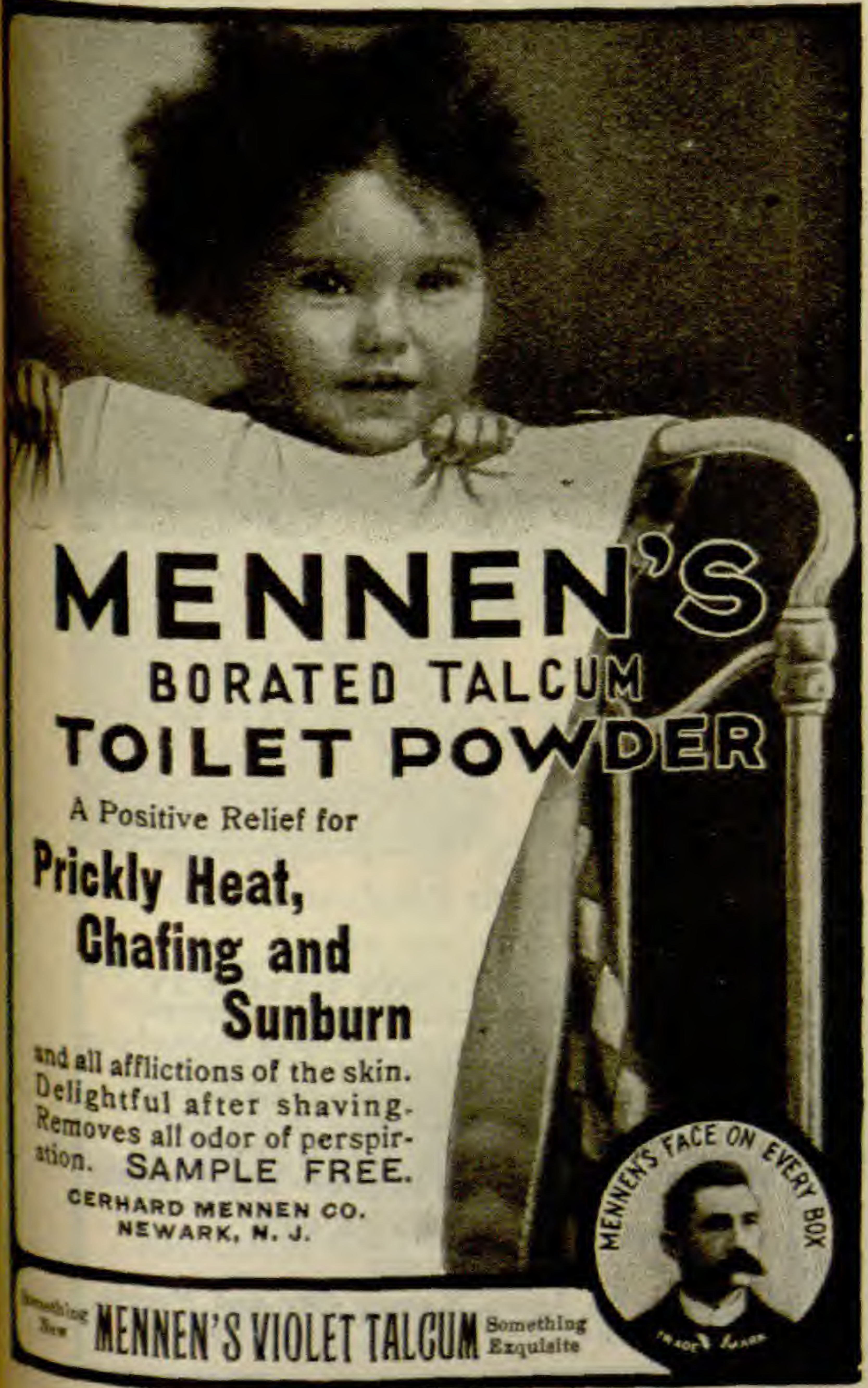
THE DEATH of Dr. August Garcke, professor of botany in Berlin and a curator of the Royal Botanical Museum, has been announced. He is best known as author of a *Flora of Germany.*

PROFESSOR F. S. EARLE, of the New York Botanical Garden, has been asked by the Cuban government to aid in the establishment of a Department of Agriculture. He has been granted leave of absence from the Garden for this purpose.

OHIO STATE UNIVERSITY has announced the work at its lake laboratory for the summer of 1904. The Cedar Point Lake Laboratory has an admirable location on Lake Erie near Sandusky, Ohio; it opens June 27 and closes August 5; and the courses in botany will be given by Professor W. A. Kellerman. The director is Professor Herbert Osborn, Ohio State University, Columbus.

THE DEATH of Dr. Karl Schumann, professor of botany in Berlin and a curator of the Royal Botanical Museum, has been announced. His numerous contributions to the morphology and taxonomy of flowering plants are well known, and especially his recent studies of the Cactaceae. A great collection of living representatives of this perplexing family was enabling Dr. Schumann to come to some very definite conclusions concerning their classification, and it is a great loss to taxonomy that these studies were not much further advanced.

DR. JOSÉ RAMIREZ, for many years head of the section of botany of the Instituto Medico Nacional of the City of Mexico, died recently. He has for many years been one of the leading scientific men of Mexico and perhaps has done more than any other person to develop botanical research in that country. He has also occupied for a long time the position of secretary to the Board of Health of Mexico, where he has accomplished much in bettering the sanitary conditions in that country. He is the author of some thirty-seven papers on botanical subjects, a list of which is published as a supplement to his *Sinonimia vulgar y cientifica de las plantas* published in 1902.—J. N. ROSE.



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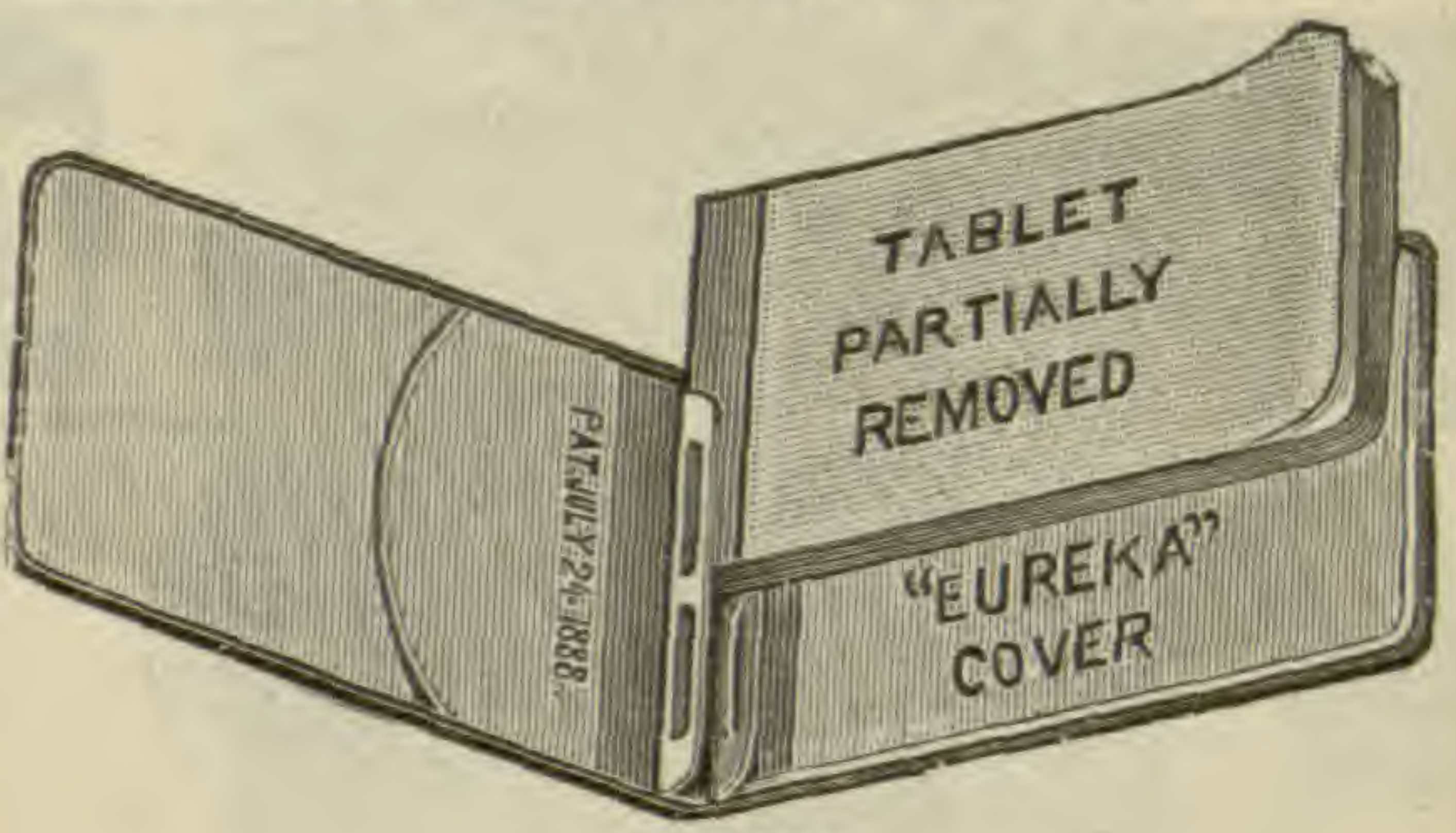

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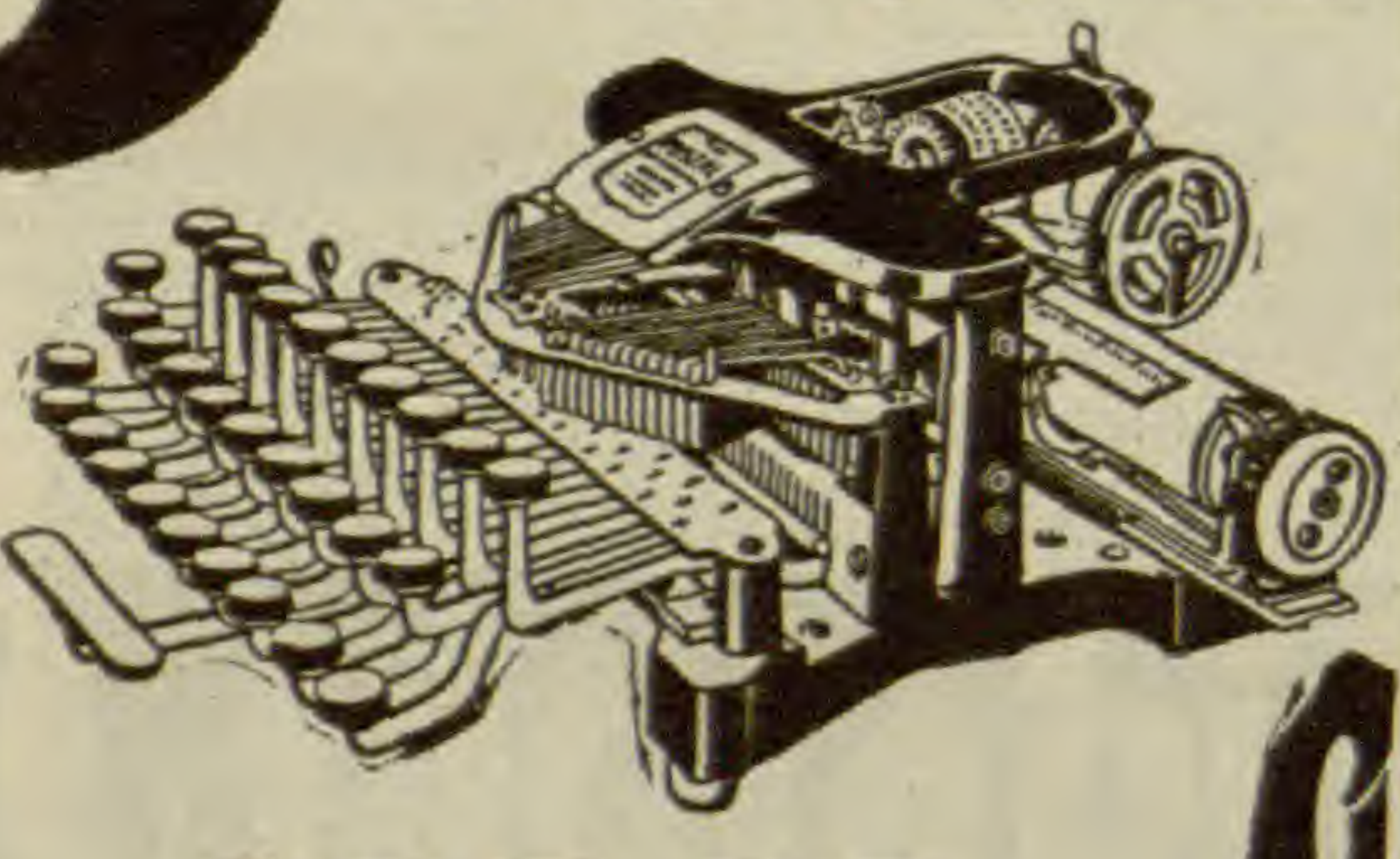

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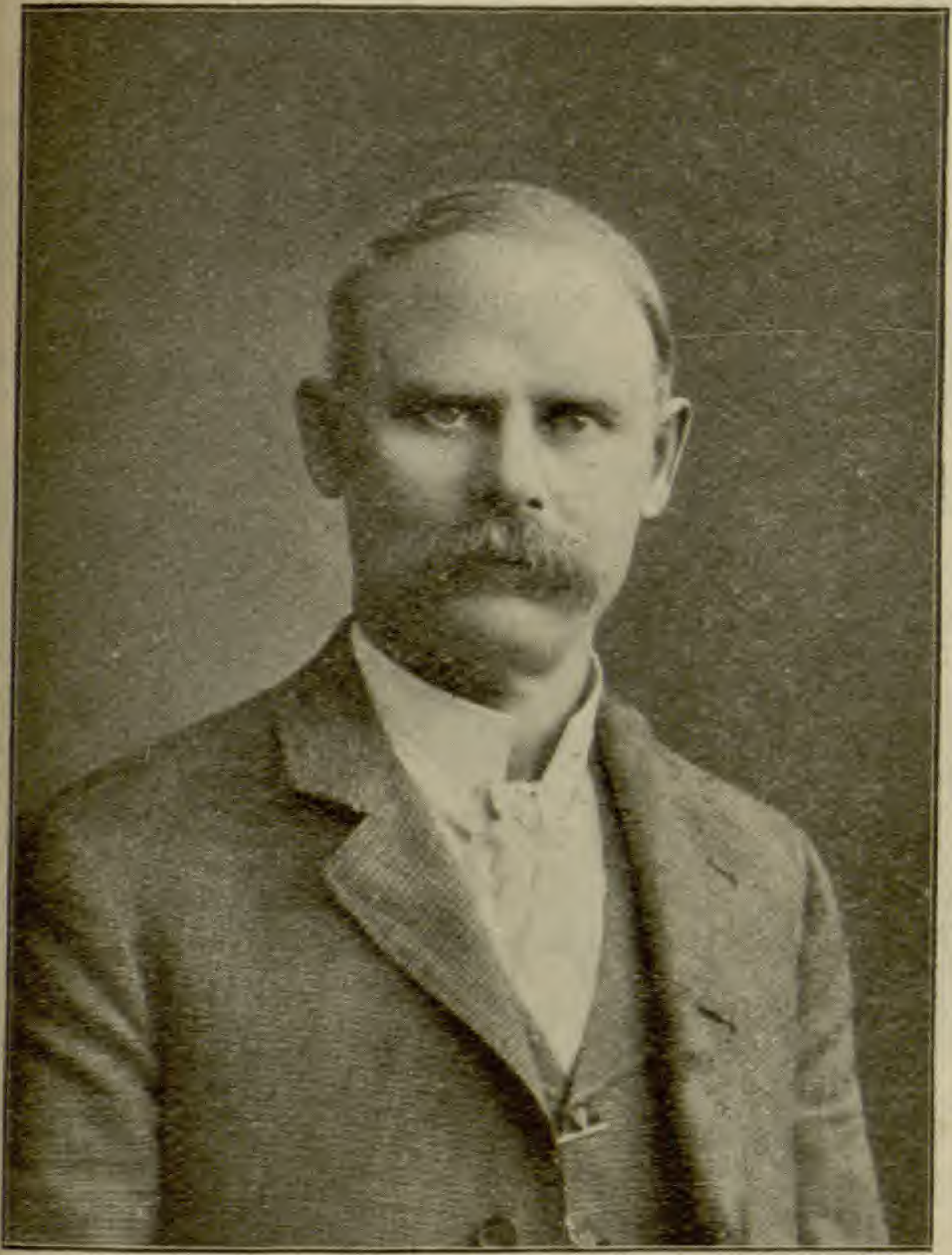

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VOLUME XXXVII NUMBER 6

BOTANICAL GAZETTE

JUNE, 1904

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. LVI.

NOTES ON THE MYXOBACTERIACEAE.

ROLAND THAXTER.

(WITH PLATES XXVI AND XXVII)

SINCE the appearance in this journal (June 1897) of the author's second paper on this group, comparatively little attention has been given to it, and with few exceptions one finds no mention of it in current text-books, or in bacteriological literature. Dr. Migula in his otherwise very complete *System der Bacterien* passes it with scant mention in his preliminary volume, and omits it wholly from the systematic part; where one finds such forms as Beggiatoa or Amoebobacter included in their proper connection. The *Pflanzenfamilien* also still appears to contain no mention of it, despite the inclusion of a menagerie of organisms whose zoology is orthodox to a degree.

In the second notice of the Myxobacteriaceae just referred to, mention was made of two papers by the late Dr. Zukal, in which he maintained the mycetozoan nature of these forms in connection with a new theory of the constitution of the myxomycetous plasmodium, based on his interpretation of the conditions seen by him in *Chondromyces crocatus*. In a third paper (Ber. Deutsch. Bot. Gesell. 15: 542. 1897), however, he has discarded this opinion in favor of the writer's view of their nature, although still unable to abandon the idea that the gelatinous matrix associated with their vegetative condition may be protoplasmic. He further calls attention to the fact that *Myxobacter aureus* Thax. is synonymous with *Polyangium vitellinum* Lk., an organism which has at various times been looked upon as a gasteromycete, a myxomycete, and even as "insect eggs." He also describes as *Myxococcus macrosporus* n. sp. a form having spores 3 μ in diameter, and producing orange or flesh-colored pustules in a laboratory culture of moist bark. The figures which he gives in this connection are so evidently diagrammatic, however, that it is difficult to determine whether he was really dealing with a species of this genus. The appearances shown in *figs. 2* and *3*, and especially in *fig. 5* of his paper, are certainly not such as have ever been observed by the present writer.

A second addition to the order has been made by Miss A. L. Smith (Jour. of Bot. Feb. 1903), who has described as *Myxococcus pyriformis* n. sp. a short-stalked form found on rabbit dung from Wales; bright pinkish orange, about 250 μ high, and with spores $2 \times 1.5 \mu$. Whether the pear-shaped cysts of this species are deliquescent or not is not stated. The cultures of dirty white motile rods obtained by transfers may certainly be assumed to have been impurities; since they do not appear to have had the characters which so clearly distinguish the vegetative conditions of the members of this group from that of other bacteria.

The third and last contribution that has appeared within the past six years was presented by Dr. E. Zederbauer at the May (1903) meeting of the Vienna Academy, and published in the proceedings (**112**: 447). In this paper, a considerable portion of which is devoted to an interpretative criticism of the two contributions which have been published in the GAZETTE, the author holds that the Myxobacteriaceae, as an independent order of organisms, has no real existence; and that the conditions supposed to have been observed merely represent a symbiotic association between ordinary Eubacteria and hyphomycetous molds. Since they are thus "no order of bacteria," this author, at the suggestion of Professor von Wettstein, proposes to designate them as "Spaltpilzflechten."

This treatment of the group, though novel, seems somewhat hasty; especially in view of the fact that the figures and descriptions given in this paper show very clearly that its author is as yet unacquainted with any member of the order he discusses, having been misled by fancied resemblances and influenced no doubt by an exaggerated notion of the difficulties associated with the differentiation of rod-like bacteria from Oedocephalum, Torula, and similar hyphomycetous types. A specimen of *Myxococcus incrustans* (*Torula Myxococci-incrustantis* n. sp. × *Bacterium Myxococci-incrustantis* n. sp.), which Dr. Zederbauer has kindly communicated to the writer, serves further to confirm this impression. An examination of this specimen shows it to consist of a horny incrustation which at least closely resembles a dried up mouldy plasmodium, blackened by the abundant fructifications of a toruloid hyphomycete; and from the fact that the bulk of the mass consists of calcic carbonate, one might perhaps venture the suggestion that it may be related to the Physareae. That a number of organisms are associated in this lichen can scarcely be disputed; yet whatever it may prove to be, either as a whole, or in detail, it surely has no connection with any of the Myxobacteriaceae, as this group is at present understood.[1] It seems, therefore, hardly necessary in the present connection to discuss the general characters of the order in the light of Dr. Zederbauer's conclusions; or to do more than reaffirm the account given in the writer's second paper, which is in his opinion substantially correct throughout.

The literary history of the Myxobacteriaceae thus bids fair to become as remarkable in its diversity as are the characters which make the order an anomaly among the plants which appear to be its nearest allies. There are certainly few groups including members which, as in the present instance, have been relegated to several genera of the Hyphomycetes, to the Gasteromycetes, to Eubacteria, to insect eggs, to Myxobacteria, to Myxomycetes, and finally to a group of "Splatpilzflechten;" and one can but

---

[1] Since the present paper was sent to the GAZETTE for publication a mounted preparation containing sections of authentic material of *Chondromyces glomeratus* has been received from Dr. Zederbauer and proves to be the conidial condition of *Coryne sarcoides* (Jacq.) Tul., to which the name *Tremella sarcoides* was given by Fries. It need hardly be remarked that this fungus is a widely distributed and very common form, well known to mycologists, having no connection either with "lichens" or Myxobacteriaceae.

look with no small interest, and perhaps with some misgivings, to such further taxonomic vicissitudes as may be in store for them.

Since the publication of his last paper, the writer has made no further detailed study of the group, having merely reexamined his preparations in order to assure himself that he had not been guilty of such blunders as were, perhaps unconsciously, attributed to him in Dr. Zederbauer's account. Although he has thus nothing new to add in relation to the general characteristics of the group as a whole, further careful study of these organisms is much needed, especially in connection with the movements of the rods and with their detailed cell characters. It seems by no means impossible that the pale pinkish coloring matter which appears to be invariably associated with the contents of the vegetative cells may be similar to bacteriopurpurin, and that these organisms may perhaps prove very near relatives of the Rhodobacteria; although there appears to be no indication of the presence of sulfur in the cell. It may be further remarked that the writer feels somewhat more inclined than formerly to entertain the suggestion, previously made, that these organisms may possibly represent transitional conditions between the higher bacteria and the lower Mycetozoa; having been partly influenced in this opinion by an examination of Dr. Olive's preparations of Diplophrys and the Sorophoreae, which seem to indicate that there may not be so wide a difference in cell structure between these groups as has been assumed.

Within the past few years a certain number of new forms has been accumulated, a majority of which are illustrated in the present contribution. In addition to these, two species of Chondromyces have also been met with; one of which was collected by Mr. A. F. Blakeslee on rotten wood in the Island of Margarita, Venezuela, and is allied to *C. crocatus*, although possessing a simple cystophore and differently shaped cysts; while the other, a somewhat amorphous species, was found on mosses growing on tree trunks at Intervale, N. H. Neither of these is available, however, in sufficient quantity for proper description. The species of Myxococcus are also certainly more numerous than the number of described forms would indicate; but as these need more careful examination and culture than it has been possible to give them, no additional species are here included; attention being merely called to the fact that a number of forms of the "rubescens" type, having spore masses of various colors, as, for example, magenta red, various shades of orange or yellow, milk-white, etc., should in all probability be eventually separated.

Among the new forms described below, *Chondromyces catenulatus* is a most interesting contribution to the group, since it presents a new type of cyst formation, and still further illustrates the remarkable resemblance which these pseudofructifications bear to the spores and sporophores of some of the higher *Fungi imperfecti.* As has been previously pointed out, the differences that are so marked in some of the species result largely from secondary impulses which, influencing the ultimate rod-masses at the period of cyst formation, produce in the mature cyst the distinctive form which in many cases is the most easily recognized and sometimes the only visible specific character. In *C. catenulatus* the conditions are unusually complicated for the reason that the ultimate rod-masses, having become more or less cylindrical, elongated, and sparingly branched,instead of responding to a single impulse in order to form a single ultimate cyst, is affected by a series of such impulses which cause the rods to stream together from opposite directions toward numerous successive points in the continuity of the mass; each point forming the nucleus of a distinct cyst. The ultimate masses thus become converted into chains of cysts united by slender isthmuses of variable length formed from the shriveled, tough, gelatinous secretions left behind by the moving rods (*figs. 3–4*), the whole pseudofructification thus assuming the form of a main axis or cystophore from the summit of which arise and diverge numerous series of spore-like cysts cohering in sparingly branched chains.

Of the three forms which have been referred to Polyangium, none corresponds very closely to the type, and the copious matrix of gelatinous material which surrounds the cysts in *P. vitellinum* is either wanting, or at least not as well differentiated. Of the new forms, *P. septatum* and *P. compositum* are both further peculiar from the secondary division of the primary cysts, of which the sori are composed, into a variable number of subequal portions clearly separated by straight lines of demarcation which give them a very spore-like appearance.

Chondromyces catenulatus, nov. sp. *Plate XXVI, figs. 1–5.*

Color bright yellow-orange. Cystophore simple, relatively rather short, the rather broad base spreading somewhat on the substratum, tapering to the distal end, where it is several times cleft; the divisions thus formed pointed, short, slightly swollen above the base and bearing one to several divergent chains of cysts. Cysts pale yellow, united in sparingly (once or twice) branched chains, fusiform to long elliptical, or often somewhat irregular in shape, the surface becoming more or less distinctly wrinkled at maturity, separated by longer or shorter, shriveled, membranous isthmuses; ten or twelve cysts often succeeding one another in a continuous series. Cystophore about 180–360μ in height. Cysts about 20–50 × 18μ, the longer chains 300μ. Average height of the pseudofructification 650μ. Rods 4–6 × 1–1.3μ.

On a rotten poplar log, Hanover, N. H.

This very interesting form was communicated to me by Professor G. R. Lyman, from whom I have received living material which, although it renews itself readily on the original substratum, I have been unable to cultivate on such media as I have tried. From the size of the spreading tuft of chains, often much more copiously developed than in *fig. 3*, it is a conspicuous species and is the only one thus far discovered with this peculiar cyst arrangement. The formation of the chain of cysts, which has been briefly referred to above, does not usually take place simultaneously throughout the ultimate rod-mass, but proceeds somewhat gradually from the base upward. As in other species, culture in a saturated atmosphere leads to the production of a variety of irregular and more or less abnormal forms, both in the cysts and in the cystophores, which tend to become short and stout.

Chondromyces pediculatus, nov. sp. *Plate XXVI, figs. 7–13.*

Orange-yellow becoming orange-red on drying. Cystophore solitary, erect, simple, usually rather slender and somewhat wrinkled; the cysts forming a loose, umbel-like head. Cysts pale yellowish, often nodding, nearly spherical to long-cylindrical, clavate or pyriform, usually broader and more or less abruptly flattened distally, where the papery cyst wall may be creased or folded so as to produce a more or less conspicuously roughened appearance; the base somewhat narrower, more or less wrinkled, passing with various degrees of abruptness to the pedicel, which is usually relatively long, slender, and shriveled. Cystophore about 300–700 μ in height, the head 150–500 μ in diameter. Cysts about 45–60 × 30–40 μ, their pedicels often 40–60 μ long. Rods of rising pseudoplasmodium 2–4 × 0.6–0.7 μ.

On goose dung from Sandy Run, S. C.

This species was first brought to my attention by my assistant, Mr. J. J. Wolfe, who found a few of its fructifications appearing on a laboratory culture. I have kept it in cultivation for more than a year and have thus been able to determine the constancy of the characters which seem to distinguish it very clearly from *C. crocatus*, or others of its nearest allies. In a saturated atmosphere its growth becomes very irregular, the cysts assuming a subcylindrical form, the portion of the ultimate rod-mass which is usually emptied to form the long pedicel encysting with little contraction, as shown in *figs. 6* and *11*. Under normal conditions, however, the peculiar form shown in *figs. 8*, *9*, *12*, and *13* appears to be very constant.

Chondromyces sessilis, nov. sp. *Plate XXVII, figs. 14–15.*

Reddish-orange. Cysts forming a sessile rosette or tuft on the substratum without any clearly differentiated cystophore; the individual cysts very variable in shape, irregularly broadly fusiform, often subapiculate, the surface somewhat wrinkled, very irregular in size, coherent at the base or more or less completely confluent into irregular masses. Cysts 18–55 × 25–75 μ, average about 40 × 55μ. Diameter of rosettes about 100–250μ.

On rotten wood near Miami, Florida.

This species was found in the hammock immediately south of Miami, and has the general appearance of *C. aurantiacus* to the naked eye. It is very irregular in its mode of growth, and specimens occasionally occur in which there seems to have been an attempt to differentiate an irregular cystophore. The rosettes can be removed *in toto* from the substratum, and when examined from the under side show the irregular area of insertion clearly differentiated from the cyst surface (*fig. 15*). Though often very variable and misshapen, the cysts are normally shaped like those shown in *fig. 14*, and always cohere.

Chondromyces muscorum, nov. sp. *Plate XXVII, figs. 16–18.*

Bright yellow-orange. Cysts simple or rarely furcate, sessile without any differentiated cystophore, erect, variously elongated;

stout or usually somewhat slender, tapering more or less prominently to the bluntly pointed apex. Cysts 90–300 × 20–50 μ. Rods 4–6 × 1–1.3 μ.

On hepatics on trunks of living beech trees, Crawfordsville, Indiana.

This species, which was kindly communicated by Dr. E. W. Olive, though unlike any other species of Chondromyces in general habit, is very similar in shape to some forms of *Myxococcus coralloides;* from which it differs, however, in its bright color, and more slender form, as well as by the absence of spores. It varies considerably in shape, from stout, bluntly rounded, to slender, more or less attenuated forms.

Myxococcus disciformis, nov. sp. *Plate XXVII, figs. 19–21.*

Cysts disk-shaped, crowded, sessile, attached by a more or less ragged scar-like insertion, or irregularly heaped in masses; at first faintly pinkish, becoming pale dull orange-yellow; circular to oval or somewhat irregular in outline; the cyst wall distinct, thin, becoming very slightly wrinkled. Cysts about 30–35 × 10 μ. Rods 2–3 × 0.5–0.6 μ. Spores irregularly spherical, hardly distinguishable in the tenacious matrix.

On muskrat dung from Stony Brook, Mass., and on deer dung from New Hampshire.

This well marked species, clearly distinguished by its color and disk-shaped cysts, has appeared twice on laboratory cultures, and is one of the most minute members of the group. At the period of cyst formation the rod often heap themselves in masses of varying size, and in these masses the cysts become differentiated by secondary aggregation somewhat as in Polyangium, so that many of them mature quite free from the substratum and thus lack the more or less characteristic scar corresponding to their insertion (*fig. 19, x*). In other cases the pseudoplasmodium appears to spread itself over certain areas of the substratum, which thus become powdered with a multitude of sessile cysts. The pale orange color is assumed only after the cysts are well matured, and seems due to a thin, papery, slightly wrinkled wall, within which the spores cohere in a matrix as tenacious as in the most characteristic cysts of Chondromyces, and in which it is only with great difficulty that the colorless rounded spores can be distinguished after crushing, even when examined with the highest objectives. Like *M. cruentus*, this species may thus be looked upon as representing a transitional condition between the Myxococcus and the Chondromyces types.

Polyangium septatum, nov. sp. *Plate XXVII, figs. 25–28.*

Sori yellowish-orange, becoming dull red-orange when dry, very variable in size, from fifty to several hundred μ in diameter, forming irregular, often variously confluent masses. Cysts irregularly rounded, subspherical to ovoid, irregularly angular or subcylindrical, divided into an irregular number of secondary cysts through clearly defined pseudosepta, the septation transverse or various. Cysts 18–22 × 12–22 μ. Secondary cysts about 10–12 μ. Rods 3–5 × 0.8–1 μ.

On horse dung, Cambridge, Mass.

This curious form has appeared twice in laboratory cultures, and is at once distinguished by its compound cysts, the septation of which is so regular and clearly defined that they have the appearance of fungus spores of the phragmosporic or dictyosporic type. The peculiarities of the species result, as is evident, from three successive aggregation impulses; first the general heaping up of the rod-mass, next the secondary aggregation of groups of rods within this mass to form the primary cysts, and lastly the ultimate aggregation of groups of individuals in these cyst masses by which they become divided into portions of considerable uniformity. The gelatinous matrix which holds the primary cysts loosely together is often scarcely distinguishable, and hardly to be compared to the well marked envelope of *P. vitellinum*. Although this as well as the following species differ in so marked a manner from the type, both in this respect and from the presence of compound cysts, it seems undesirable to separate these forms generically, especially in view of the fact that *P. sorediatum*, described below, appears in a manner to connect the two conditions.

Polyangium compositum, nov. sp. *Plate XXVII, figs. 29–30.*

Color dull yellowish-orange changing to dark red on drying. Sori irregularly scattered or loosely grouped on the surface of the substratum, consisting of one to several, rarely more than six, irregularly rounded primary cysts surrounded by a more or less distinct common gelatinous envelope. The primary cysts irregular in size, elliptical to irregularly rounded or variously lobed or elongated, divided into very numerous secondary cysts which are irregularly polygonal from pressure, and thin-walled, tending to become more or less evidently arranged in definite secondary groups within the primary cyst wall. Larger sori about 100 × 170 μ. Primary cysts 75 × 125–35 × 35 μ, average about 75 × 100 μ. Secondary cysts about 10–15 μ in diameter.

On rabbit dung from Sandy Run, S. C.

This peculiar form appeared on a somewhat old laboratory culture while the present paper was in preparation. It is very inconspicuous from its small size and dull color, as well as from the fact that the sori tend to become somewhat sunken in the viscous surface of the substratum. No rising rod-masses were obtained owing to the age of the culture, so that it was impossible to determine the dimensions of the rods. The general yellowish mucus envelope about the cysts is usually readily distinguished, and the primary cysts possess a sufficiently well-defined wall which in turn forms a common envelope about the thin-walled polygonal secondary cysts.

Polyangium sorediatum, nov. sp. *Plate XXVII, figs. 22–24.*

Sori dull orange-red, irregularly lobulated, the primary lobes usually forming more or less clearly distinguished irregularly rounded secondary lobules; the whole sorus consisting of a compact mass of small cysts, somewhat firmly coherent, the matrix forming a very thin scarcely distinguishable film about them. Cysts irregularly rounded, often somewhat polygonal from pressure, rarely double, the wall thick and clearly defined, their average diameter 6–7 μ, the smallest about 3 μ. Rods about 3–5 × 0.8 μ.

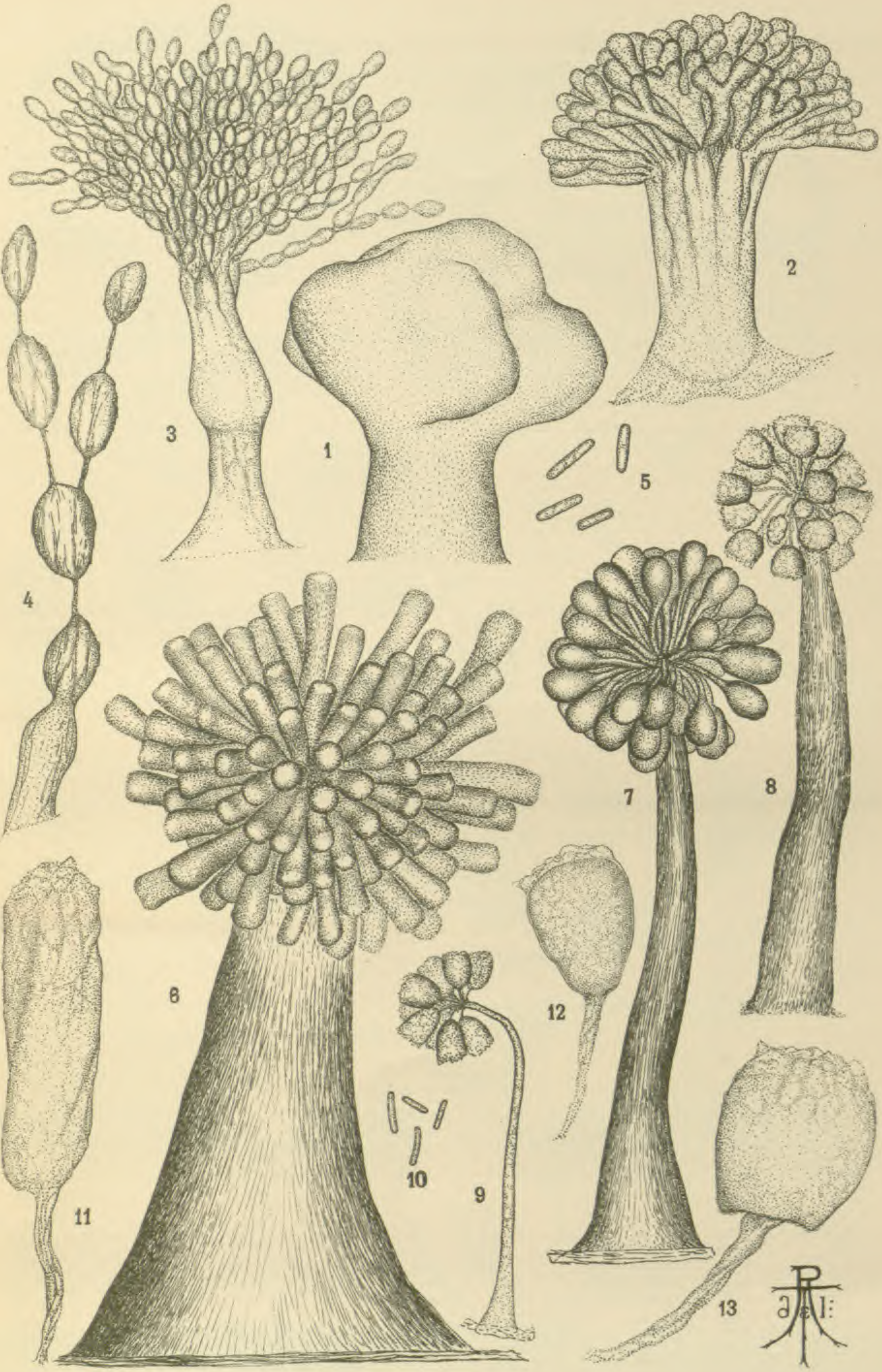
On rabbit dung from Sandy Run, S. C.

This species has been seen but once and in small quantity, attempts to cultivate it having failed. It is abundantly distinguished by its large sori and very minute cysts, which seem rarely divided in two, probably through accidental adherence.

POLYANGIUM and CYSTOBACTER having proved synonymous, the former genus should include in addition to the above new species P. VITELLINUM Lk. (= C. aureus Thax.), **P. simplex** (Thax.) n. comb., and **P. fuscum** (Schröt.) n. comb. (= C. aureus Thax.).

CHONDROMYCES CROCATUS B. & C. has within the last few years been found at New Haven, Conn., by Professor Setchell; at Tabor, Iowa, by Professor H. Metcalf; and in Florida by myself; while Graf Solms Laubach (Bot. Zeit. **62**:39), in a criticism of Dr. Zederbauer's paper above mentioned, states that he found it on the fruit of Pandanus during his visit to Java.

CHONDROMYCES SACCHARI Speg. had been described in the *Revista de la Facultad de Agronomia y Veterinaria la Plata,* no. XVII, June 1896, but the description had not been seen when I published my last paper. The axis of this species is described as being formed "ex hyphis coalescentibus," although in the note following the description this statement is accompanied with



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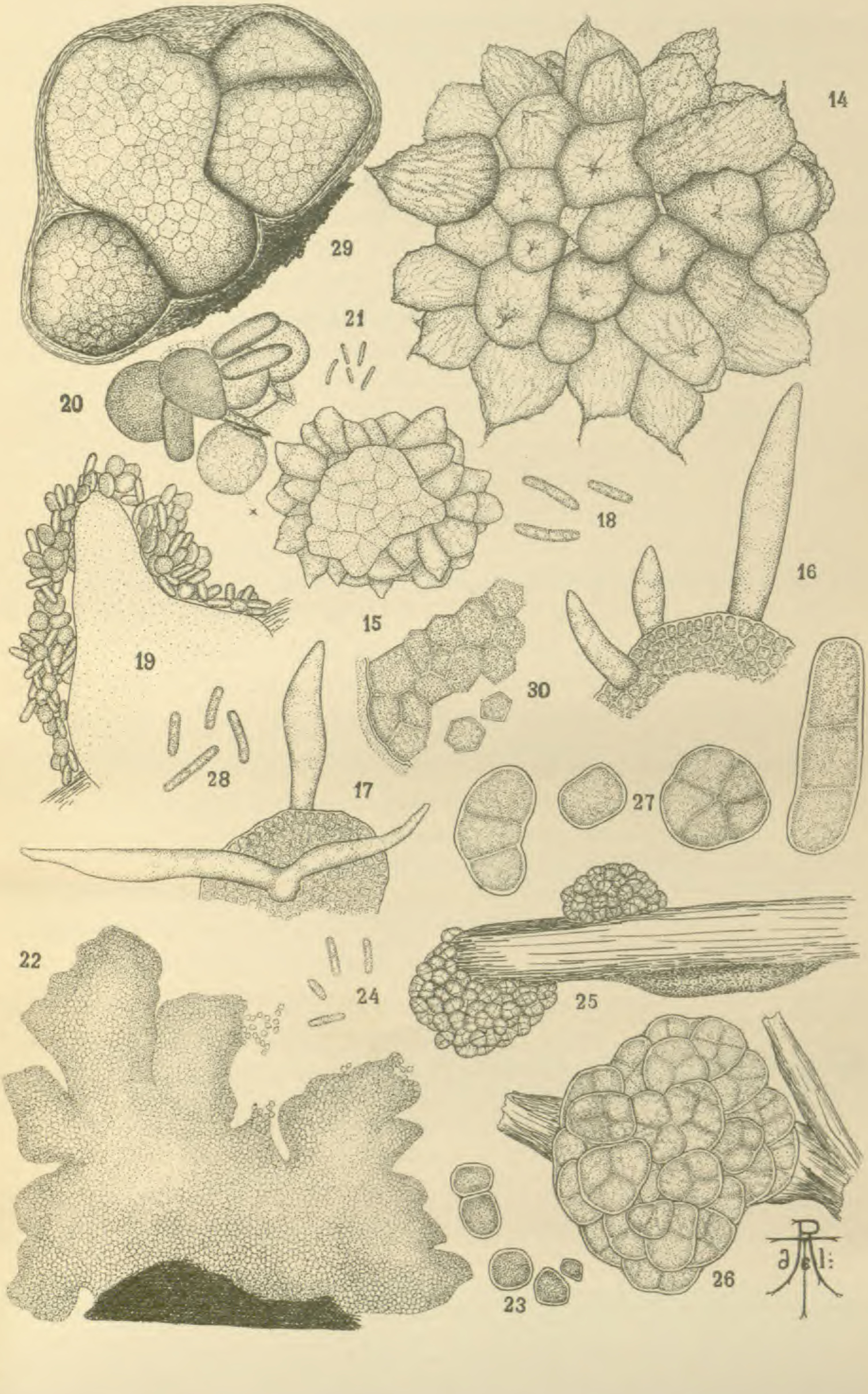

THAXTER on MYXOBACTERIACEAE.

an interrogation. Except for its somewhat larger gross dimensions, this form, if really a Chondromyces, seems to correspond in all respects to *C. crocatus*, with which it is not compared by the author. Until further data are available concerning it, it is perhaps best omitted from an enumeration of the species of the group.

CHONDROMYCES AURANTIACUS (B. & C.) has been collected by the writer in Florida and received from the Philippine Islands, where it was found by Mr. Reade. This species is also reported from the environs of Vienna by Zukal.

CHONDROMYCES LICHENICOLUS Thaxter has been sent me on lichens from Crawfordsville, Indiana, by Dr. Olive, and I have myself found it growing on the algal scum covering wet boards of a mill race in Weston, Mass. Zukal also reports this species from Austria.

CHONDROMYCES SERPENS Thaxter is reported by Zukal from Austria, and I have myself recently found it again growing on an old dung culture.

CHONDROMYCES APICULATUS Thaxter, or what appeared at the time identical with this species, was found by me more than once during my stay in Florida a few years since, but as my preparations have been unfortunately lost or destroyed, I am unable to make sure of the accuracy of this determination. It has also been obtained on deer dung from the Philippine Islands.

EXPLANATION OF PLATES XXVI AND XXVII.

PLATE XXVI.—Chondromyces catenulatus Thaxter.

FIG. 1. Pseudoplasmodium rising to form pseudofructification. A + 4.

FIG. 2. A young pseudofructification in which the elongating ultimate rod-masses are beginning to branch before cyst formation. A + 4.

FIG. 3. An older stage in which cyst formation is almost completed. A + 4.

FIG. 4. A small chain of mature cysts. D + 4

FIG. 5. Rods from rising mass. Leitz $\frac{1}{16}$ oil + 4.

PLATE XXVI.—Chondromyces pediculatus Thaxter.

FIG. 6. Pseudofructification grown in saturated atmosphere, the subcylindrical cysts in process of formation. A + 4.

FIG. 7. Normal form in which cysts are forming, the cyst and pedicel already differentiated. A + 4.

FIGS. 8, 9. Normal forms with cysts nearly mature. A + 4.

FIG. 10. Rods from rising mass. Leitz $\frac{1}{16}$ oil + 4.

FIG. 11. Somewhat elongated cysts with shorter pedicel. D + 4.

FIGS. 12, 13. Normal cysts. D + 4.

PLATE XXVII.—Chondromyces sessilis Thaxter.

FIG. 14. Rosette of cysts seen from above. D + 4.

FIG. 15. Rosette seen from below. A + 4.

PLATE XXVII.—Chondromyces muscorum Thaxter.

FIGS. 16, 17. Habit of mature cysts on hepatic leaves. A + 4.

FIG. 18. Rods of rising mass. Leitz $\frac{1}{16}$ oil + 4.

PLATE XXVII.—Myxococcus disciformis Thaxter.

FIG. 19. Group of cysts on Sphagnum leaf, two showing Myxococcus-like appearance of immature condition. D + 4.

FIG. 20. Masses of cysts formed on an old perithecium of Sordaria, the narrow ones seen edgewise. A + 4.

FIG. 21. Rods. Leitz $\frac{1}{16}$ oil + 4.

PLATE XXVII.—Polyangium sorediatum Thaxter.

FIG. 22. General habit of large cyst sorus. A + 4.

FIG. 23. Isolated cysts, two cohering. Apoch. water + 4.

FIG. 24. Rods in rising mass. Leitz $\frac{1}{16}$ + 4.

PLATE XXVII.—Polyangium septatum Thaxter.

FIG. 25. General habit of mature sori, with a rising rod-mass. A + 4.

FIG. 26. Small sorus enlarged. D + 4.

FIG. 27. Five cysts of various form. Apoch. water + 4.

FIG. 28. Rods from rising rod-mass. Leitz $\frac{1}{16}$ oil + 4.

PLATE XXVII.—Polyangium compositum Thaxter

FIG. 29. Sorus of four primary cysts. D + 2.

FIG. 30. Portion of margin of a broken primary cyst, showing secondary cysts, two of which are separate. D + 4.

NOTE.—The figures were drawn with camera, the combinations of eyepieces and objectives used being indicated in each case. Unless otherwise indicated, Zeiss objectives were used. The original drawings are reduced about one-fourth.

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

JOHN DONNELL SMITH.

Robinsonella edentula Rose et Donn. Sm.—Folia supra sparsim, subtus molliter, stellato-pubescentia circumscriptione suborbicularia sinu profundo vix lato cordata leviter trilobata, lobis acutis obtusis vel rotundatis integris vel obscure denticulatis. Paniculae axillares floribundae, pedicellis gracilibus prope apicem articulatis simul pilosis et stellato-pubescentibus. Tubus staminalis brevissimus. Carpellae parvae obtusae tenues reticulatae.

Arborescens, ramis inflorescentiis alabastris stellulato-pubescentibus. Folia 6–10^{cm} longa. Pedicelli 8–16^{mm} longi. Corolla violacea 2^{cm} diam. Carpellae maturae 7^{mm} longae. *R. divergenti* Baker f. et Rose proxima differt ramis minus dense pubescentibus, foliis margine integris vel undulatis, pedicellis pilosis, tubo staminali breviore, ovariis sparsius pubescentibus, carpellis multo minoribus.

Cobán, Depart. Alta Verapaz, Guat., alt. 1300^{m}, Nov. 1902, *H. von Tuerckheim*, n. 8382 ex Pl. Guat. &c., quas ed. Donn. Sm.

Hoffmannia arborescens Donn. Sm.—Folia glabra subcoriacea oblanceolato-elliptica acuminata in petiolum brevissimum longe attenuata. Cymae fasciculatae majusculae multiflorae fusco-pubescentes, bracteis foliaceis. Calycis tubus tetragonus, limbus triangulari-dentatus. Corolla calyce 3-plo longior usque ad medium paene fissa, tubo tetragono late cylindrico faucibus ampliato, lobis concavis incurvo-suberectis. Antherae late oblongae. Ovarium biloculare, stigmate globoso.

Arbuscula (*Tonduz* in sched.), ramulis superne quadrangularibus. Folia 15–19^{cm} longa, 3.5–5.5^{cm} lata subtus pallida, nervis lateralibus utrinque 8–9, venis immersis, petiolis 3–5^{mm} longis, stipulis deciduis. Cymae 2–3.5^{cm} longae, bracteis 1^{cm} longis deciduis, pedicellis calycem subaequantibus, floribus pubescentibus 4-meris. Corolla carnulosa 12^{mm} longa pallide rosea (*Tonduz* in sched.), tubo 2^{mm} crasso, lobis oblongo-ovatis. Antherae 4^{mm} longae obtusae, filamentis 1^{mm} longis. Discus annularis. Stylus 9^{mm} longus. Bacca ignota.—*H. tetrastigmati* Donn. Sm. inflorescentia affinis foliis glabris, ovario biloculari, stigmate globoso praesertim differt.

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[1] Continued from BOT. GAZ. 37:214. 1904.

In silvis ad Santa Rosa, Copey, Cost., alt. 1800^{m}, Apr. 1898, *Tonduz*, n. 8121 ex Pl. Guat. &c., quas ed. Donn. Sm. (N. 12230 herb. nat. Cost.)

Coussarea impetiolaris Donn. Sm.—Folia subsessilia nitida obovato-elliptica vel-oblonga cuspidato-acuminata, basi ipsa angustissima rotundata. Paniculae pubescentes contractae, ramis paucis simplicibus apice subcapitulifloris. Calycis limbus cupularis sinuato-dentatus tubo bis longior. Corollae tubus tenuiter cylindricus lobos lineares bis superans. Antherae tenuissime lineares. Bacca ellipsoidea compressa.

Arbuscula, ramulis subquadrangularibus verrucosis. Folia membranaceo-coriacea 13–16^{cm} longa medio 5–6.5^{cm}, basi 4–5^{mm}, lata, nervis lateralibus 1.5–2^{cm} inter se distantibus, venis reticulatis, petiolis 2–3^{mm} longis, stipulis vix connatis rotundatis mucrunculatis 4^{mm} longis. Pedunculi terminales bini 3–4^{cm} longi supra medium foliis 2 circiter 6–8^{cm} longis instructi. Paniculae floriferae axis 9–11^{mm} longus, rami utrinsecus 2 oppositi et terminalis 4–7^{mm} longi, pedicelli vix ulli, bracteolae 0.5^{mm} longae, flores 3–5-subglomerati pubescentes suaveolentes. Calyx 4.5^{mm} longus, tubo obconico, Corolla alba tomentulosa 26–28^{mm} longa, tubo vix 2^{mm} crasso, lobis alabastrum tetragonum tubo vix latius formantibus. Stamina paulo supra medium tubi inserta, filamentis 3^{mm} longis, antheris subinclusis 8^{mm} longis vix 0.5^{mm} latis ad $\frac{1}{4}$ altitudinis fixis. Discus breviter cylindricus. Ovarium 1-loculare, ovulis dissepimento rudimentario connatis, stylo stigmatibus linearibus 2.5^{mm} longis adjectis 12^{mm} longo. Bacca ochracea verrucosa 19^{mm} longa 8^{mm} lata utrinque obtusiuscula, semine obovato-orbiculari 1^{cm} longo, pericarpio carnoso.

La Colombiana, Llanuras de Santa Clara, Cost., alt. 200^{m}, Jun. 1899, *Pittier*, n. 7582 ex Pl. Guat. &c., quas ed. Donn. Sm. (N. 13408 herb. nat. Cost.)

Neurolaena cobanensis Greenman.—Herba robusta circiter 2^{m} alta. Folia lanceolata utrinque attenuata acuta. Inflorescentia corymboso-cymosa composita polycephala.

Caulis teres striatus puberulus purpureus. Folia 1–3^{dm} longa 1.5–4^{cm} lata indivisa vel rarius subinciso-trilobata mucronato-denticulata supra atroviridia et parce hirto-puberula vel denique subglabrata subtus pallidiora et praesertim ad costam nervosque minutissime pubescentia. Inflorescentia polycephala corymboso-cymosa ramoisissima, pedunculis usque ad 2.5^{cm} longis gracilibus adpresse puberulis. Capitula heterogama 8–10^{mm} longa radiata. Involucrum campanulatum 6–7^{mm} altum, bracteis imbricatis circiter 4-seriatis angustato-ovatis vel oblongo-lanceolatis acutis vel obtusis ciliolatis adpresse puberulis vel subglabris. Flosculi liguliferi feminei 8–10, ligulis flavibus circa 0.5^{cm} longibus. Flosculi disci hermaphroditi 20–25, acheniis glabris.—Species

N. macrophyllae Greenm. affinis, differt foliis angustioribus, inflorescentia ramosiore, capitulis radiatis et brevioribus.

Cobán, Depart. Alta Verapaz, Guat., alt. 1350^{m} Feb. 1903, *von Tuerckheim*, n. 8414 ex Pl. Guat. &c., quas ed. Donn. Sm.

Senecio calyculatus Greenman (§STREPTOTHAMNI Greenm.).— Folia alterna petiolata subsecunda elliptico-lanceolata vel elliptico-obovata breviter acuminata acuta integra basi cuneata subcoriacea. Inflorescentia albo-tomentosa subcorymboso- vel paniculato- cymosa polycephala. Capitula discoidea.

Caulis scandens lignosus, ramis striato-angulosis primo tomentosis denique glabrescentibus. Folia 3–6^{cm} longa 1.5–3^{cm} lata plerumque breviter acuminata utrinque glaberima, costa subtus prominente, nervis lateralibus utrinque 4–5 subtus conspicuis, marginibus revolutis. Capitula homogama 8–9^{mm} alta. Flosculi circiter 10. Involucrum calyculatum, bracteolis 5–6 spathulatis lanato-tomentosis conspicuis, involucri veri campanulati bracteis plerumque 8 parce tomentulosis. Achenia glabra.

Volcán Turrialba, Cost., alt. 2700^{m}, Jan. 1899, *H. Pittier*, n. 7503 ex Pl. Guat. &c., quas ed. Donn. Sm. (n. 13242 herb. nat. Cost.).

Senecio petasioides Greenman (§PALMATINERVII Hoffm.).— Frutex erectus. Folia alterna petiolata subrotundata palmatinervia plerumque cordata. Inflorescentia terminalis paniculata polycephala.

Caulis primo ferrugineo-tomentosus denique plus minusve glabratus saepe verrucoso-papillosus. Folia subrotundata 3.5–15^{cm} longa et lata 7–11-sinuato-lobata plerumque cordata mucronato-denticulata supra primo dense pubescentia denique aliquid hirtella. Capitula heterogama 12–14^{mm} alta radiata. Involucrum campanulatum calyculatum, bracteolis paucis subsetaceis, involucri veri bracteis oblongis vel lanceolato-oblongis circa 7^{mm} longis obtusis minute et dense glanduloso-hirtellis vel aliquid granulosis. Flosculi liguliferi feminei plerumque 6, ligulis oblongis 4-nerviis flavis. Flosculi disci 10–12 hermaphroditi. Achenia striato-costata glabra.— Monogr. Senecio I. Th. 26. 1901; Engler Bot. Jahrb. **32**: 22. 1902.—Species *S. Petasiti* DC. Mexicano proxime affinis, differt involucri bracteis glanduloso-hirtellis (nec subhirsutis) et quam flores multo brevioribus &c.

Chucaneb, Depart. Alta Verapaz, Guat., alt. 1825^{m} Apr. 1889, *J. Donnell Smith*, n. 1609 ex Pl. Guat. &c.. quas ed. Donn. Sm.—Guatemala, Depart. Guatemala, alt. 1500^{m} Febr. 1890, *J. Donnell Smith*, n. 2358 ex Pl. Guat. &c., quas ed. Donn. Sm.—Ceneguilla, Depart. Santa Rosa, Guat., alt. 1220^{m} Feb. 1892, *Heyde et Lux*, n. 4522 (typo) Pl. Guat. &c., quas ed. Donn. Sm.— Volcán Fuego, Depart. Zacatepéquez. Guat., alt. 1515^{m} Mart. 1892, *J. Donnell Smith*, n. 2870 ex Pl. Guat., &c., quas ed. Donn. Sm.—Chichén, Depart.

Alta Verapaz, Guat., alt. 1600^{m} Jun. 1903, *von Tuerckheim*, n. 8411 ex Pl. Guat., &c., quas ed. Donn. Sm.

Cavendishia longiflora Donn. Sm.—Ramuli trigoni cum foliis petiolis corollis pilosi. Folia oblongo-elliptica caudato-acuminata basi leviter cordata 5–7-plinervia supra insculpto-subtus prominulo-reticulata. Racemus terminalis et ex axillis superioribus ortus, perulis squamiformibus, floribus longissimis. Calyx glaber, limbo campanulato. Stamina aequilonga, antheris paulo inaequilongis, filamentis brevibus, alternis brevissimis.

Folia crasso-coriacea supra sparsim subtus densius pilosa 11–21^{cm} longa 4–9^{cm} lata, nervis intimis paulo supra basin folii progredientibus apicem attingentibus, petiolis 5–12^{mm} longis. Racemus solitarius, perulis parvis coriaceis haud coloratis, rhachi 6–8^{cm} longa glabra angulata, bracteis glabris oblongo-obovatis 3.5–5^{cm} longis, pedicellis 10–14^{mm} longis. Calyx 9^{mm} altus, tubo angulato basi intruso supra ovarium constricto, limbo tubum bis superante, dentibus deltoideis 1.5^{mm} longis coloratis. Corolla rosea graciliter cylindrica 33^{mm} longa dense pilosa, dentibus deltoideis 1.5^{mm} longis erectis margine involuto purpureis. Antherarum majorum 28^{mm} longarum loculi 11^{mm} longi, filamenta 3^{mm} longa, minorum 23^{mm} longarum loculi 9^{mm} longi, filamenta 8^{mm} longa, Stigma exsertum. Bacca ignota.—Species bracteis floribusque generis adhuc noti maximis insignis ad *C. callistam* Donn. Sm. calycis indole accedit, differt autem inter alia indumento foliis perulis staminibus.

Alto de La Palma, Prov. San José, Cost., alt. 1700^{m} Aug. 1898, *Tonduz*, n. 7391 ex Pl. Guat., &c., quas ed. Donn. Sm. (n. 12486 herb. nat. Cost.).—(Sub *C. callista* Donn. Sm. olim distributa).

Solanum amatitlanense Coult. et Donn. Sm. (§LOBANTHES Dun.).—Fruticulus simplex pilosus. Folia gemina, altero nano orbiculari-ovato, altero inaequilateraliter lanceolato-oblongo utrinque acuminato. Pedicelli 1–5-ni. Calycis tubus hemisphericus truncatus, segmentis 10 filiformibus, Corolla partita.

Inerme. Caulis e rhizomate prostrato ascendens 2.5–3.5^{dm} altus. Folia herbacea utrinque setuloso-pilosa, minore sessili 6–14^{mm} longo, majore 8–20^{cm} longo ad medium 2–5.5^{cm} lato, apice subfalcato acutissimo, basi obliqua acuta, nervis lateralibus utrinsecus 12–15, petiolis 5–10^{mm} longis. Pedicelli plerumque 3–4-ni 6–12^{mm} longi et calyx pilis patentibus conspersi. Calycis tubus 2^{mm} altus 10-costatus segmenta subaequans. Corolla flava 9^{mm} longa, segmentis lanceolatis tubo 3-plo longioribus extus pilosellis. Stamina 4.5^{mm} longa, antheris conniventibus lanceolatis filamenta applanata bis superantibus, poris orbicularibus minutis. Pistillum stamina aequans. Bacca globosa 6^{mm} diam. aurantiacea, seminibus cuneatis scrobiculatis 1^{mm} longis.

Barranca de Eminencia, Depart. Amatitlán, Guat., alt. 1200^{m} Febr. 1892, *J. Donnell Smith*, n. 1457 ex Pl. Guat., &c., quas ed. Donn. Sm.—In truncis prostratis putridis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m} *von Tuerckheim*, Jul. 1901, Febr. 1903, nn. 7753 et 8488 ex Pl. Guat., &c., quas ed. Donn. Sm.—(Sub *S. Amatitlanensi* Coulter ined. olim distributa).

Solanum arrazolense Coult. et Donn. Sm. (§ GONIANTHES Dun.)—Pubescens. Folia gemina lanceolato-elliptica vel-oblonga sursum longiuscule, basi brevius, acuminata. Pedicelli axillares numerosi floribus subaequilongi. Calyx infra apicem membranaceum inaequaliter 10-denticulatus. Stamina 4 filamentum staminis quinti aequantia.

Fruticulus metralis inermis dichotomo-ramosus, ramis subflexuosis. Folia utrinque appresso-pubescentia, majoribus 6.5–9.5^{cm} longis 2.5–4^{cm} latis, altero subduplo minore, petiolis 8–12^{mm} longis. Pedicelli 4–12–ni 10–14^{mm} longi. Calyx 3.5^{mm} altus, denticulis crasso-subulatis, alternis 3-plo majoribus 1.5^{mm} longis. Corolla angulato-plicata 12^{mm} longa, radiis extus pubescentibus. Antherae cylindricae 2.5^{mm} longae, poris orbicularibus, filamentis 4 brevioribus 1^{mm} longis. Pistillum corolla paulo brevius. Bacca immatura globosa.

Arrazola, Depart. Guatemala, Guat., alt. 1600^{m}, Apr. 1893, *Heyde et Lux*, n. 4736 ex Pl. Guat. &c., quas ed. Donn. Sm.—(Sub *S. Arrazolensi* Coulter ined. olim distributum.)

Solanum mazatenangense Coult. et Donn. Sm. (§ MOGENOPLUM Dun.)—Aculeatum glabrum. Folia plerumque singula longe petiolata elliptica vel oblongo-ovata cuspidato-acuminata ima basi cuneata integra vel pinnatipartita et pinnatisecta. Racemi elongati in corymbum terminalem dichotomum dispositi. Stamina inaequalia calyce dimidio longiora corollae angulato-plicatae dimidium aequantia. Ovarium pyramidale.

Fruticosum scandens ramosum, aculeis parvis recurvis in ramulis inflorescentiisque parcis. Folia subcoriacea nitida, superioribus integris 9–16^{cm} longis 4–8^{cm} latis, inferiorum segmentis utrinque 1–3 circiter 3–5^{cm} longis 2–3^{cm} latis terminali minoribus, inferioribus basi contracta ovatis, costa subtus aculeata, petiolis 4–8^{cm} longis aculeatis. Pedunculus 4–6^{cm} longus, racemis primum suberecti denique divaricatis 6–15^{cm} longis apice recurvatis secundifloris, pedicellis 1–1.5^{cm} longis, floribus plerumque pistillo rudimenrario 3^{mm} longo sterilibus, fertilibus minoribus. Calyx 7–8^{mm} altus, lobis rotundatis 4–5^{mm} longis cuspidatis. Corolla 4–4.5^{cm} diam. caerulea angulis mucronatis, sinibus arcuatis. Antherae lineares 1^{cm} longae, rimis anticis dein lateralibus, filamento quinto 3.5^{mm} longo ceteris bis longiore. Ovarium stylo adjecto stamina paulo superans. Baccae haud suppetunt.

Escuintla, Depart. Escuintla, Guat., alt. 440^{m}, Apr. 1890, *J. Donnell Smith*, n. 2263 ex Pl. Guat. &c., quas ed. Donn. Sm.—Santa Bárbara, Depart. Sololá, Guat., alt. 410^{m}, Aug. 1891, *W. C. Shannon*, n. 618 ex Pl. Guat. &c., quas ed. Donn. Sm.—Las Ánimas Depart. Suchitepéquez, Guat., alt. 200^{m}, Sept. 1891, *W. C. Shannon*, n. 624 ex Pl. Guat. &c., quas. ed. Donn. Sm.—Embaulada, Depart. Zacatepéquez, Guat., alt. 1400^{m}, Nov. 1891, *Heyde et Lux*, n. 4735 ex Pl. Guat. &c., quas ed. Donn. Sm.— San Felipe, Depart. Retalhuleu, Guat., alt. 620^{m}, Apr. 1892, *J. Donnell Smith*, n. 2669 ex Pl. Guat., &c., quas. ed. Donn. Sm.— Arrazola, Depart. Guatemala, Guat., alt. 1600^{m}, Maj. 1892, *Heyde et Lux*, n. 3442 ex Pl. Guat. &c., quas ed. Donn. Sm.— (Sub *S Mazatenangensi* Coult. ined. olim distributa.)

Solanum quichense Coult. et Donn. Sm. (§ GONIANTHES Dun.) —Folia glabrescentia gemina disparia lanceolato-rhomboidea vel-elliptica utrinque acuminata. Pedunculi axillares singuli vel bini foliis breviores, floribus cernuis. Calycis puberuli laciniae 10 lineares ad basin membrana pellucida junctae, alternis majoribus tubo bis longioribus. Stamina aequalia, antheris quam filamenta 3-plo fere longioribus, rimis anticis.

Frutex orgyalis inermis, ramis dichotomis, novellis pubescentibus. Folia nascentia pilosiuscula, adulta supra sparsissime pilosiuscula subtus glabra, inferioribus elongato-rhomboideis circiter 13^{cm} longis et 5.5^{cm} latis, superioribus lanceolato-ellipticis 7–9^{cm} longis 2.5–3.5^{cm} latis, petiolis pubescentibus 8-15^{mm} longis. Pedunculi pubescentes plerumque solitarii 3-6^{cm} longi apice incrassati. Calyx 10-costatus 6–8^{mm} altus. Corolla angulato-plicata 3–3.5^{cm} lata extus pulverulenta. Antherae lanceolato-oblongae 5.5^{mm} longae, filamentis deorsum dilatatis. Pistillum stamina paulo superans. Bacca globosa 9^{mm} diam., seminibus obdeltoideis 3^{mm} longis laevibus.—*S. pilosiusculo* Mart. et Gal. ex char. proximum.—Chiul, Depart. Quiché, Guat., alt. 2400^{m}, Apr. 1892, *Heyde et Lux*, n. 3450 ex Pl. Guat., &c., quas et. Donn. Sm.— (Sub *S. Quichensi* Coulter ined. olim distributum.)

Louteridium costaricense Radlk. et Donn. Sm.—Omnibus in partibus glabrum. Folia oblongo-elliptica caudato-acuminata basi acuta vel in petiolum angustata integra, nervis lateralibus utrinsecus 6–8. Calycis segmenta reticulato-venosa oblonga pedicellis medio exarticulatis longiora. Corolla gibboso-ventricosa altior quam latior calycem vix superans, tubo vix ullo. Filamenta basi glabra.

Frutex, ut videtur. Folia petiolo circa 6^{cm} longo adjecto 28–31^{cm} longa membranacea concoloria, cystolithis subulatis rectis vel curvatis in diachymatis (nec epidermidis) cellulis nidulantilus, ut et in *L. Donnell-Smithii*

S. Wats. (et in perpaucis aliis Acanthaceis teste Hobein in Engl. Bot Jahrb. 5.438, de qua re cl. Lindau quoque refert in Engl. et Pax Nat, Pflanzenfam. IV. 3^{B}. 277 sub lit. A), nervis lateralibus angulo circa 45° a costa abeuntibus $1.5–2.5^{cm}$ inter se distantibus. Cyma pedunculo circa 15^{cm} longo adjecto folia aequans vel superans laxiflora, bracteis bracteolisque persistentibus lanceolato-ovatis $6–9^{mm}$ longis, pedicellis $2–3.5^{cm}$ longis. Calycis segmenta tria libera acutiuscula herbacea cystolithis farcta, posticum e sepalis 3 connatum carinatum 4.3^{cm} longum 1.3^{cm} latum anticis paulo longius atque latius. Corollae flavidae in alabastro convolutae tubus 3^{mm} longus, lobi 5 (in exemplis suppetentibus non satisperfecti). Genitalia exserta. Stamina 2, filamentis basi membranaceo-dilatatis, antherarum usque ad medium bifidarum loculis parallelis aequalibus 1^{cm} longis, granulis pollinis omnino ut in *L. Donnell-Smithii* S. Wats. (cf. et Lindau *l. c.* 282, *fig, 111 A*. 295). Ovarium in disco crasso sessile 8^{mm} longum pluri-ovulatum, stylo filiformi apice bifido. Capsula ignota.

In silvis prope Las Vueltas, Tucurrique, Cost., alt. $900–1000^{m}$, Mart. 1899, *Tonduz*, n. 8123 ex Pl. Guat , &c., quas ed. Donn. Sm. (n. 13036 herb. nat. Cost.)

PTERIS LONGIFOLIA L., var. **angusta** Christ.— Rhachi pilis densis albidis rigidulis patentibus obtecta; pinnis, praesertim eis frondis fertilis, angustissimis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1902, *von Tuerckheim*, n. 8344^{B}. ex Pl. Guat., &c., quas. ed. Donn. Sm.

BALTIMORE.

ARE PLANTS OF SEA BEACHES AND DUNES TRUE HALOPHYTES?[1]

THOMAS H. KEARNEY.

It seems to be generally implied, and in some cases expressly stated, by writers on ecological plant geography that the sands of the seashore, even at some distance above high tide, are impregnated with sodium chlorid and other readily soluble salts in quantity sufficient to determine the character of the vegetation. Thus, Contejean[2] gives the reader the impression that his second zone of strand vegetation in southwestern France, that of the beach proper, flourishes in a saline soil. Warming[3] writes: "The vegetation of the sand strand . . . . is a halophytic vegetation, because sand along the sea contains salt and the salty ground water comes close to the surface." Schimper,[4] describing the "Barringtonia formation" of trees and shrubs that occupies the higher beaches in tropical Asia and is separated from the high tide limit by a strip of bare sand devoid of vegetation, states: "It is the salt content of the soil which [here], as in the mangrove [formation] has called forth the most varied means of protection against transpiration. To the same factor is perhaps to be ascribed the rarity of thick [stemmed] lianas, growths which only flourish when the conditions for water-absorption are most favorable." Again, in his *Pflanzengeographie* (p. 688), he writes: "The cliffs [along the seashore] possess a less distinctly halophytic flora than the sandy and especially the marshy strand"—clearly implying his belief that the sand strand is a halophytic environment.

On the other hand, Massart,[5] who has investigated the vegetation of the Belgian strand, quotes an analysis of dune sand,

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[1] Published by permission of the Secretary of Agriculture.

[2] Géographie Botanique 56, 60. 1881.

[3] Oekologische Pflanzengeographie 304. 1896.

[4] Indomalayische Strandflora 68, 73. 1891.

[5] Bull. Soc. Roy. Bot. Belg. 32^1:—. 1893. (Mém. p. 8).

giving only 0.02 parts of matter soluble in water in 100 parts of soil, and remarks: "It is therefore erroneously that the soil of the dunes is often considered as strongly impregnated with lime and with sodium chlorid. This opinion is justified only in the case of the seaward slope of the line [of dunes] nearest the beach and for the little valleys that penetrate it; hither the wind constantly carries the spray from the waves and fragments of shells, which it piles up on the strand. But as one goes farther from the sea, one encounters no longer anything but pure sand; what sea salt is carried so far is quickly washed out; the débris of shells is disintegrated and dissolved by carbon dioxid; and the calcium carbonate, in turn, is carried away by rainwater. Thanks to the sandy character of the soil, this filters rapidly downward."

While at Woods Hole, on the coast of Massachusetts, last July, it occurred to the writer to make a number of tests for soluble salts in the sands of the dunes and the beach, as well as in soils that are under water at high tide and bear a typical salt marsh vegetation. In September of the same year an opportunity offered to examine the sands of Long Beach, near Los Angeles, California. As a considerable difference was noted between the results obtained at Woods Hole and at Long Beach, a trip was made early in December to the neighborhood of Norfolk, Virginia, where soils of the dunes, the beach, and the salt marsh were examined.

In all cases the salt content of the soil was determined by the method employed in the Bureau of Soils of the U. S. Department of Agriculture and extensively applied by the bureau in its investigations of saline soils in the arid parts of the United States.[6] By means of an auger having a screw-diameter of 4^{cm} and a shaft of any length desired, marked at intervals of 3^{dm}, borings are made into the soil, which is brought up on the thread of the screw. Each 3^{dm} of soil is separately examined. After being thoroughly mixed, distilled water is added to the soil in quantity sufficient to saturate it. A cell of determined capacity is then

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[6] A full description of this method is given in "Instruction to field parties," Bureau of Soils (1903). The apparatus used is described in Bull. 15, Division of Soils.

filled with the saturated soil and the electrical resistance is taken by means of the Wheatstone electrolytic bridge. Correction is then made for temperature, 15.5° C. being taken as the standard. A further correction for soil texture is made. By a simple calculation the percentage by weight of water-soluble salts to soil can then be determined from the electrical resistance in ohms of the soil solution. Hundreds of determinations have been made by the Bureau of Soils in which both the electrolytic method and the method of chemical analysis have been applied to the same sample of soil, in order to determine its content of salts readily soluble in water; and these have demonstrated that the former method is sufficiently accurate for all purposes of the present inquiry.[7]

First of all let us consider the salt marsh soils, which are inundated at every high tide. Two borings in such soil were made on the Massachusetts coast, the first to a depth of 6^{dm} in coarse gravelly sand, standing water being reached at $4-5^{dm}$. The boring was made amid a luxuriant growth of *Salicornia herbacea*, with some *Statice Limonium caroliniana;* while *Distichlis spicata* and *Suaeda maritima* occurred near by. Here the first 3^{dm} contained 1.5, and the second 1.4 per cent. of salt. The second boring was taken about 8^{dm} farther from the shore. Here standing water appeared at a depth of $2-3^{dm}$, precluding carrying the boring any deeper, and the coarse sand was mixed with some silt and considerable vegetable matter. The vegetation consisted of *Spartina stricta glabra* and a species of Fucus, with *Salicornia herbacea*, the latter smaller and less abundant than where the first sample was taken. Salt was present to the extent of 2.6 per cent. Near Norfolk, Virginia, a 6^{dm} boring was made in a narrow strip of marsh bordering a tidal inlet amid a fine growth of *Spartina stricta glabra.* The soil was a yellow sandy loam to a depth of about 4^{dm}, below that a blue clay, standing water being reached in the second 3^{dm}. Only 0.32 per cent. of salt was found here in the first 3^{dm}, and 0.29 per cent. in the second, although

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[7] A sample of salt marsh soil collected in the course of this investigation showed by the electrolytic method the presence of 0.30 and by chemical analysis 0.27 per cent. of soluble salts.

this spot is under water every day at high tide.[8] The lateness of the season (December 2), and consequently reduced evaporation from the soil when exposed at ebb tide, may partly account for the unexpectedly small amount of salt found. Otherwise we must admit a very wide range of salt content in the soil of salt marshes on the same coast, only a few hundred miles apart, since on the Massachusetts coast, all other conditions being quite similar, more than eight times as much salt occurred in the surface 3^{dm}.

The results obtained on the Massachusetts coast are sufficient, nevertheless, to indicate that the soil of salt marshes is highly saline, at least during certain seasons of the year, and that the ecological peculiarities of their vegetation may safely be attributed, in large part, to this factor. Yet, we may observe in passing, there are large tracts of land remote from the coast, in the arid parts of North America, which contain still greater amounts of soluble salts and bear a vegetation of even more pronouncedly halophytic character than the marshes of the Atlantic coast.[9]

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[8] A chemical analysis of this soil was obtained through the courtesy of Dr. F. K. Cameron of the Bureau of Soils, U. S. Department of Agriculture. The total content of salts readily soluble in water in the sample analyzed was 0.27 per cent. (of total weight of soil), made up as follows:

1. BASES AND ACIDS.

Calcium	trace
Magnesium	2.19
Sodium	27.73
Potassium	8.03
Sulfions	16.79
Chlorid	40.88
Carbonic acid	4.38
	100.00

2. CONVENTIONAL COMBINATIONS.

Magnesium sulfate	10.22
Potassium chlorid	15.33
Sodium chlorid	55.48
Sodium sulfate	13.14
Sodium bicarbonate	5.83
	100.00

[9] Thus a number of examinations of saline soils in southern Arizona showed that *Suaeda Torreyana* will grow in the presence of 3.5 per cent. of salt in the surface 3^{dm} of the soil, and of an average for the upper 9^{dm} of 3 per cent.; *Sarcobatus vermicularis*, where an equal amount occurs; *Allenrolfea* (*Spirostachys*) *occidentalis* in the presence of 3.1 per cent. in the surface 3^{dm}, an average of 2.7 per cent. in the first 9^{dm}, and an average of 0.75 per cent. in the first 18^{dm}; *Atriplex lentiformis* where 3.3 per cent. of salt in the surface 3^{dm}, and an average of 1.6 per cent. in the first 9^{dm} occurs. In the San Joaquin Valley, in central California, "salt grass" (*Distichlis spicata*), a rather shallow-rooting plant, grows vigorously in the presence of 3.3 per cent. of soluble salts in the surface 3^{dm} of the soil.

Turning now to the beach and dune sands the results are tabulated for convenient reference as follows:

Locality	Situation where sample was taken	Salt content (in percentages of soil) at various depths		
		0–3 dm	4–6 dm	7–9 dm
Woods Hole, Mass.	Dune marsh	0.003	.....	.....
" "	Inner dune	0.003	.....	.....
" "	Beach, outer limit vegetation	0.006	0.004	.....
" "	Beach near outer limit vegetation	0.003	.....	.....
Norfolk, Va.	Low dune, inside outermost	0.004	0.004	0.007
" "	Break in outermost line dunes	0.03	0.02	0.02
" "	Beach, outer limit vegetation	0.003	0.009	0.006
" "	Beach, outer limit vegetation	0.004	0.003	0.003
Long Beach, Calif.	Beach, near outer limit veg.	0.14	0.02	.....
" "	" "	0.12	0.12	.....
" "	" "	0.13	0.13	.....
" "	" "	0.13	0.06	.....
" "	" "	0.15	0.12	.....

It is evident that we have here a condition as regards salt content of the soil quite different from that prevailing in the salt marshes. In order to a proper interpretation of these results some details of the examinations which yielded them must be given. On the Massachusetts coast a small "dune marsh," a level expanse among the dunes, covered with a thick carpet of vegetation—*Utricularia cornuta*, *Oxycoccus macrocarpus*, *Drosera intermedia*, *Lycopodium inundatum*—was first examined. Here a 3^{dm} boring into the coarse moist sand, of which the uppermost $3–6^{dm}$ contained a little vegetable matter, revealed the presence of only about 0.003 per cent. of salt. But in view of the character of the vegetation no considerable amount of salt was expected here.

An examination of the dunes themselves was the next step in the investigation. A low dune, some distance inside the outermost line of dunes, was selected for examination. Here the soil was a nearly pure coarse quartz sand, practically devoid of humus, and was quite moist immediately beneath the surface, as was found to be generally the case with the dune sands, as well as with those of the outer beach. This dune was covered with a growth of *Ammophila arenaria* and *Hudsonia tomentosa*. The first

3^{dm} of soil taken here had an electrical resistance too high to be read with the instrument used; indicating an amount of soluble salt too small to warrant carrying the boring deeper.

On the Virginia coast, a 9^{dm} boring was made into a low dune, just inside the outermost line of dunes (that which forms the landward limit of the beach proper). Here again the soil was a nearly pure quartz sand containing merely a trace of vegetable matter. While moist very nearly to the surface, the sand at a depth of $6–9^{dm}$ had a considerably greater water content and was also decidedly coarser than that nearer the surface. The vegetation consisted solely of a showy grass, the "sea oats" (*Uniola paniculata*).[10] Here the first 3^{dm} of soil contained about 0.004 per cent. of water-soluble salts, the second also about 0.004 per cent., and the third about 0.007 per cent.

Another 9^{dm} boring was made where a break occurred in the line of low outermost dunes, not far above the reach of the highest tides (as was shown by the presence of much driftwood just beyond), but at least 6^{m} back from the actual limit of high tide at the time the boring was made. It was about 2^{m} nearer the beach than the boring just described. Here the vegetation consisted of Ammophila and *Panicum amarum minus*. The soil was a rather fine, nearly pure quartz sand, moderately moist in the first 3^{dm}, quite moist below that depth. The salt content of the first 3^{dm} was about 0.03 per cent., of the second about 0.02 per cent., and of the third also about 0.02 per cent. Hence, for the 9^{dm} column of soil the proportion of soluble salts to total weight of soil was here about five times as great as in the dune covered with Uniola. This large difference is not easy to explain, although a somewhat smaller salt content in the dune would naturally be expected, as it was higher above sea level and farther from the high tide line.

It was of course anticipated that borings made on the beach

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[10] An account of this grass, as well as of other plants mentioned here, is given by the writer in his papers on "The plant covering of Ocracoke Island," Contrib. U. S. Nat. Herb. **5**: 261–319. 1900, and on "A botanical survey of the Dismal Swamp region," *ibid.* 321–550. 1901. A general ecological-geographical description of the vegetation of the North Carolina and Virginia strand is presented in the papers cited.

proper, outside the outermost line of dunes, would reveal a greater salt content in the sand than was found in the boring just described, but such did not prove to be the case. On the Virginia coast two borings, each to a depth of 9^{dm}, were made along the line marking the outermost limit of vegetation towards the waves, one only a few meters distant from the boring in the breach in the outermost line of dunes just described, the other within a quarter of a mile of the first. In both cases the soil was a rather coarse quartz sand, with traces of decaying vegetable matter, quite moist to within $2-3^{cm}$ of the surface. The first boring was about 1.5^{m} outside the outermost line of dunes, and $4-5^{m}$ above the limit reached by flood tide at the date of the examination. Small plants of *Panicum amarum minus* grew where the boring was made. Here the resistance given by the saturated soil indicated in the first 3^{dm} about 0.003 per cent. of water-soluble salts, in the second about 0.009 per cent., and in the third about 0.006 per cent. Hence the percentage of salt in the 9^{dm} of sand was only about one-fourth as great as in the opening in the line of outermost dunes. It corresponds very closely, inexplicable though the fact may appear, with that of the dune covered with Uniola, which was still farther from the waves than was the opening through the dunes. The second boring on the outer beach was made amid small plants of *Ammophila arenaria* and *Salsola Kali*, about 5^{m} outside the outermost line of dunes and a considerable distance above the limit reached at that season by flood tide. Here the electrical resistance of the saturated soil indicated about 0.004 per cent. of salts in the first 3^{dm}, about 0.003 per cent. in the second, and about 0.003 per cent. in the third.

In the sands of the outer beach on the coast of Massachusetts two borings were made in July. The first sample for examination was taken at the outer limit of vegetation, which in this case extended only abont 1^{m} beyond the seaward base of the low outermost dunes. A luxuriant growth of *Ammodenia* (*Arenaria*) *peploides* occurred there, with *Atriplex arenaria* and *Ammophila arenaria* near by. The soil was a nearly pure quartz sand, moist as usual just below the surface. The boring was made to a depth of 6^{dm}, the first 3^{dm} giving an electrical resistance indicating about 0.006 per cent. of water-soluble salts, the second about 0.004 per cent. The results here were therefore closely comparable with those of the two borings made in December on the outer beach in Virginia.[11]

The second boring on the Massachusetts beach was made to a depth of only 3^{dm}, on the outer limit of vegetation, at a point where a small tidal inlet crosses the beach. The coarse sand here contained considerable partially decayed vegetable matter (chiefly Zostera) and was nearly saturated with water. The vegetation consisted of numerous vigorous plants of *Cakile americana*, and a few plants each of *Salsola Kali*, *Ammodenia peploides*, *Atriplex arenaria*, *Ammophila arenaria*, and *Xanthium* sp. The electrical resistance of the water-saturated sand here indicated the presence of about 0.03 per cent. of salts—about six times as much as was found in the first 3^{dm} of the preceding boring. This difference was doubtless due to the second boring having been taken at a point nearer the level of flood tide and quite close to the bank of a tidal inlet.

All the beach and dune soils examined along the Atlantic coast of the United States contained a considerable amount of water at a slight depth below the surface, which is indeed a well-known peculiarity of such soils. The data just given make it sufficiently evident that this water does not come from the sea, unless we can assume that sea-water, moving through but a few meters of sand, will give up nearly all the soluble salts it normally contains.[12] This assumption is *a priori* unlikely, and

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[11] The remarkably small amounts of salts present in the dune and beach soils just described would indicate a deficiency of mineral plant food, in view of the fact that cultivated soils in the eastern United States usually contain at least 0.02 per cent. of matter soluble in water. Perhaps to such deficiency may partly be ascribed the habit of many strand plants, particularly grasses, of extending their stems or roots so extensively over or through the soil. The necessity for feeding over the largest possible area of the sterile soil may cooperate with the necessity for the firmest possible foothold in the shifting, unstable sand in producing this habit of growth.

[12] A great number of samples of ocean water were taken on the Challenger Expedition. Of these a sample of surface water from near the latitude of Woods Hole (lat. 40° 17′ N., long. 66° 48′ W.) contained 3.287 parts per 100 of total solids, as estimated by Dittmar's method from the chlorin content; while a sample of bottom

we are justified in concluding that this water comes from the other direction, and represents an underground movement, toward the sea, of water that had fallen as rain upon the soil farther inland. If this be the case, we need not be surprised that the salt content of sea beach soils appears to be generally very small, notwithstanding that considerable amounts of sea salt are probably at times deposited upon the beach by unusually high tides, and by spray from the waves. For in addition to this lateral movement of fresh water that drains from inland soils into the sea, the rain water that falls directly upon the beach and the dunes must cause a rapid leaching of soluble salts out of these coarse-textured soils, quickly carrying the salts to the depth at which the lateral flow of the soil water towards the sea is encountered.

An examination of the salt content of beach sands on the Pacific coast of the United States affords data for an interesting comparision with conditions on the Atlantic coast, as just described. Five borings, each to a depth of 6^{dm}, and all within a few meters of one another, were made at Long Beach, near Los Angeles, California. Here, as is the case with a great part of the coast of California, the beach is but a narrow strip of sand, limited on the landward side by a line of perpendicular

water from lat. 35° 58′ N., long. 70° 35′ W. (hence somewhat north of the latitude of Cape Hatteras) contained 3.611 parts per 100 (Rep. Challenger Exp. 1:41, 43. 1884). Dr. Joseph S. Chamberlain determined the mean total solids in three samples of sea water taken at Woods Hole in July 1902 to be 3.206 parts per 100, using Dittmar's method of calculating from the chlorin content. A sample taken at Woods Hole in April of the same year, analyzed by Dr. A. P. Saunders, gave 3.192 parts per 100. Dittmar (*ibid.*, p. 203) found the composition of the solids in sea water, in various parts of the world and at different depths, to be remarkably uniform. Taking the average of 77 samples, his results in parts per 100 of total solids are as follows:

Chlorin	55.292
Bromin	0.188
Sulfuric acid (SO_3)	6.410
Carbonic acid (CO_2)	0.152
Lime (CaO)	1.676
Magnesia (MgO)	6.209
Potash (K_2O)	1.332
Soda (Na_2O)	41.234
Basic oxygen equivalent to the halogens	−12.493
	100.000

cliffs. Well-developed dunes are wanting. The soil is a nearly pure quartz sand, much finer than that examined on the coast of Massachusetts and of Virginia, and contained much less water at the time the examination was made than is usually the case on the Atlantic coast. The vegetation amid which the borings were made comprised *Abronia maritima*—with round fleshy leaves and showy crimson flowers, *Franseria bipinnatifida*, *Distichlis spicata*, the succulent glaucous *Heliotropium Curassavicum*, *Suaeda* sp. (perhaps *S. Torreyana*), and *Atriplex leucophylla*. It is noteworthy that in three of these plants—Abronia, Heliotropium, and Suaeda—succulency is very highly developed. Heliotropium, Suaeda, and Distichlis are also characteristic plants of the highly saline soils of the interior of California.

These borings at Long Beach showed a quite uniform salt content for the first 3^{dm} of soil, ranging only from 0.12 to 0.15 per cent. of water-soluble salts. At a depth of $4–6^{dm}$ the differences between the several borings were more pronounced, the maximum content being 0.13 per cent. and the minimum 0.02. The mean salt content, as indicated by the five borings, is about 0.13 per cent. in the first 3^{dm}, and 0.09 per cent. in the second.[13]

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[13] A chemical analysis of this soil was obligingly furnished by Dr. Cameron. The total salt content for the upper 6^{dm} of soil was found to be 0.22 per cent. in the sample examined. The composition is as follows, each component being stated in percentages of the total amount of water-soluble salts in the soil:

1. ACIDS AND BASES	
Calcium	2.72
Magnesium	3.63
Sodium	20.91
Potassium	7.27
Sulfions (SO_4)	20.00
Chlorin	31.84
Carbonic acid (HCO_3)	13.63
	100.00

2. CONVENTIONAL COMBINATIONS	
Calcium sulfate	9.09
Magnesium sulfate	17.28
Potassium chlorid	13.63
Sodium chlorid	41.82
Sodium bicarbonate	18.18
	100.00

Comparing this analysis with that of a salt marsh soil on p. 427, we note that magnesium, sodium, and potassium correspond pretty closely in both soils. As would be expected, the easily leached-out chlorids are relatively more abundant in the marsh than in the beach soil, while the converse holds true of sulfates, a considerable portion of which is doubtless the relatively insoluble calcium sulfate. It is interesting that while the marsh soil contains a mere trace of calcium (not determinable quantitatively by ordinary methods), the beach sand contains a considerable amount of this base. This difference may be accounted for by the fact that in the sea water, which is occasionally deposited on the beach by winds and very high tides, calcium carbonate is one of the first substances precipitated as the water evaporates, and is one of the

We have then a much higher content of soluble salts in the beach sands of the coast of southern California than in corresponding situations on the Atlantic coast of the United States. The fact that the sand was much drier at Long Beach than in the localities examined in Massachusetts and Virginia gives us the clue for a probable explanation of this difference. In all likelihood, climatic differences between the two regions, especially as regards quantity and distribution of the rainfall, account for this marked difference in the salt content of the soils. Where the rainfall is slight, either throughout the year or at some one season, the concentration of the soil solution must correspondingly increase, for evaporation from the surface is constantly going forward. The same climatic conditions which cause the formation of extensive tracts of saline soil in the interior of continents will, *caeteris paribus*, bring about a similar result along the coast. The mean annual rainfall at Los Angeles is 39.3^{cm}, and normally only 0.5^{cm} falls in that region between June 1 and September 30. At the time the results just described were obtained (September 29, 1903), only 1.12^{cm} of rain had fallen during the previous four months.

At Norfolk, on the other hand, the mean annual rainfall is 130.2^{cm}, and during the four months from June 1 to September 30, it is 52.05^{cm}. In the two months preceding the date on which the soil samples above described were taken, *i. e.*, October and November 1903, 20.5^{cm} of rain fell. Furthermore, in the season of the year when the examination was made near Norfolk (December 2), evaporation must be considerably reduced and the tendency towards a concentration of salts near the surface of the soil due to this cause, in conjunction with the capillary rise of water in the soil, must be considerably less than during the summer. However, the results obtained in midsummer on the coast of Massachusetts, where conditions as to rainfall are much like those on the Virginia coast, go to show that the concentra-

last components to be leached out of the soil by subsequent rainfall. In salt marsh soils, on the other hand, the daily ebb and flow of the tide prevents any marked accumulation by evaporation of such calcium salts as are deposited. But the possibility that part, at least, of this calcium is carried into the beach sands from soils farther inland cannot be ignored, since California soils are often very rich in lime.

tion of the soil solution in beach sands of the Atlantic coast of the United States must be at all times considerably less than on the California coast. This is further confirmed by the character of the vegetation, which is more decidedly halophytic on the California than on the Atlantic coast.

This brings us to the question which serves as the title for this paper. In the light of the investigations just described, are we justified in classifying the vegetation of sea beaches and dunes as halophytic?[14]

If the soil is not saline, or but slightly so, while the climatic conditions are such as to render protection against excessive transpiration necessary, it is obvious that the vegetation, while xerophytic, is not halophytic.

Ordinary cultivated soils of the eastern United States generally contain matter readily soluble in water to the amount of 0.02 to 0.2 per cent. (by weight to dry weight of soil).[15] Now

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[14] In employing this term we do not lose sight of the fact that halophytes do not constitute an ecological class coordinate with hydrophytes and xerophytes, but are properly only a subdivision of the latter. Like other xerophytes, they are characterized chiefly by the possession of various adaptations for reducing transpiration, as Warming (Halofyt-Studie, p. 235) and Schimper (Pflanzengeographie, p. 99) have pointed out. Halophytes are such xerophytes as owe their necessity for a reduction of transpiration largely to the presence in the soil of an excessive amount of readily soluble salts. The character of the soil is the final criterion which decides whether we shall call a given vegetation halophytic or non-halophytic. No ecological characters can be cited as exclusively halophytic, although halophytes seem to show a more marked tendency than other xerophytes toward a development of water-storage parenchyma. In halophytes the xerophytic habit is often developed to an extreme. This is what we should *a priori* expect, since saline soils are generally found in places where the climatic conditions (apart from peculiarities of the soil) tend to a development of xerophytic characters, as along the sea coast and in desert regions. The addition of a soil factor that makes absorption of water by the roots difficult (as is perhaps the case when salts are present in excessive amount) to climatic factors which tend to cause excessive transpiration from the leaves and stems should necessitate development in the plant of every possible means for hoarding its water content.

[15] Data as to the amounts of salts in the soil solution endurable by various cultivated plants not regarded as peculiarly resistant, are afforded by the very numerous examinations of cultivated soils that have been made by the Bureau of Soils in the arid western part of the United States. The bureau has found that lucerne, when young, will endure 0.4 per cent., in later stages of development 0.6 to 1.0 per cent. of water-soluble salts; wheat, something less than 0.4 per cent.; barley, seedlings 0.6 per cent., older plants 1.0 per cent. The writer has found in Egypt the cotton plant maturing its fiber in the presence of 1.0 per cent. of salts in the surface 3^{dm} of the soil; and in Arizona in the presence of 0.9 per cent. in the first meter of soil.

the greatest concentration of soil solution found in beach sands in the course of these investigations—at Long Beach, on the coast of California—does not exceed the maximum occurring in ordinary cultivated soils, according to the above figures. On the Atlantic strand the salt content of the sand is generally far below the minimum present in ordinary cultivated soils, if not actually too small to supply the optimum amount of mineral nutrients required by most cultivated plants.

So far as the data yet available may warrant a generalization, we must therefore conclude that plants of sandy sea beaches and dunes are not generally halophytic, although, as is the case at Long Beach, species that are elsewhere characteristic of strongly saline soils and belong to truly halophytic associations may enter into the vegetation of the sand strand.

We must look to factors of the physical environment other than an excessive concentration of the soil solution for an explanation of the usually distinctly xerophytic character of sand-strand vegetation. Among such factors may be mentioned strong winds (often carrying salt spray from the surf), intense light and a great amount of heat radiated from the surface of the sand in summer, all of which would doubtless have a share in bringing about excessive transpiration from plant surfaces not protected by special adaptations. To these factors then we must attribute the occurrence in plants of the sand strand (although growing in a soil usually amply supplied with water and in an atmosphere often nearly saturated with moisture) of many of those modifications of structure by which desert plants protect themselves against excessive loss of water by transpiration. All these conditions of the environment are common as well to the sandy beaches of great freshwater lakes, so that it is in no way remarkable, from an ecological point of view, that such typical sea coast plants, for example, as *Ammophila arenaria*, *Cakile americana*, *Lathyrus maritimus*, and *Euphorbia polygonifolia* are likewise found on the shores of Lake Michigan.

U. S. Department of Agriculture,
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SOME NEW SPECIES OF WESTERN POLEMONIACEAE.

ALICE EASTWOOD.

Polemonium albiflorum, sp. nov.—Stems simple to the inflorescence or branched from the base, rather tall, glandular-hairy throughout: leaves with 11–15 lanceolate-acuminate, callous-tipped divisions, 2^{cm} long, 2–4^{mm} wide; petioles none or short on the lower cauline leaves; radical leaves not seen: inflorescence thyrsoid, the peduncles of the lower clusters longer than the leaves; bracts small, foliaceous; bractlets none: calyx 7^{mm} long, densely glandular on the outer surface, sparingly so on the inner; divisions about as long as the campanulate tube, obtuse or acute: corolla crateriform, white, 2^{cm} in diameter, the orbicular divisions twice as long as the tube, 6^{mm} wide, margin suberose: stamens exserted, the filaments 7^{mm} long with a hairy tuft at base, inserted 2^{mm} above the base of tube; anthers oblong, 4^{mm} long, mucronate: style and stigmas conspicuously exserted from the opening bud, stigmas about half as long as the style; ovary ovoid, containing several ovules.

This differs from *P. occidentale* Greene in the different shape of the corolla and the different leaves with leaflets confluent on the winged rachis. Perhaps it might be considered a form of *P. foliosissimum*, but the pubescence is much finer and the leaflets more like those of *P. filicinum* Greene, while the stamens and stigmas are exserted even in the bud, and the flower is larger.

We have three specimens from Utah in our collection, the type having been collected at Scofield by Mr. S. J. Harkness, June 29, 1902. No. 5601 Marcus E. Jones, collected on Soldier Summit at an altitude of 7300^{ft}, growing in gravel, and a specimen collected by Mrs. Willie C. Dodd are probably the same.

Polemonium californicum, sp. nov.—Caudex branched underground from a tap root and again at the surface: stems 10–15^{cm} high, sparingly pilose with lax, jointed hairs, viscid-glandular throughout, slightly angled, leafy only below the few flowering branches: radical leaves often as long as the entire plant, the leaflets rather distant, opposite or alternate, 21–23; rachis and petiole slender, margined and ribbed, the petiole about one-third the entire length, gradually dilated to a sheathing membranous base; leaflets elliptical-ovate, obtuse or acute at apex, the base confluent with the rachis, generally acute and appearing petiolulate, the upper more distinctly confluent, somewhat oblique, 5–15^{mm} long, 3–7^{mm} wide; cauline leaves similar but with fewer leaflets and almost no petioles: flowers cymose in rather close clusters, erect in bud and flower; pedicels apparently flat, 2–5^{mm} long; bracts simple or with 3–5 divisions longer and more lanceolate than the leaflets: calyx tubular-campanulate, about 5^{mm} long, the linear-lanceolate acute segments twice as long as the tube, a little more than 1^{mm} wide: corolla blue, funnelform with spreading divisions; these oblong, truncate or emarginate, 5^{mm} long, 4^{mm} wide, glabrous or slightly pubescent; throat and tube about 3^{mm} long: stamens slightly unequal, the attached part of the filament densely woolly and forming a ridge in the corolla tube, the free portion 5^{mm} long; anthers white, elliptical, obtusely sagittate at base, almost 2^{mm} long, surpassing the corolla but not the stigmas; stigma lobes white, conspicuously exserted both in bud and flower; ovary oblong in outline, about 1^{mm} long: fruit not seen.

The type was collected by the author at Snow Flat on the old Tioga Road in the Yosemite National Park, in early July 1902. There are fine specimens also from Yosemite collected by Mr. F. T. Bioletti. There are specimens also from Summit, Placer county, collected by Dr. G. Eisen and later by the author. It seems to be the form included under *P. humile* Willd., common in the higher mountains of central California, and can always be distinguished from allied forms by the conspicuously exserted white stigmas and long radical leaves.

Polemonium calycinum, sp. nov.—Stems 10–20^{cm} high, pilose and viscid-glandular throughout, ribbed: radical leaves not quite equaling the stem, about 10^{cm} or less; rachis and petiole ribbed and margined, the latter about one-third the entire length, dilated and membranous at base; leaflets oblanceolate-obovate, 5–20^{mm} long, 3–5^{mm} wide, decurrent by the acute base, the three uppermost confluent, apex acute or callous-mucronate: flowers in short, close cymes, with entire or 3–5-foliate bracts; the bracts and divisions longer and narrower than those of the leaflets;

pedicels short: calyx about equaling the corolla, more than 7 mm long, the segments triangular-acute, as long as the tube, veiny: corolla funnelform, with the divisions spreading, orbicular-obovate, erosely denticulate, 5 mm long and wide, purplish-blue: stamens shorter than the corolla, the attached part very woolly, longer than the free portion, the latter 2 mm; anthers elliptical, 2.33 mm long, obtuse at apex and obtusely sagittate at base: pistil with style and stigma extending slightly beyond the calyx, exserted but little from the bud; ovary suborbicular.

This also comes in the aggregate under *P. humile* Willd. and is near *P. californicum*. It is peculiar in having a much larger calyx, shorter stamens and style, and leaflets differently shaped. The type was collected near Cinder Cone, Mount Lassen, California, by Mrs. C. C. Bruce, July 1897.

Polemonium tricolor, sp. nov.—Stems 10–15 cm high, apparently from running rootstocks; caudex clothed with broad chartaceous bases of old petioles; sparingly villous throughout with jointed hairs and glandular especially on the flowering stems: radical leaves erect, the rachis and petiole margined, strongly ribbed through the middle, 1 mm wide; petioles 2–4 cm long, dilated for almost half the length, reddish; leaflets 11–17, obovate or elliptical, callous-mucronate at apex, oblique and cuneate at base, confluent with the rachis, lowest alternate, upper opposite; cauline shorter and with shorter and broader petioles, the leaflets fewer, longer, and narrower: flowers in close, erect, compound cymes; buds erect; pedicels and peduncles flat, margined, viscid, 1–5 mm long; bracts simple or 3–5-foliate: calyx open-campanulate, rounded at base, 5 mm long, the triangular-obtuse segments half the entire length, densely glandular on both sides: corolla rotate-campanulate, violet with a reddish-purple spot near the base of the divisions, throat yellow; divisions suborbicular, emarginate at apex, 6 mm long, 5.5 mm wide, almost twice as long as the included tube; this glandular and ridged with the woolly adherent bases of the filaments: stamens with the free part of the filaments about 4 mm long; anthers white, elliptical, auriculate at base, obtuse, 1.5 mm long: ovary orbicular in outline; style not surpassing the calyx; stigmas 3–4, 3 mm long: capsule 3-valved, but not ripe in the type specimen.

The type is no. 1671 of the collection made by Harley P. Chandler on Marble Mountain, Siskiyou county, California, at an altitude of 8,000 ft. It was distributed as *P. humile pulchellum* Gray, and undoubtedly comes under that polymorphous aggregate. The small tricolored corolla with short tube distinguishes it easily from the other allied species or varieties.

Polemonium Berryi, sp. nov.— Caudex branched apparently from a tap root: stems slender, about 10 cm high, lower part sparingly glandular, upper part more densely clothed with short glandular pubescence: radical leaves clustered, the long ribbed petioles membranously dilated and imbricated at base, as long as the blades or longer, together 4–8 cm; leaflets imbricated before unfolding, later somewhat distant, 15–19, obovate to spatulate and rhomboid, acute or obtuse at apex, cuneate at base and confluent on the rachis, 2–4 mm long and about as wide, veinless and slightly viscid: cymes rather loosely flowered; the pedicels from shorter than the calyx to 7 mm; bracts trifoliate or entire and simple: calyx tubular-campanulate, 4 mm long, the deltoid-subulate obtuse divisions half as long, glandular-hairy on both sides: corolla white, tinged with lilac, throat yellow, tube white, funnel form, 9 mm long; the divisions obovate, rounded and entire at apex, 4 mm long, 3 mm wide: stamens inserted in the tube and attached by the hairy base, the free part glabrous, 4–5 mm long; anthers obtusely sagittate at base, retuse at apex, not quite 2 mm long, elliptical, the two cells attached half the length: pistil with style and stigma 8 mm long, the upper part of the stigma lobes exserted in the bud; ovary ellipsoidal, 3-valved, containing several ovules: fruit not seen.

This delicate little Polemonium is perhaps nearest to *P. viscosum* Nutt. It differs from the description of that species in the short, broad calyx divisions. The type was discovered in Desolation Valley, near Lake Tahoe, California, by Mr. S. Lucien Berry, in whose honor it is named, and was collected July 10, 1902. There is a specimen of what appears to be the same species in the herbarium of the California Academy of Sciences, collected by J. G. Lemmon near Lassen's Peak, June 1875, no. 26.

Polemonium Tevisii, sp. nov.— Rootstock somewhat shreddy, the upper part of caudex clothed with imbricated membranous petioles of old leaves: stems about 10 cm high, slightly angled, glaucous and almost glabrous at base, the upper part clothed with short glandular hairs: radical leaves 6–8$^{\mathrm{cm}}$ long with 15–19 leaflets; petiole generally more than half the entire length, slender, slightly glandular, strongly ribbed and scarcely margined, membranously dilated at base; leaflets imbricate when young, orbicular to elliptical-ovate, acute at apex and base, confluent on the rachis, 1–6$^{\mathrm{mm}}$ long, 2–4$^{\mathrm{mm}}$ wide; cauline leaves subtending the flowering branches, with shorter petioles, the leaflets few, narrower and longer than on the radical leaves: flowers closely cymose on capillary pedicels, 2–5$^{\mathrm{mm}}$ long; bracts simple or trifoliate, similar to the cauline leaflets: calyx campanulate, 5$^{\mathrm{mm}}$ long, the linear-lanceolate divisions 3$^{\mathrm{mm}}$, acute, glandular-hairy: corolla blue with yellow throat, funnelform, 9–10$^{\mathrm{mm}}$ long, the broad elliptical divisions 5$^{\mathrm{mm}}$ long, 4$^{\mathrm{mm}}$ wide, rounded and entire at apex: stamens inserted in the tube of the corolla, attached from below the throat to the base, hairy along the insertion and within the tube, the free part of the filaments 3–4$^{\mathrm{mm}}$ long; anthers elliptical, the cells united to below the middle, obtusely sagittate, obtuse at apex, 2$^{\mathrm{mm}}$ long, white: stigmas included in the bud, lobes 1.5$^{\mathrm{mm}}$ long; style 5.5$^{\mathrm{mm}}$ long; ovary elliptical in outline, acute at apex, with several ovules in each cell: fruit not seen.

The type was collected in Desolation Valley, near Lake Tahoe, California, July 10, 1902, by Mr. S. L. Berry; and in the same region by Lloyd P. Tevis, in whose honor it is named; and by Miss Lutie Goldstein at Lakeside Park, in the same region, July 1903.

Polemonium rotatum, sp. nov.—Cespitose from a thick twisted rootstock densely clothed with the persistent petioles of former leaves: stems slender, 10–15$^{\mathrm{cm}}$ high, striate, glandular-hairy, paniculately branching with erect branchlets: radical leaves 3–4$^{\mathrm{cm}}$ long, the blade equaling the petiole; leaflets about 15, generally alternate, elliptical, obtuse, oblique, sessile, 3–4$^{\mathrm{mm}}$ long, wrinkled but not veiny, sparingly clothed with glandular hairs; rachis and petiole glandular-hairy, keeled, the latter dilated at base; cauline leaves similar but short-petioled or sessile, the leaflets diminishing in number to the single entire bracts: flowers in erect panicles on short erect pedicels, as long as the calyx or longer: calyx campanulate, 4$^{\mathrm{mm}}$ long, tinged with rose-color, broad at base, the divisions as long as the tube, oblong, obtuse, extending to the throat of the corolla: corolla rotate, with tube 2^{mm} long, throat saucer-shaped, and limb salverform; divisions orbicular, 7^{mm} in diameter; the entire limb about 16^{mm} in diameter: stamens inserted in the tube, unequal, none exceeding the petals; anthers oblong, obtusely sagittate at base, more than 2^{mm} long, obtuse at apex: style surpassing the stamens: capsule distinctly 3-lobed, with one seed in each cell: seeds concave on one side, 2^{mm} long, brown.

This was collected in the Klondyke, Yukon Territory, by John MacLean, in 1898–1901, and was distributed as *P. pulchellum* Bunge.

✓ **Polemonium fasciculatum,** sp. nov.—Stems numerous from a caudex densely clothed with the broad membranous bases of old petioles, rather stout, glandular throughout with a crisp pubescence, 20^{cm} high, paniculately branched with the branchlets erect: radical leaves 5^{cm} long, with petioles one-third the entire length, membranously dilated half the length, striate; rachis broad and flat, ribbed; divisions alternate, distant, 17–21, sessile, orbicular, 2^{mm} in diameter; cauline leaves few, generally with branchlets in the axils, similar to the radical but shorter, with few distant divisions, almost sessile: flowers numerous, cymosely paniculate in close clusters, sometimes subumbellate; pedicels slender, shorter or longer than the calyx: calyx 5^{mm} long, cuneate at base; the divisions 3^{mm} long, oblong-lanceolate, obtuse, veiny, surpassing the throat and tube of the corolla: corolla blue, rotate, the tube 2.5^{mm} long, the throat and limb 13^{mm} in diameter; divisions obovate, truncate or retuse, 5^{mm} wide near the apex, 6^{mm} long: stamens inserted in the tube, hairy at base, somewhat unequal, shorter than the divisions of the corolla; anthers orbicular, 1^{mm} in diameter, united at the apex only: style surpassing the stamens, not so long as the corolla and not exserted from the bud: capsule 3-lobed, somewhat pointed: seeds 2–3 in each cell.

This was collected by Mr. John MacLean in 1898 or 1901 on the Klondyke, Yukon Territory, and was distributed as *P. pulchellum* Bunge. It is much nearer *P. viscosum* Nutt.

✓ **Linanthus croceus,** sp. nov.—Stems generally several from an annual root, slender, $10–20^{\mathrm{cm}}$ high, hispid with a white pubescence appressed on the stems, spreading on the leaves, bracts, and flowers: leaves opposite, palmately divided generally into six spatulate or linear-acute segments, 3–7 mm long on the lower stem and almost twice as long near the flowers, appearing as if whorled with the internodes lengthening with age, in the young plants scarcely longer than the leaves: bracts of the terminal head of flowers as long as the calyx, palmately divided into five linear-acuminate divisions 7 mm long, 1 mm or less wide, the inner surface glabrous but the outer surface and involute margins hispid: divisions of the calyx twice as long as the cuneate tube, linear-subulate, aristate with pubescence similar to that of the bracts: corolla yellow, the tube filiform, 4–5 cm long, clothed with fine scattered spreading jointed hairs; throat broadly funnelform, expanding to the limb which is 1.5 cm across, with the divisions suborbicular, 5 mm wide, rounded at apex, generally with two faint lilac dots at base, sometimes the outer part of the lobes tinged with rose or lilac: stamens on capillary filaments, exserted, inserted at the base of the throat, 4 mm long; anthers yellow or orange, narrowly elliptical, a little more than 1 mm long: stigmas surpassing the stamens, 3 mm long; ovary with few ovules: fruit not seen.

This beautiful species was collected by the author May 9, 1901, near Pt. San Pedro, San Mateo county, California. It covered the ground for several acres, but was seen in no other place, and is probably a strictly local species. It is perhaps the most strikingly beautiful species of the group where it belongs, with the long threadlike tubes of the corolla supporting the wonderfully beautiful yellow disks. The great masses almost monopolized the ground. The species is well worthy of a place in the gardens, and would do well under the same conditions as its near relative *L. androsaceus*, from which it differs not only in color but also in leaves, shape and size of flower, and pubescence.

Linanthus Plaskettii, sp. nov.—Branching diffusely from an annual tap root and also above; the numerous stems slender, often reddish and cinereous with a scabrous, hispid pubescence: leaves opposite, digitately divided, appearing verticillate, spatulate, scabrous-ciliate or somewhat serrate with aristate teeth, 3–8 mm long, surface grooved between the midrib and the thick margins, somewhat scabrous especially near the apex and on the margins, appearing serrulate-aristate, the apex bristle-tipped:

involucral leaves linear, very hispid, scarcely distinguishable from the calyx divisions: calyx 8 mm long, keeled below each sinus, the division attenuate to a long stiff point a little more than half as long as the turbinate tube, bristly hispid with short, spreading, stiff-jointed hairs: tube of corolla filiform with pubescence similar to the calyx, exserted about 2.5 cm, the throat saucer-shaped, purple or brownish, the limb lilac, white or rose, 1 cm in diameter; divisions obovate, obtuse: stamens inserted in the throat of the corolla, with capillary filaments as long as the style: stigmas surpassing the anthers but not extending beyond the petals.

This is near *L. androsaceus* Greene, of which it may prove only a geographical variety. It differs in shorter, more pointed leaves, scabrous and glandular pubescence, flowers with more slender corolla tube, in which character it resembles *L. parviflorus* Greene. The stems are more numerous and more leafy, and the general appearance suggests a different plant.

The type is no. 90 of the collection of Mr. R. A. Plaskett from the Santa Lucia Mountains, collected April 11, 1898. It has also been collected by the author on the Milpitas Ranch in the San Antonio Valley, Monterey county, a part of the same mountain system.

✓**Navarretia Bowmanae**, sp. nov.—Stems simple or branched, often reddish, scabrous and cinereous with a fine, close, glandular pubescence, erect or spreading, 10–20 cm high: leaves bipinnately divided, the main divisions alternate or opposite, 7–15; ultimate and lowest divisions narrowly linear, less than 0.5 mm, spinescent at apex; rachis strongly ribbed, the distinction between it and the petiole not evident, the latter broadening at base, wanting on the upper leaves, varying much in length on the lower; blade and petiole on lower leaves about 7 cm long, on uppermost 1–2 cm; flowers lemon-yellow, in heads at the ends of the branches, 1–2 cm broad, surrounded at base by involucral leaves; bracts broadly ovate in outline, white-woolly near the base and glandular throughout, 7 mm long, 1 cm wide: calyx tube white, chartaceous, glandular, narrowly turbinate, ribbed, 4 mm long; divisions 3–5, unequal, aristate two longer than the others, corolla tube shorter than the longest divisions of the calyx, slightly glandular, throat funnelform, the limb consisting of 4–6 linear-oblong, obtuse lobes, 3 mm long, 1.5 mm wide: filaments inserted between the lobes and shorter, as long as the anthers: style extending 3 mm beyond the petals, conspicuously exserted even in the bud; stigmas small; ovary with one ovule in each cell.

This is related to *N. cotulaefolia* H. & A., to which it may be too closely allied. It is distinguished from this species, as I know it, by the glandular scabrous pubescence of stem and leaves, the woolly pubescence of bracts and calyx, the yellow corollas, the short stamens, and the conspicuously exserted style. It was collected at Anderson's Ranch, Lower Lake, Lake county, California, May 11, 1901, by Miss Agnes Bowman, in whose honor it is named. Heller's 5638 and 5432 appear to be the same. These were distributed as *N. cotulaefolia* H. & A.

Navarretia pterosperma, sp. nov.—Stems simple, low, 5–6^{cm} high, glandular pubescent and slightly villous-arachnoid: cauline leaves pinnatifid with 5–7 linear-acerose divisions almost as wide as the rachis; lower ones petioled, upper sessile and with the lower divisions again divided: heads small, about 1.5^{cm} broad, with the bracts broadly ovate in outline, once or twice deeply pinnatifid, the divisions linear-acerose, arachnoid on the margins (with a good lens): calyx 1^{cm} long, of five unequal, narrowly linear, acerose divisions, twice as long as the tube, which is thin and membranous between the stout ribs: corolla blue, with tube 7^{mm} long, narrowest at the middle below the insertion of the stamens, dilated to a base as broad as the funnelform throat; divisions 2.5^{mm} long, 1^{mm} wide, oblong, obtuse, entire, surpassing the calyx: stamens unequally inserted on short filaments, included, not reaching the throat of the corolla; anthers white: style short, with short divisions: capsule with thin walls through which the brown seeds can be seen: seeds flat, oblong or orbicular, winged, 1^{mm} in diameter, without spiracles or mucilage when wet, about five in each cell.

This is a rare species on Bodega Point, California, or it was late in the season, for few specimens were found growing amid the grass on the bluffs above the bay. It was collected July 4, 1900.

It is near *N. mellita* Greene, but has larger flowers, bracts less arachnoid and more dissected and larger, and seeds more distinctly winged. I noticed no odor about this plant when it was fresh, and there is none in the dried state. *N. mellita* does not lose its odor even when dry, and when the dried plants have been wet the odor is quite noticeable.

Gilia collina, sp. nov.—Stems branching, 15^{cm} high; lower part leafy, more or less clothed with cottony wool; inflorescence dotted with black or white stipitate glands: leaves lanceolate in outline, pinnately parted with 9–15 short divisions, the lobes or teeth of which are aristate; lowest divisions shortest, becoming tooth-like; rachis and petiole margined, the latter longest on the lowest leaves but not equaling the blade, together 1–3^{cm} long, 1^{mm} wide; upper leaves sessile: panicle loosely branching from above the leaves, more than half the height of the entire plant; bracts small and appressed to the stem, subulate; pedicels varying much in length: calyx 3^{mm} long, with five green or purplish-dotted ribs alternating with white membranous folds, the tube as long as the subulate-aristate teeth, ribs glandular: corolla pink, the tube 1.4^{cm} long, glandular, widening at base and throat; the divisions narrowly obovate, obtuse, margins entire or crisped: stamens inserted in the funnelform throat, with unequal filaments shorter than the petals; anthers small, orbicular: style surpassing the petals; stigmas hairy on the inner side; ovary with two ovules in each cell: capsule obovate to elliptical, 14^{mm} long, yellow, not all ovules maturing: seeds flat, elliptical, margined, becoming mucilaginous when wet.

This well-marked species belongs near *G. tenuifolia* Benth. and *G. inconspicua* Dougl. It differs from both in shape of leaves, and size and form of flower, having corollas with much longer tubes than any of the group. It was collected on a mountain near Hockett Meadows, Tulare county, California, by C. A. Purpus, June 1896, being no. 1783 of his collection. According to Mr. Purpus, it is found in openings under the trees in forests of *Pinus Jeffreyi*. It is common on gravelly hills on Hindman's Trail to Coyote Pass in the same region, where it was collected by the author July 1903.

✓**Gilia pedunculata,** sp. nov.—Stems diffusely branching with many slender stems, 10–30^{cm} high, upper part sparingly glandular and with a few scattered woolly hairs especially near the base of stem and in axils of leaves: leaves once or twice pinnately divided with 3–7 narrowly oblanceolate or filiform leaflets, the lower petioled, the upper sessile; peduncles filiform, axillary, 1–3-flowered, naked, 3–10^{cm} long: calyx 5^{mm} long, the subulate-acuminate divisions 3^{mm} long, the greenish or purplish midvein 3-nerved, the membranous margins and intermediate folds purplish-dotted, sparingly lanose: corolla blue, tubular-funnelform, the tube barely exserted, 5^{mm} long; the divisions oval, acute, 3^{mm} long: stamens inserted at the sinus, on filaments shorter than the anthers, less than 1^{mm}: style included in the tube, the stigmas extending to the throat: capsule surpassed but little by the divisions of the calyx, elliptical in outline, dotted with purple at summit, mucronate, glabrous: seeds several in each cell with trace of a white wing at some of the obtuse angles.

The type of this species was collected by the author on Alamo Creek, not far from Santa Maria, Santa Barbara county, California, May 24, 1896. It belongs to the same group as *G. millefoliata*, from which it differs in the less dissected leaves, more diffusely branching stem, longer and mostly one-flowered peduncles, and thick seeds. It presents quite a different appearance and seems peculiar to the southern part of San Luis Obispo county and northern Santa Barbara. There is a specimen from Santa Margarita and another from the Suey Ranch in the same general region collected also by the author.

GILIA PEDUNCULATA **minima**, var. nov.—Similar to the preceding in every way, but flowers and fruits less than half as large, and whole plant smaller.

Collected at Cuyama, May 5, 1896.

GILIA PEDUNCULATA **calycina**, var. nov.—Distinguished from the typical form by the smaller flowers, corolla tube constricted near the middle, and narrower calyx divisions conspicuously attenuate and green and surpassing the ripe capsule.

Collected by the author between Huasna and Pozo, San Luis Obispo county, June 15, 1902.

GILIA CALIFORNICA **glandulosa**, var. nov.— Differs from the typical form in the more crowded fascicles of leaves clothed with arachnoid-glandular hairs, and in the tomentose stems.

It is the common form growing around Pasadena, California. There are specimens in the Herbarium of the California Academy of Sciences from Mount Wilson, collected June 1903 by Fordyce Grinnell Jr.; from La Cañada Cañon by Miss Lulu Forbes; and from Arroyo Seco by Miss M. E. Parsons; also in the Sierra Santa Monica by J. C. Nevin.

CALIFORNIA ACADEMY OF SCIENCES,
SAN FRANCISCO.

NOTES ON THE MONTEREY PINE.

GEORGE J. PEIRCE.

(WITH FIVE FIGURES)

IN the spring of 1898 the entomologists of Stanford University discovered a fly, *Diplosis pini-radiatæ* Snow,[1] which produced a leaf-gall or at least a basal hypertrophy of the leaves (needles) of the Monterey pine (*Pinus radiata* D. Don.) Some of the botanical features of this insect attack were described in 1900 by Cannon.[2] Certain other features, as well as notes on other matters connected with this tree, I wish to add to what Cannon said.

As its name implies, the Monterey pine is a coast tree, "very restricted in its distribution: Pescadero, southwest of Monterey and Pacific Grove."[3] It is commonly planted, however, over a rather extended territory, though with a success which is evidently proportioned to two things: the rainfall and the humidity of the air in summer. It seems to thrive about San Francisco and on the ocean side of the peninsula which separates the southern half of San Francisco Bay from the sea, but it needs moister, cooler air in summer than it gets in this part of the Santa Clara Valley, although careful watering will keep it in fair condition even here. Along with the coast redwood (*Sequoia sempervirens* Endl.) this tree is subject to a great variety of enemies, in addition to being exposed in cultivation to unfavorable climatic conditions. In the arboretum of the university the unfavorable factors in the environment are most evident. To mention only conspicuous enemies of the pine, one finds *Arceuthobium occidentale*,[4] a *Peridermium*, certain fungi causing spots on the leaves, scale-insects, bark-borers, and the gall-

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[1] SNOW, W. A., and MILLS, MISS H., in Entomological News 11 :—. 1900.

[2] CANNON, W. A., The gall of the Monterey pine. Amer. Nat. 34 : 801–810. 1900.

[3] JEPSON, W. L., Flora of western middle California. 1901.

[4] I purpose publishing later a study of this phanerogamic parasite.

fly. In addition to these, field mice and other animals, whose depredations were concealed and facilitated by the long grass which was allowed to grow among the trees for a few years, made the already unfavorable environment almost unbearable. In various respects, however, conditions in the arboretum have improved.

Even at Pacific Grove, in a natural forest, this pine is just now having a hard struggle for existence. Conditions in this bit of forest have been considerably changed of late years, paths and roads having been cut through it, and a few years ago a serious fire swept over part of it. This forest is extremely important, for it is the main protection of the town of Pacific Grove against the sand which, now piled up in magnificent dunes, would otherwise be blown inland and over the town. It is still too early to determine whether the effort now being made to save this forest will be altogether successful.

The evident sensitiveness of these two trees, the redwood and the Monterey pine, is interesting in connection with their limited distribution. The redwood seems to be confined to the fog belt, the Monterey pine to only a small part of this. Moisture in the air is apparently the principal limiting factor, but the still further limiting one in the case of the Monterey pine is not evident. Seeds of this pine are now being extensively distributed for purposes of experiment. Whether it will prove under these new conditions to be more widely successful than it has hitherto been is a question of great theoretical as well as practical interest.

Turning now to the leaves of Monterey pines which have been attacked by the gall-fly, Diplosis, we shall see, in addition to the characters described by Cannon, certain other significant differences from normal leaves. At the same time that there is a very considerable thickening of the leaf throughout its length, but especially at the base, the leaf-surface is greatly decreased. The average diameter of 20 normal leaves one year old is 0.735^{mm}, as measured by micrometer caliper, and the length 94.8^{mm}. The average diameter of 20 galled leaves one year old ranges from 1.72^{mm} at the base to 0.62^{mm} at the middle, and the average length is 19.5^{mm}. The shape of all these leaves is far from mathematically regular, hence any attempt at measuring the surface area will necessarily give only approximate results; but let us assume for comparison that the difference between a galled and a healthy leaf on the one hand and a regular cone on the other is approximately equal. If we multiply the diameter at the base by $\pi = 3.14$, thus getting the circumference of a regular cone at the base, and this figure by one half the length of the needle (one half the height of a regular cone), we shall get the area of a regular cone. The calculated circumference is too large, for two of the lines bounding the base of a pine needle are straight; but, on the other hand, the diameter of a pine needle is less at the base than a short distance above. The cone, therefore, is not regular; the needle is larger above than at the base, tapering toward both base and tip. Nevertheless, using this faulty method of estimating surface areas, we have comparable figures —$109.35^{\text{sq mm}}$ as the area of an average normal needle, and $52.65^{\text{sq mm}}$ as the area of an average galled needle. The surface of average normal leaves, therefore, is approximately twice that of galled cones.

The weight of the 20 normal leaves which I measured is 0.8595^{gm} and of the 20 galled ones 0.395. So far as expenditure of leaf-building material is concerned, there is a difference of about 50 per cent. between normal and galled leaves. But besides weight and surface area the number, size, etc., of stomata should also be considered. The stomata appear alike on normal and on galled leaves, but there are four times as many on the former as on the latter.

Between normal and galled leaves the physiological differences will at least equal the anatomical ones. Thus there will be considerable differences in the amount of water lost through the stomata, in the amount of food made in the chlorophyll-containing tissues, and in the amount of food consumed in healthy and in diseased leaves. The larvae in the galls may consume more food than is made in the leaves at the bases of which they develop from the eggs, as they may be sufficiently nourished from the leaves alone. On this point there is at present no light. If the larvae consume more food than the immediately adjacent leaves make, this food will certainly consist mainly of organic compounds drawn through, if not exclusively from, the branch on which the leaves stand. It is therefore the phloem elements upon which the demand for food will be made directly. If bundles coming into fallen leaves be cross-sectioned, for example at such a point that the bundles lie in the cortex of the branch about midway between the epidermis and inner bark, and these cross-sections be compared with corresponding ones of the bundles of healthy leaves, the differences between the bundles will be clear. The simplest way to compare is to cut out and weigh the pieces of bristol-board on which camera drawings of the sections have been made. Thus the cross-section of the normal "leaf-trace" (phloem, xylem, and enclosed pith) weighs 0.429$^{\text{gm}}$, that of the "leaf-trace" of a group of the galled leaves weighs 0.210$^{\text{gm}}$; the xylem of the former 0.082$^{\text{gm}}$, the phloem 0.335$^{\text{gm}}$; the xylem of the latter 0.052$^{\text{gm}}$, the phloem 0.155$^{\text{gm}}$. That is, the normal "leaf-trace" is more than twice as large as that of the galled cluster, the xylem of the normal one and a half times the galled, while the phloem of the normal is also more than twice that of the galled. If one judge the efficiency of tissues by the extent to which they are developed — a criterion by no means above criticism — the conclusion is forced upon one that, so far as one year old leaves show, healthy leaves have more work done in them than do galled leaves. This work is of various kinds. *First*, more water and mineral solutes pass through the bundles into normal than into galled leaves, and more water is transpired from healthy than from diseased leaves. *Second*, more food is made in normal than in galled leaves, assuming that the greater amount and more favorable exposure of chlorophyll-containing tissues in normal leaves is a safe index. *Third*, more food is removed through the phloem to other parts of the plant from healthy than from galled leaves. Although the galled leaves nourish larval insects, the development of their conducting tissues is less than that of normal leaves. The processes especially characteristic of leaves — food-manufacture and the attendant movements of solutions up and down the leaf — are less active in galled than in healthy leaves, and the conducting and other tissues especially concerned with these processes are developed correspondingly.

Passing from the leaves to the branches, comparison of cross-sections of branches bearing galled leaves with cross-sections of other branches bearing only normal leaves, reveals certain differences. If one makes a series of cross-sections through successive segments of one branch, the leaves of which have been attacked in successive years by the gall-fly, and a similar series of cross-sections through a branch which has borne only healthy leaves, we shall see that the growth of the branch in thickness each year is proportioned to the amount of galling which has taken place. The accompanying figures show this. In *fig. 1* we have part of a cross-section of a branch, the oldest wood in which was formed in 1894. The drawing is by Leitz drawing prism. I have known this tree and watched it constantly, beginning with the spring of 1898, the year when, according to entomologists, the attacks of the gall-fly were the worst. The fly first appeared in noticeable numbers in 1896, and since 1900 it has been far less numerous than in the preceding five years. The narrow annual rings indicated in the above drawing coincide exactly with the most serious attacks of the gall-fly.

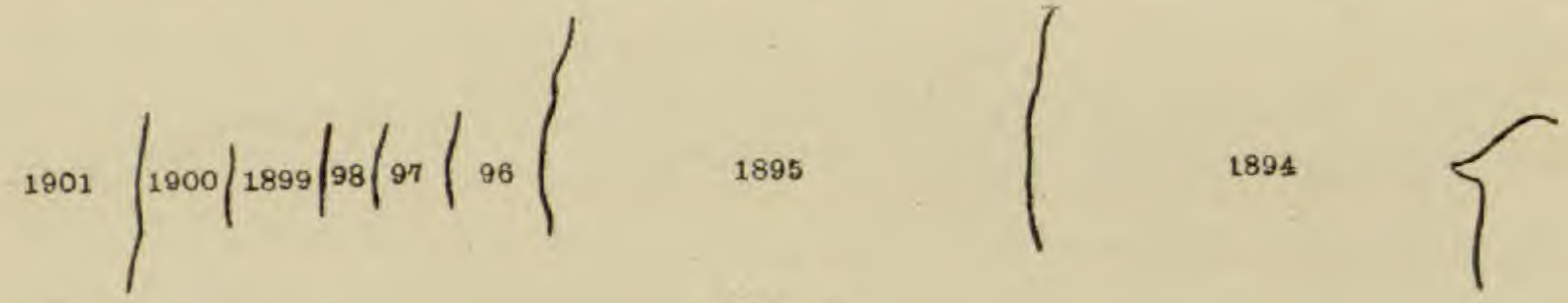

FIG. 1.

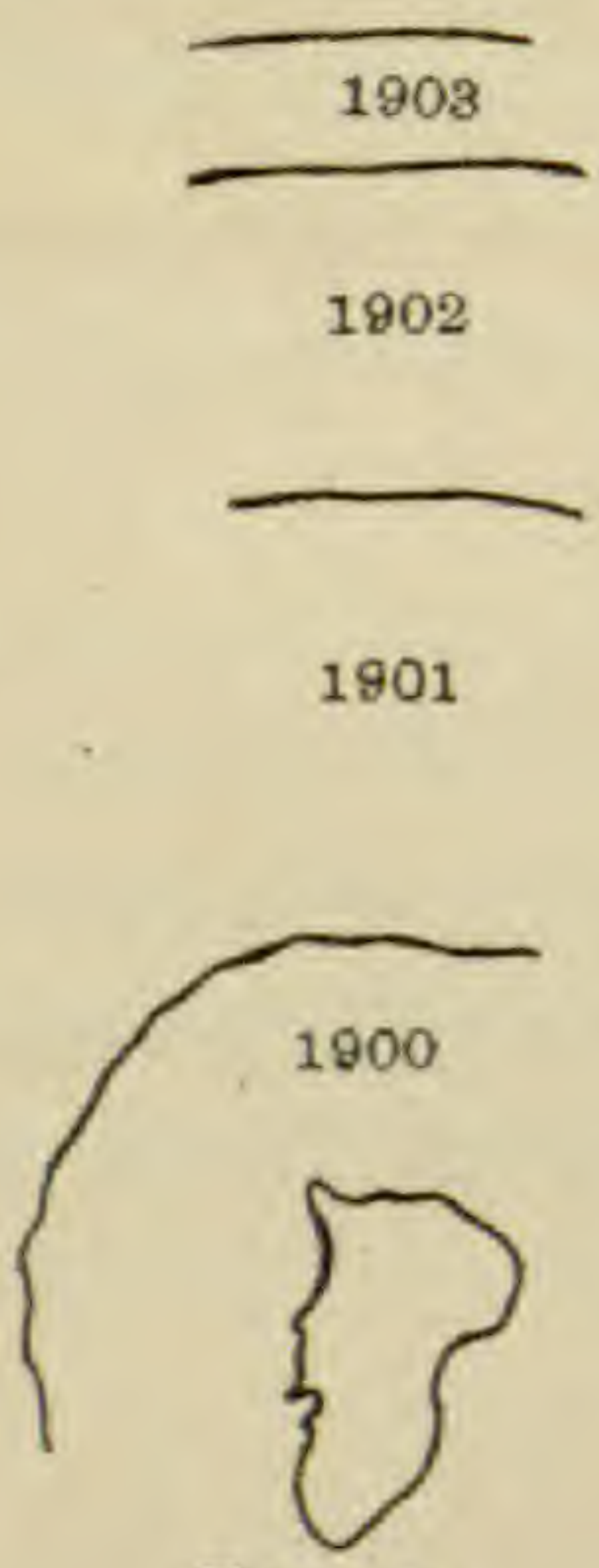

FIG. 2.

In *fig. 2* we have a branch the oldest wood in which was found in 1900. The terminal bud of this branch had been injured shortly before I cut it, which was in March 1903, when I collected all the material here figured. On this branch I counted all the leaves still present, and the numbers were as follows: 1 normal leaf still attached to the part of the branch begun in 1900, 40 galled and 26 normal leaves on the 1901 segment, 31 galled and 70 normal leaves on the 1902 segment, and no galled leaves at all on the new growth of 1903. It may be mere accident, of course, that the one leaf which held on from 1900 to 1903 should have been a normal one, but this is what one should expect from the nature of the case. A healthy leaf, contributing normally to the plant which bears it, should be retained longer than diseased leaves.

FIG. 3.—No galls.

In *fig. 3* is shown a cross-section of the youngest part of a branch on which there were no galled leaves. The growth at the time of collecting had already been considerable. This growth is greater than that on a branch which had borne galled leaves, for the diameter of this branch is greater than the diameter of the whole first season's growth of the branches shown in *figs. 2–5*, which were drawn on the same scale. I believe this to be a general difference, for all the sections I have made are consistent with those here figured. And we should expect on general principles that the growth of a tree or a branch which had been healthy in preceding seasons would be greater and better than that of diseased trees or branches.

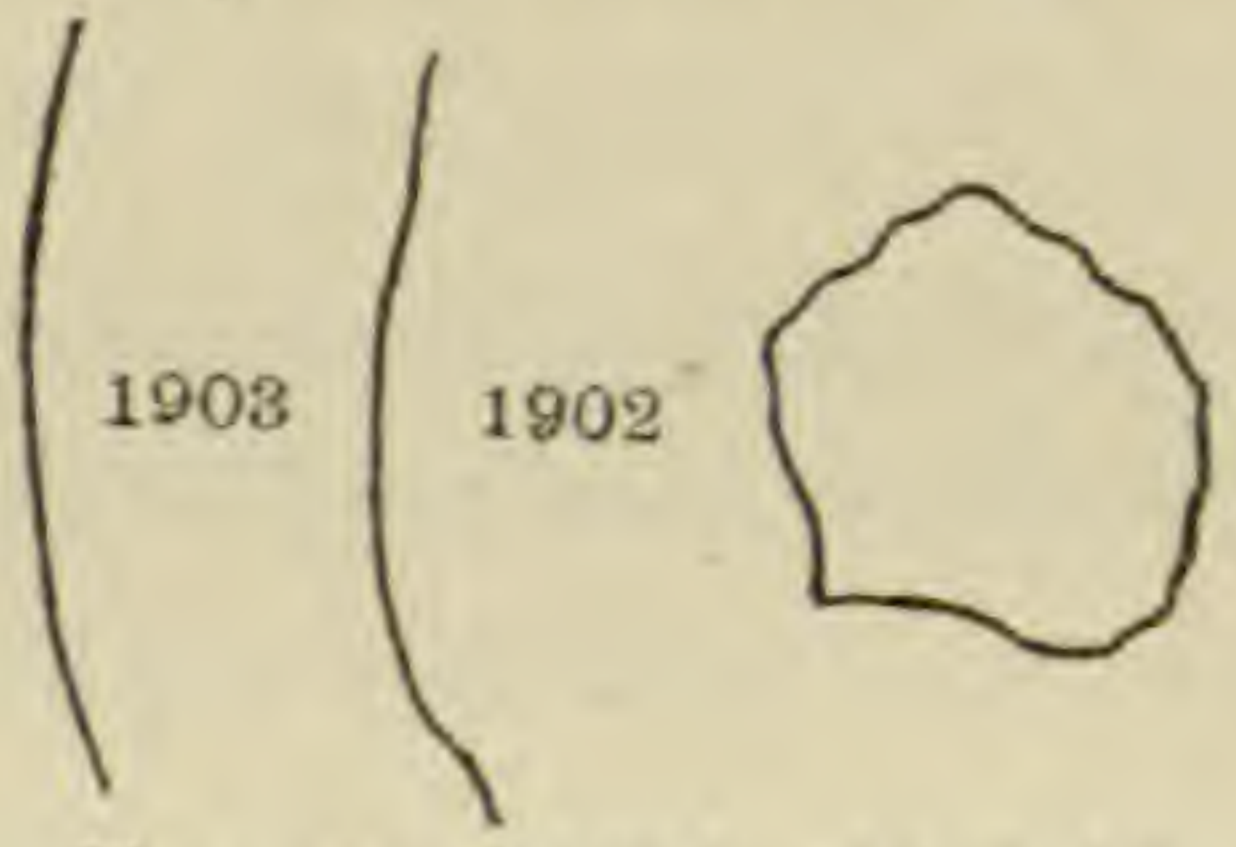

FIG. 4.—1902, 15g. to 68n. 1903, no galls.

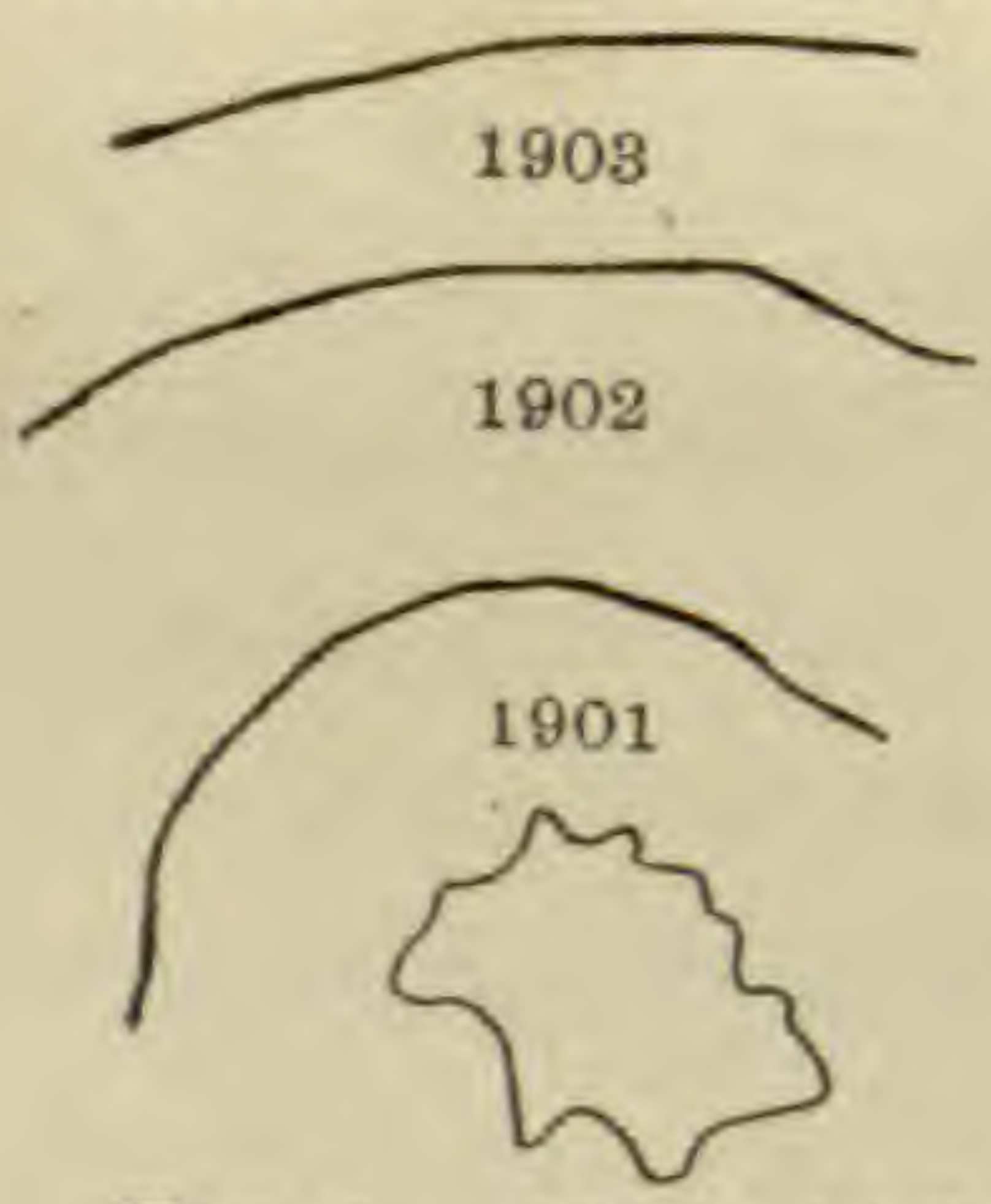

FIG. 5.—1901, 14g. to 8n. 1902, 15g. to 68n. 1903, no galls.

In *figs. 4* and *5* we have further evidence to confirm the opinion expressed above, that the width of the annual ring, or to put it more generally, the growth of the vascular bundle, is proportioned to the growth of the leaves borne on the branch. When one realizes that these sections are from different branches on the same sides of the same trees, that therefore the conditions other than those produced by the parasite were similar each season for healthy and for galled branches, one is compelled to attribute the difference to the effects of insects.

Taking into account what was said above about the differences in area between normal and galled leaves, and also the fact that there are no anatomical or microchemical differences in the surface cells of the two sorts of leaves, one is led to infer that the differences in the quantities of water (and solutes) drawn up through the xylem into galled and normal leaves furnish the reason for the differences in the amounts of conducting tissue as shown by the annual rings.

In 1893 Jost[5] concluded from a series of experiments which he made on seedlings and on certain older woody plants, that the development of the vascular bundles is very intimately connected with the development of the leaves. His experiments consisted in part in removing the leaves when the seedlings were very young or in forcing leaves to develop from the bud in darkness. Any experiment which involves amputation or other serious injury is obviously to be used only very guardedly as the basis of conclusions regarding the relations of parts to each other. An experiment involving the amputation of a leaf shows two things: the effect of the wound and the effects due to abuses of the leaf and of the processes normally going on in it. Which is the predominant influence no one knows, and whether the result is not a *resultant* rather than the *sum* of two different effects is also unknown. It is conceivable that a reduction of the leaf surface, or the suppression of the whole organ without wounding, might have a different effect from cutting off a leaf. This Jost tried by causing leaves to develop in darkness from the bud. But here again more than one thing is involved. The formative and directive influences of light as well as its influence on the photosynthetic and other processes connected with nutrition going on in the leaf, are all eliminated. Though no wound is made, the result may again be a *resultant* rather than the *sum* of the factors concerned. The results which Jost obtained agreed, however, in that, whether the leaves were removed or were reduced by being grown in darkness, the vascular bundles were much smaller. Jost used among other plants two species of Pinus.

If we now compare Jost's results with ours, we see that they

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[5] JOST, K., Beziehungen zwischen Blattentwickelung und Gefässbildung in der Pflanze. Bot. Zeit. **51**:89–138. 1893.

are similar. Normal seedlings and normal-leaved pine branches develop bundles of normal proportions, while amputated seedlings and branches bearing galled leaves develop bundles which vary from the normal according to the degree of injury which the leaves have undergone. In the case of Jost's seedlings the consequences of amputation are clear. That they are the results of any one set of factors is by no means clear. In the case of these Monterey pines we have plants which are also profoundly although gradually influenced by the treatment to which they have been subjected. No wounds are produced by the gall-fly depositing its eggs at the bases of the young pine needles, there is no sudden shock to the whole plant, and there is no sudden or great change in the weights, or the position of the weights of the leaves. The galled leaves have less area and less chlorophyll-containing tissue than normal leaves, they lose less water by evaporation and contribute less food to the plant as a whole than normal leaves do. They may consume more food than normal leaves, but this is by no means certain. The products of the gall-larvae—excreta of various sorts—certainly affect the leaves at the bases of which they live and it may be that these substances are carried to considerable distances and affect the growth of the tissues in the branches. But of this there is no evidence unless we assume that these excreta affect only the young cells of the xylem. It seems to me reasonable, therefore, to conclude that it is principally the reduced surface from which water is evaporated, and that the decreased food-manufacturing tissue is only a minor cause, to which the smaller amount of wood and the narrower annual rings can be attributed. We have then in this pine a confirmation of Jost's conclusions that leaves and vascular bundles are closely correlated in their development, a confirmation the more interesting because it is furnished by gradual change rather than by sudden and shocking influences, by influences which operate out of doors, under natural conditions, where there can be no suspicion that the results are due to more or less obscure laboratory causes.

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BRIEFER ARTICLES.

THE CELLOIDIN METHOD WITH HARD TISSUES.

THE following celloidin method, developed and perfected by Dr. E. C. Jeffrey, has been incompletely described at second or third-hand elsewhere,[1] but is here published in full for the first time, in response to numerous inquiries from persons interested in the photomicrography of plant tissues, and in the preparation of large numbers of uniform sections for class use. This method has been employed in the laboratories of plant morphology of Harvard University for two years, and when judiciously applied it is found to leave practically nothing to be desired. The hardest tissues may be cut as thin as 5 μ or less, without difficulty, if they are first properly treated, and the sections thus obtained are perfectly adapted to photographic requirements. Briefly stated, the method as specialized for the study of wood and other objects containing skeletal tissues, is as follows:

I. *Preparation of material.*—If wood is to be studied, it should be cut up into cubical blocks, in such a way that the faces represent accurate transverse, radial, and tangential sections. The best results are obtained from cubic blocks of not more than 1^{cc}, though much larger ones may be used if the time of treatment be proportionately increased. Material other than wood should be cut in similarly small pieces, and in such a way as to afford the desired plane of section. If the material is dead and dry, the pieces should be repeatedly boiled in water and cooled, in order to remove the air. It is well to pump out the remaining air with a good vacuum pump. In case living material is to be studied, the protoplasm may be killed and fixed by placing the blocks directly in the following solution:

Mercuric chloride, saturated solution, in 30% alcohol - - -	3 parts
Picric acid, saturated solution, in 30% alcohol - - - -	1 part

After twenty-four hours this solution is to be washed out by passing the blocks through alcohols of grades 40, 50, 60, 70, and 80 per cent. Twelve to twenty-four hours should be allowed for each change of alcohol, and the 80 per cent. alcohol should have enough iodin solu-

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[1] CHAMBERLAIN, C. J., Methods in plant histology, p. 55; also MILLER, C. H., On embedding in celloidin. Jour. Applied Micr. **6**: 2253–2254. 1903.

tion added to it to keep it of a deep brown color. Moderate heat — 50° C. — hastens the process. Chromic acid and chromates, though extremely useful fixing agents for certain kinds of objects, are not at all desirable for lignified tissues, as they are rendered yet harder by the use of these reagents.

II. *Desilicification, etc.*— Woody tissues usually contain more or less silica and other mineral deposits which render sectioning difficult or impossible. Hence it is of primary importance that these substances be removed as thoroughly as possible. For this purpose dilute hydrofluoric acid is indispensable. A 10 per cent. aqueous solution of the commercial acid is most useful. This may be kept in a bottle coated internally with a thick layer of hard paraffin. The blocks of material are transferred directly from the water in which they were boiled, or from the 80 per cent. alcohol and iodin, as the case may be, and are kept in the acid three or four days, with one or two changes of the acid and frequent shaking of the bottle. Wash out the acid thoroughly in running water for two to four hours. This treatment frees the tissues completely of all mineral deposits, while the organic structure remains unaffected. It has been shown[2] that cellulose, constituting the cell-walls of plants, when freed from mineral deposits is of practically uniform hardness, regardless of the plant or part of the plant in which it may occur. This hardness is about equal to that of muscovite, while the tissues in their natural condition often are equal in hardness to calcite, fluorite, or even opal. Hence it is evident that the usefulness of hydrofluoric acid in this connection can scarcely be overestimated.

III. *Dehydration.*— The water must be again removed from the material by passing it through alcohols of grades 30, 50, 70, 90 per cent., and absolute, allowing twelve hours in each grade. At least one change of absolute alcohol is usually desirable, as complete dehydration is of the first importance. The remaining air should be removed from the blocks when they are in 60 or 70 per cent. alcohol, by means of the vacuum pump.

IV. *Infiltration with celloidin.*— Make a series of celloidin solutions by dissolving Schering's celloidin (Schering & Glatz, New York) in equal parts of ether and synthol or absolute alcohol. There should be ten grades: 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 per cent. For the 2 per cent. solution take two grams of celloidin to 100^{cc} of the ether and synthol, or ether and absolute alcohol mixture. For 4 per cent. take

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[2] OTT, EMMA, Beiträge zur Kenntniss der Härte vegetabilischer Zellmembranen. Oesterr. Bot. Zeitschr. **50**: 237–241. 1900.

four grams to 100^{cc}, and so on, through the series. Synthol (Bausch & Lomb Optical Co., Rochester, N. Y.) is a better solvent of celloidin than is absolute alcohol, and when it is used two more grades of celloidin — 22 and 24 per cent.— may well be used.[2]

Transfer the blocks from absolute alcohol to the 2 per cent. solution celloidin. See that the bottle is almost filled, then wire or clamp the stopper firmly in place, and put the bottle on its side in an ordinary paraffin bath at 50° to 60° C. for twelve or eighteen hours. Then cool the bottle quickly in cold water, taking care that the water does not get into the bottle. Next pour out the 2 per cent. celloidin solution and replace it with the 4 per cent. solution. Proceed in the same way with this and all the following grades of celloidin, up to the most concentrated, and when this grade is reached it is to be graduallv thickened by adding a few chips of dry celloidin from time to time, until the mixture in the bottle is quite stiff and firm. With a pair of forceps the blocks are now to be pulled out of the bottle, each with a coat of celloidin adhering, and are to be put into a bottle of chloroform to harden for twelve hours. From this they are transferred to a mixture of equal parts of 95 per cent. alcohol and glycerin, where they should remain for a few days before cutting, and where they will keep for an indefinite period. The time given to the process of infiltration should in no case be shortened, except for very small objects. An increase of the time is often advantageous.

V. *Sectioning*.—The sliding type of microtome is a necessity in the cutting of celloidin material. The best pattern is the Thoma, as recently adapted, at the suggestion of Dr. Jeffrey, for cutting hard tissues. The knife should be extremely hard, as supplied for this purpose by Jung of Heidelberg, and should be kept honed to a keen, smooth edge. It is best to grind and hone the knife with a back, in order that the edge may not be too thin. The blade of the knife should have a dip of about ten degrees in the holder, and should be set more or less obliquely to the line of motion, according to the nature of the material, so as to make a long sliding cut. All bearing surfaces should be thoroughly cleaned with ether and then flooded with the best quality of oil each time the microtome is set up for use. The block of material, if very hard or large, is to be clamped in a special object-carrier (as supplied by Jung), in such a way as to give the desired plane of section. Smaller and softer objects may be cut on the ordinary

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[2] The celloidin solutions may be used repeatedly, and should be kept in bottles lying on their sides, to prevent excessive evaporation and concentration of the solutions.

object-carrier. The object-holder in the latter instance consists of a tube of thin metal, plugged with hard wood. The end of this wooden plug is thoroughly coated with celloidin by dipping it repeatedly in 4 per cent. celloidin and drying in the paraffin bath. The block of material is attached to this holder by means of a drop of the 4 per cent. celloidin. One face of the block must be trimmed flat and freed from glycerin before applying it to the moistened surface of the holder. It will set firmly in a few minutes. Run the carrier slowly up the ways by means of the feed-screw, cutting off the celloidin and trimming the block to the desired level. Do not cut thick pieces from the block with the microtome knife, as the latter is very apt to be injured in this way. Adjust the feed-mechanism to give the desired thickness, and then with a camel's-hair brush flood the knife with 90 per cent. alcohol, and, holding the brush lightly on the top of the object, float the section out upon the knife. A slow, steady stroke of the knife generally gives the best results. The section is then removed from the knife by means of the brush, and is to be kept in 90 per cent. alcohol until needed for the next step in the process. The thickness of the section must depend upon the purpose for which the sections are made. For ordinary study with the microscope, 10μ is usually quite thin enough, but for photomicrography it is often desirable to have sections as thin as 5μ or even less.

VI. *Staining and mounting.*— To prepare the sections for staining and mounting, it is usually most convenient to remove the celloidin at once by placing the sections for ten or fifteen minutes in ether, then wash in 95 per cent. alcohol, after which they may be transferred to water, stained, cleared, and mounted in the usual way. One of the most useful stains is the haematoxylin-safranin double stain. First stain the sections to a fairly dense purple in an aqueous solution of Erlich's haematoxylin ; wash in dilute aqueous solution of calcium or sodium carbonate, and then in two changes of distilled water. Add a few drops of alcoholic solution of equal parts of Grübler's alcoholic and aqueous safranin, and stain to a rich red. A fairly dilute stain acting for one or two hours will give better results than a more concentrated stain acting for a shorter time. Transfer the sections directly to absolute alcohol, dehydrate rapidly, and transfer to xylol, benzol, or chloroform, and mount in Canada balsam (which has been previously thoroughly dried) dissolved in xylol, benzol, or chloroform. Sections should be cleared in the same kind of liquid as is used for dissolving the balsam in which they are to be mounted.

An extremely satisfactory stain for photographic purposes is the iron-alum haematoxylin of Heidenhain. The method with this stain is given in full by Chamberlain.[3] We find it desirable to wash the sections repeatedly in distilled water after using the iron-alum, before placing them in the haematoxylin. This stain is especially useful in the study of wood sections. A contrast stain of safranin may be added if desired, but it is of doubtful value for practical purposes.

It frequently happens, as in sectioning buds, ovaries, etc., that it is necessary to preserve the celloidin matrix of the section in order to prevent displacement of the otherwise separate parts of the section. In this case the sections are transferred directly from 90 per cent. alcohol to water, and are stained as usual. Dehydrate in a mixture of absolute alcohol and chloroform, clear and mount. The chloroform counteracts the solvent action of the absolute alcohol, and preserves the celloidin film perfectly.

VII. *Serial sectioning*.—In order to make serial mounts by the celloidin method, the sections are cut in the following mixture, instead of in 90 per cent. alcohol: 90 per cent. alcohol 85 parts, glycerin 15 parts. As the sections are cut they are to be arranged on a piece of smooth, thin paper. As soon as the alcohol has evaporated from the sections, turn the slip of paper face down upon a slide which has been coated with albumen fixative, add several layers of paper, and press the whole firmly down upon the slide by means of a photographic squeegee roller; then put another slide on top of the layers of paper, clamp all together by suitable spring clips, and place in the paraffin bath to dry for not more than twelve hours. A longer time than this renders the celloidin more or less insoluble. The paper may now be stripped off, leaving the sections firmly attached to the slide. Pass the slide through alcohol, ether, alcohol, stain, etc., as with separate sections.

The most important steps in this method are desilicification and dehydration of the material. With due attention to these points, and with a proper allowance of time for infiltration, the hardest tissues may be put in perfect condition for sectioning.

The method is found to be of special value wherever it is desirable to reproduce with absolute fidelity by means of photomicrography the appearance of skeletal and other hard tissues of plants. The greatest usefulness of the method, however, is in connection with the teaching of morphology and histology, insuring as it does the absolute uni-

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[3] CHAMBERLAIN, C. J., Methods in plant histology, p. 38.

formity of sections for the entire class, thus greatly facilitating the work of instruction, and conserving the energy of both instructor and student.—AMON B. PLOWMAN, *Harvard University.*

ANATOMICAL NOTES ON CERTAIN STRAND PLANTS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LVIII.

THE following notes embody the results of a comparative study of the leaf anatomy of certain plants occurring on the Atlantic coast in the vicinity of Woods Hole, Mass., and also near Lake Michigan in the vicinity of Chicago, Ill. Several of the plants are typical strand plants, *e. g.*, *Cakile americana;* others frequently or even generally occur at a greater distance from the shore. A similar study ot French strand plants has been made by Lesage,[1] and the results recorded in the present paper largely confirm those of the earlier writer.

1. Plants growing in the maritime situation are found to have thicker leaves than the same species growing inland.

Plants	THICKNESS OF LEAF IN MM.	
	Inland	Maritime
Cakile americana	0.76	1.17
Lathyrus maritimus	0.28	0.32
Euphorbia polygonifolia	0.28	0.38
Xanthium canadense	0.39	0.60
Atriplex hastata	0.19	0.49
Hibiscus Moscheutos	0.13	0.23
Convolvulus sepium	0.24	0.31
Solanum nigrum	0.31	0.37
Polygonum aviculare	0.15	0.27

The foregoing measurements represent average thickness of different leaves and different parts of leaves. Since the Lake Michigan specimens were collected in June and the Woods Hole specimens in July and August, it was thought that the difference in time of collection of the inland and maritime material might introduce a source of error. Accordingly additional specimens of several species were secured in the Lake Michigan region in October, and these yielded the same measurements as those collected in June. It will be seen from the table that in some cases the maritime form is only slightly thicker than the inland form, while in other cases the former is nearly twice as thick. Measure-

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[1] Rev. Gén. Bot. 2:55. 1890.

ments of fourteen species found only on the seashore or in the adjoining salt marshes showed that most of them possess thick leaves, while several cases merit the term succulent, *e. g.*, *Arenaria peploides* (thickness 3^{mm}); in this plant and several others the stem also partakes of the fleshy character.

2. This increase in thickness of the leaf is always due, at least in part, to an increase in thickness of the palisade layer; for example, in *Xanthium canadense* and *Atriplex hastata* the palisade is about twice as thick in the maritime form as in the inland form.

3. In some cases the number of palisade layers is increased in the maritime situation; for instance, *Convolvulus sepium* has two layers in the inland form, but three in the maritime.

4. Several species, such as *Atriplex hastata*, *Xanthium canadense*, and *Polygonum aviculare*, show a tendency to the isolateral form on the seashore, while they are distinctly bifacial when growing inland. In Xanthium the cells of the spongy parenchyma adjoining the lower epidermis are irregular in the inland form, but in the maritime form are elongated in a direction at right angles to the surface, forming a true palisade, which is more lacunar, however, than that on the dorsal side of the leaf. The only plant which showed the isolateral structure in both habitats is Cakile; this showed merely an increase in the number of layers of palisade cells in the maritime form. However, of the fourteen distinctly maritime plants mentioned above, only three showed the bifacial structure, viz., *Ligusticum scoticum*, *Artemisia Stelleriana*, and *Sabbatia stellaris;* so that the isolateral structure seems to be typical of the maritime condition.[2]

5. A marked increase in compactness of the mesophyll was observed only in *Convolvulus sepium;* several other species showed this character in a very slight degree.

6. Turning to the epidermis, the outer wall was found to be from one and a half to two times as thick in the maritime form as in the inland form in *Cakile americana*, *Lathyrus maritimus*, and *Atriplex hastata*, but did not exceed 7μ in any of these cases.

7. The surface was found to be rougher in the maritime form in the case of *Euphorbia polygonifolia* and *Atriplex hastata.*

8. A noteworthy observation is the presence of hairs in the maritime form of *Lathyrus maritimus* and *Convolvulus sepium*, while no hairs were found in the inland form. The Convolvulus material collected on an exposed gravelly shore at Woods Hole showed long stiff

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[2] WARMING, EUG., Halofyt-Studier 247.

dead (protective?) hairs and knob-shaped partly sunken glands; the inland form showed only the glands. None of the true halophytes showed slender dead hairs, though a few, such as *Buda marina*, possess glandular hairs. *Artemisia Stelleriana*, found in the same habitat as Convolvulus, has a dense covering of long silky hairs.

9. The stomata were examined with respect to distribution on the two surfaces, level with regard to the surface, and form. The only significant point observed is the presence of a few stomata on the upper surface of Convolvulus in the maritime form, while stomata are confined to the lower surface in the inland form. This observation does not support the accepted view that conditions on the maritime strand are essentially xerophytic, for so-called xerophytic leaves usually have stomata only on the under surface. Moreover, out of twenty-four species found near the shore at Woods Hole, all but three (viz., *Ligusticum scoticum*, *Artemisia Stelleriana*, and *Sabbatia stellaris*) have stomata on both surfaces. In seventeen species the stomata are level with the surface, in three sunken less than half the thickness of the epidermis, in four (viz., *Euphorbia polygonifolia*, *Atriplex hastata*, *A. arenaria*, and *Polygonum maritimum*) sunken half or more than half the thickness of the epidermis.

The differences noted in the foregoing paragraphs point with few exceptions to a more xerophytic structure in the leaves of the maritime specimens than in those of the inland specimens of the same species. Since most of the conditions on the strand of Lake Michigan are very similar to those on the Massachusetts coast, it is natural to look to presence of salt in the soil or in the air as the cause of the differences observed. To further test this point specimens of *Solidago sempervirens* were collected from stations (1) as near as possible to the strand, (2) one hundred feet back from the water's edge, on the slope of a hill, (3) on the edge of a marsh bordering a brackish pond. The leaves presented the same structure in all three cases, but the average thickness was as follows: from (1) 0.50^{mm}, from (2) 0.36^{mm}, from (3) 0.56^{mm}. There are evidently several factors of which account must be taken in dealing with figures such as these, but the observation seems plainly to support the assumption that the amount of salt present influences the thickness of a leaf. Measurements were also made of leaves of *Statice Limonium* collected from four situations whose salt content was estimated by titration with silver nitrate. The results of this set of experiments show a general correspondence between thickness of leaf and saltiness of substratum, but the results are not altogether trustworthy because of the inconstancy in amount of salt in a salt-marsh during the growing season.—M. A. CHRYSLER, *The University of Chicago.*

CHROMOSOME REDUCTION IN LILIUM CANADENSE.

THE investigations, a brief résumé of whose results is given below, were carried on upon the dividing pollen mother-cells of *Lilium canadense* L., collected in the vicinity of Madison during the past five summers. A fuller account, with figures, is practically completed, but as it must be some time before it appears in print, and as the results are in some points quite different from those obtained by any previous observer, it seems advisable at this time to publish a brief statement of my observations.

After the completion of the division which forms the pollen mother-cell, there is a long period during which the cell and nucleus increase greatly in size. The nucleus contains during this period, in addition to the nucleoles, numerous irregular masses of considerable size, connected by narrow strands or fibers, the whole forming an extremely irregular network. In preparations stained with Flemming's triple stain, the larger masses show an affinity for the safranin, the fibers for the violet. There are also numerous short, fine, blue-staining fibers attached to the larger bodies, giving the network a ragged appearance.

This general arrangement persists until just before the passage of the nucleus into the condition of synapsis, when the blue-staining fibers begin to grow longer and to become more uniform in thickness; at the same time the larger masses or knots decrease in size. While these changes are going on, it is evident in many portions of the network that two fibers lie side by side and parallel; sometimes such parallel strands are attached at their corresponding ends to the same red-staining mass. While this rearrangement or pulling out of the nuclear material into threads is going on, all of the chromatic nuclear substances become massed against one side of the nuclear membrane, resulting in the synaptic figure so often described. The formation of the spirem is not fully completed until after the occurrence of this eccentric massing; there is, therefore, in this case no "dolichonema" stage preceding synapsis.

As has been said, while the spirem is being formed, it is seen in many places to consist of two parallel threads; and this continues to be the case until all of the staining substance within the nucleus, excepting the nucleoles, has been distributed along the spirem. In other words, the spirem is double; and its double nature results, not from an early longitudinal split, but from the presence of two separate and distinct threads.

The two threads are in general parallel; in many places they are loosely twisted about each other, in others they diverge more or less widely. Almost immediately after their complete formation they approach each other more closely, become appressed and twisted about each other, and finally fuse into a single thread whose appearance gives no evidence of its double origin.

After the formation of the two threads and before their fusion, each one shows in favorable material (especially if stained with Heidenhain's iron-alum-haematoxylin) a differentiation, noted by many writers, into darkly-staining chromatin bodies (chromomeres) and a more lightly-staining ground substance, or linin. As the threads approach each other, they become so arranged that in general, though with occasional exceptions, each chromomere in one thread lies opposite one in the other thread; and the fusion of the threads is followed by a fusion of the chromomeres in pairs. The single thread formed by the fusion then contains a row of chromomeres which show no sign of their double origin; but each original chromomere, as well as each one resulting from the fusion, is plainly made up of a large number of smaller granules.

This fusion of the threads and of the chromomeres occurs very early in the period of synapsis; but after the fusion the synaptic condition persists, certainly for days, perhaps for a week or more. Toward the end of this period, the aggregation of the spirem becomes gradually looser, and there follows a stage in which the thread is very evenly distributed throughout the nuclear cavity, and is in contact with the nuclear membrane at very many points.

While the spirem is in this distributed condition, it becomes longitudinally split, the splitting of the thread being preceded by a fission of each chromomere. The halves of the split thread are much twisted about each other, and, except for the manner of its distribution within the nucleus, the appearance of the spirem at this stage is in all respects strikingly similar to its appearance immediately before the original fusion.

There now ensues another change in arrangement; the thread is drawn inward from many of its points of contact with the nuclear membrane, and the greater proportion of its mass becomes aggregated in the central portion of the nuclear cavity, giving rise to a figure which recalls that of synapsis. This later stage of aggregation was figured and described by Miss Sargant ('96, '97) as a "second synapsis;" and it is the stage described as synapsis by Ernst ('02), who apparently did not see the synapsis stage, properly so-called.

Those portions of the split thread which lie in the peripheral region of the nucleus at this stage consist of loops which originate in, and return to, the central mass. The number of such loops is twelve. Transverse segmentation now occurs by the breaking apart of each loop in its peripheral region; each chromosome when first formed has its ends, therefore, at the periphery, and its median portion involved in the apparently tangled mass in the center of the nucleus. This is the general rule; but sometimes a chromosome lies comparatively free from its fellows, so that it can be followed throughout its length.

An arrangement of the spirem into loops just before segmentation has been found by Schaffner ('97) in the macrospore mother-cell of *Lilium philadelphicum*, and by Farmer and Moore ('03) in the heterotypic divisions of both animals and plants; but, according to their descriptions, segmentation occurs somewhere in the central region of the nucleus, so that the peripheral portion of each loop becomes the central part of one of the newly-formed chromosomes. The looping, as they conceive it, is preparatory to the bending of each chromosome into two closely appressed arms, which are destined to be separated in the metaphases by a transverse fission. My figures agree with those of both Schaffner and Farmer and Moore as to the formation of the loops; but it is certain that in *Lilium canadense* a loop does not represent that part of the spirem which is destined to form a chromosome; but that, on the contrary, the peripheral portion of the loop marks the region in which the separation between two adjacent chromosomes is to occur. The looping, therefore, has nothing to do with a folding or bending of the chromosome, which, in fact, according to my observations, never occurs.

It will be seen that each chromosome consists, from the time of its formation, of two portions, the products of a longitudinal splitting, which are twisted about each other. This double nature persists throughout the period of shortening of the chromosomes, down to the time of separation of the daughter chromosomes in the metaphases; the separation in the heterotypic division, therefore, is along the line of the longitudinal fission which the spirem underwent before its segmentation.

My observations as to the history of the chromosomes after segmentation, and as to the method of their separation, are in harmony with the more recent results of Strasburger ('00) and Mottier ('03). When the equatorial plate is formed, the majority of the chromosomes are attached at or near one end to the spindle; but a few are attached at the middle or at some point between the middle and one end. In the commoner case, that of the attachment at one end, the daughter chromosomes separate from each other as straight rods; but just before the completion of the separation, each daughter chromosome splits longitudinally, the halves diverging at their equatorial ends and remaining in contact by the ends directed toward the pole, giving a V-shape to the daughter chromosome. It is often evident that this second longitudinal split extends the full length of the daughter chromosome, the granddaughter chromosomes so produced remaining in contact, however, at their polar ends.

In the separation of the halves of a chromosome whose attachment is at or near the middle, each daughter chromosome becomes bent at the point of attachment and assumes, during the separation, a U or V-shape. When, therefore, the second longitudinal split occurs, such a daughter chromosome is divided into two V's, which remain in contact at their angles. This variation in the appearance of the daughter chromosomes, due to the method of their attachment to the spindle, has been responsible for much of the confusion that has existed regarding the nature of the heterotypic division in plants.

After the gathering of the daughter chromosomes at each pole of the spindle, they become curved, bent, and crowded together into a dense mass, about which a nuclear membrane is formed. The curving is such that a free end of one granddaughter chromosome (turned toward the equatorial plane of the spindle) comes into contact with a corresponding end of another chromosome. Whether these ends become fused, forming a continuous spirem, I have been unable to determine. At any rate, very early in the prophases of the homoeotypic division, some time before the disappearance of the nuclear membrane, the thread loosens and spreads apart to some extent, and it is then seen to be composed of segments, which have the shape of V's with curved arms, and which occupy exactly the same position as did the daughter chromosomes in the anaphases of the preceding division. There can be no doubt, I think, that the V-shaped chromosomes of the homoeotypic division are identical with the daughter chromosomes of the heterotypic division.

These V shaped chromosomes become arranged in the equatorial plate with their angles turned toward the interior of the spindle, and it is often evident at this stage that the arms of a V are not fused, but are simply in contact at the angle. Sometimes more than twelve V's are to be observed. If, as I suspect, this fact is due to the persistence of the form of the occasional V-shaped granddaughter chromosomes of the previous division, we should expect to find now and then a V-shaped daughter chromosome in the metaphases of the homoeotypic division; but I have not as yet observed such figures. The separation in the metaphases is usually, at least, at the angle of the V, resulting in rod-shaped daughter chromosomes which are identical with the granddaughter chromosomes of the heterotypic division.

If my description be correct of the origin of the single spirem by a fusion of two originally separate threads, an explanation is offered for the sudden appearance in the heterotypic division of the reduced number of chromosomes. Each nucleus of the plant or animal, in preparing for division, forms a spirem, composed of substances derived in equal proportions from the male and female parents. There is no fusion of these hereditary substances thoughout the life history of the individual, until the initiation of nuclear division in the spore mother-cells in the case of plants, or in the primary spermatocyte or the primary oocyte in the case of animals. In the prophases of this division, the two portions of the spirem, each derived ultimately from one of the parent germ cells, become applied to each other and fuse into a single thread, so effecting the mixture or interaction of hereditary qualities which was provided for by the fusion of the sex cells at the beginning of the life-cycle.

As I have said, the chromomeres fuse in pairs; but just what this fusion involves as regards the smaller units which make up the chromomeres is a problem which at present perhaps cannot be solved by direct observation. If we adopt the hypothesis, frequently advanced, that the transmission of hereditary qualities is a function of the chromomeres, or of their component units, a very interesting parallel may be traced between the observed facts above described and the results of recent experimental studies of hybridization. A discussion of this and of related questions will be deferred until the appearance of the complete paper.

It is interesting to note that De Vries ('03) has recently concluded, upon hypothetical grounds, that before their separation in the heterotypic division the chromosomes lie side by side in pairs, each pair consisting of a paternal and a maternal segment; and that, in this condition of intimate contact, a mutual interaction, or even an interchange of hereditary units occurs. The pairing of the parental chromosomes postulated by De Vries may be conceived to be effected by the method described by Farmer and Moore ('03), who hold that each apparently double chromosome is formed by a transverse bending of one of the original segments of the spirem. If it be maintained that one of the segments which thus folds upon itself represents a paternal and a maternal chromosome attached end to end, it would seem to follow that in the spirem of a somatic mitosis the parental elements are arranged in regular alternation. If the views expressed in the present paper be correct, it is more probable that the chromosomes derived from the male parent are attached end to end to form a thread, and that those from the female parent are arranged into a similar thread; and that in a somatic mitosis these two threads in turn unite by their ends to form a continuous spirem.

The peculiarities of the heterotypic division described by Rosenberg ('04) in a hybrid Drosera, in which ten single and ten double chromosomes appear, may be accounted for by supposing a fusion of the two parental portions of the spirem in the early prophases. The portion derived from one parent, containing only ten segments, would extend only half the length of the other portion, containing twenty segments; the thread on segmenting would therefore give rise to ten segments of double thickness and ten of single thickness, the latter perhaps incapable, in this division at least, of longitudinal splitting. —CHARLES E. ALLEN, *University of Wisconsin, Madison, Wis.*

NOTE.—Since the above was written, there has appeared a further account by Rosenberg ('04 a) of the post-synaptic processes in Drosera. He is convinced that there is a fusion of the chromosomes side by side during the spirem stage. Strasburger ('04), on the other hand, has described in Thalictrum a quite different method of conjugation of the paternal and maternal chromatin in entire independence of the linin. A. and K. E. Schreiner ('04) have found a fusion and subsequent splitting of the spirem, substantially identical with the processes I have described, in the spermatogenesis of Myxine and Spinax; and similar results had been previously announced by von Winiwarter ('00) and Schoenfeld ('01) with respect to mammalian oogenesis and spermatogenesis.

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CURRENT LITERATURE.

BOOK REVIEWS.

Plant breeding.

A THIRD EDITION of Professor Bailey's *Plant breeding*[1] has just been issued. The first edition was issued in 1895,[2] and since that time remarkable changes have taken place in our point of view. As the author remarks, "these years may be said to have marked a transition between two habits of thought in respect to the means of the evolution of plants, from the points of view held by Darwin and the older writers to those arising from definite experimental studies in species and varieties." The chief practical results to plant breeding have been the recognition that not all variations in plants are of equal importance, and the belief that the offspring of hybridization follow definite laws. And yet the author did not feel justified in recasting the lecture on "The philosophy of the crossing of plants, considered in reference to their improvement under cultivation," finding that it would largely be only a matter of rephrasing. The new matter is introduced in lecture IV, the old title "Borrowed opinions (extracts from representative European writings)" being replaced by "Recent opinions: being a résumé of the investigations of DeVries, Mendel, and others, and a statement of the current tendencies of American plant-breeding practice." The title is sufficiently explicit to indicate the contents, and a compact simple statement of these matters is a boon to the general reader. It is a matter of interest to note that a bibliographical reference in one of Professor Bailey's papers led DeVries to the discovery of Mendel's publication, an account of which he published in 1900. In this chapter IV DeVries himself has written a section on hybridization.

It is a satisfaction to see that Professor Bailey has not been swept off his feet by the swelling tide of Mendelism. The wild prophecies that the application of Mendel's law will reduce plant breeding to a science of mathematical precision find him waiting for proof. Perhaps a good statement of the author's attitude is his answer to the question as to what are the great things we have learned from these newer studies.

"(1) In the first place, we have been brought to a full stop in respect to our ways of thinking on these evolution subjects. (2) We are compelled to give up forever the taxonomic idea of species as a basis for studying the process of evolution. (3) The experimental method has finally been com-

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[1] BAILEY, L. H., Plant breeding, being five lectures upon the amelioration of domestic plants. Third edition. pp. xiii + 334. New York: The Macmillan Company. 1904.

[2] See BOT. GAZ. **21**: 175. 1896.

pletely launched and set under way. (4) We must study great numbers of individuals and employ statistical methods of comparison. (5) The doctrine of discontinuous evolution is now clearly before us. (6) We are beginning to find a pathway through the bewildering maze of hybridization."—J. M. C.

River plankton.

IN a *Bulletin* of the Illinois State Laboratory of Natural History,[3] a bulky volume of something over five hundred pages, we have by far the most important contribution yet made to the subject of potamoplankton. There have been many extended series of observations on the plankton of lakes, but river plankton has received very little attention. This has been partly because of the greater richness of limnoplankton, partly because the problems of limnoplankton are simpler than those of potamoplankton, and perhaps of greater interest, and partly, doubtless, because the lakes are more important for the production of fish. The greater credit, perhaps, ought to be given for the attempt to throw light on the problems of river plankton by long continued systematic observations.

The work centered at Havana on the Illinois River, and collections were made, not only in the river, but in neighboring waters, including Spoon River, Quiver Lake, Dogfish Lake, Flag Lake, Thompson's Lake, and Phelps Lake. The conditions in the Illinois River are unusual because of the large amount of sewage that comes from Chicago and the other cities in its course. Spoon River is a typical prairie river with no artificial conditions. The lakes examined are all connected with the river at the time of high water, and some of them have a permanent connection through the year. Thus the work of investigation included a study of the Illinois River, of a river uncontaminated with sewage, and of several shallow bodies of water which were filled by overflow from the river and were stagnant for a greater or less part of the year. Something over a hundred pages are devoted to a somewhat detailed discussion of the geological and hydrographical features of the basin of the Illinois.

The remainder of the work is a discussion of the quantitative investigation of the plankton. The methods of collection worked out by Dr. Kofoid are somewhat different from those employed at other stations, and the author naturally considers them superior. It may be questioned, however, whether the methods used in the shallow silt-laden waters of the river could be used with advantage in a study of limnoplankton. The centrifuge was used to get the plankton into compact form for measurement, and this method seems to be the most practical that has yet been devised.

The study of plankton production was carried out with the most pains-

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[3] KOFOID, C. A., The plankton of the Illinois River, 1894–1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part I. Quantitative investigations and general results. Bull. Ills. State Lab. Nat. Hist. vol. 6. 8vo. pp. xviii + 629. *pls. 50.* 1903.

taking care; and this involved an amount of pure drudgery which only one who has undertaken a similar piece of work can really appreciate. Yet one must confess to some surprise that after such an enormous amount of work in testing methods and in computing collections, the somewhat elaborate discussion of the transverse distribution of plankton should be based on only two sets of collections.

At the close of the work the general results are summarized under twenty-six heads. In a brief review it is impossible even to state these, but reference may be made to such as are of most general interest. The horizontal distribution of river plankton is practically uniform. The maximum period of production is from April to June, but with great irregularities. Generally speaking, high water reduces the amount of plankton by dilution, and low water increases it by giving time for development of the various forms. So the more or less stagnant waters of the shallow lakes have a greater plankton production.

"Other things being equal, bodies of fresh water free from vegetation (submerged macro-flora) produce more plankton than those rich in such vegetation." This statement, if proven—and the author makes out a strong case—is a very important one. If it were shown, as it probably can be, that the reduction in plankton in lakes with submerged vegetation is due to lack of plankton plants rather than to the small number of plankton animals, the generalization might go far toward explaining the greater fish production of shallow lakes. It has been shown by the reviewer that deep lakes produce more animal plankton per square meter than shallow lakes, and that the greater total plankton production of shallow lakes is due to the vegetable part of the plankton. It is the animal part of the plankton that furnishes most of the food for fish. The surplus of vegetable plankton is simply waste. Hence, so far as food production is concerned, the shallow lakes have no advantage over the deeper ones. But it is a matter of common observation that the shallow lakes, with submerged vegetation, are favorable to the production of fish. Is it not probable that the superiority of the shallow lake over the deeper one is not in the greater amount of plankton, but in that the submerged vegetation furnishes a favorable physical environment in which the fish may find hiding places? Probably the submerged vegetation does not remove from the water the part of the plankton that is important as food for fish.

In comparing the plankton of the river with that of lakes, the author considers the river among the more fertile bodies of water. This fertility appears greater, however, because of the author's preference for stating plankton amounts in terms of cubic meters. This, of course, is a matter of personal preference; the reviewer prefers to state it in terms of a surface unit, as did Hensen in his original plankton work. Especially, if one is to compare the fertility of a body of water with that of a piece of ground, the surface unit is the only practical one.

Two criticisms may be made upon the work as a whole. First, its bulk is rather unfortunate, for doubtless many who would be glad to get at the general results will hesitate to read so large a book. Second, it would have been a great convenience had it been indexed. These are minor criticisms, however, for the work is a most important and valuable one. It should perhaps be mentioned that, while this work on the Illinois River was planned and carried out by Dr. Kofoid, it may, after all, be considered as the direct outcome of work which has been carried on by the director of the laboratory, Dr. S. A. Forbes, for the past generation.—C. DWIGHT MARSH.

MINOR NOTICES.

THE FIRST VOLUME of the *Jahresbericht der Vereinigung der Vertreter der angewandten Botanik* contains several articles of interest from the standpoint of applied botany. ADERHOLD[4] reviews the present status of our knowledge of Bordeaux mixture, discussing critically the results of Clark, Sturgis, Bain, Rumm, and others who have investigated the action of this fungicide, both on parasites and host plants. SCHULZE[5] discusses the influence of sterilization of soil on plants grown therein. It is found that this influence differs both with the character of the soil and with the kinds of plants used. The author points out that these factors ought to be considered in experiments where plants are grown in sterilized soil. NESTLER[6] has investigated the occurrence of thein in the tea plant. The substance is found present in varying amounts in the leaves, bark, flowers, fruit, and seeds; in fact in all parts of the plant except the roots and wood. An article by WIELER[7] deals with some little-observed smoke injuries. The author calls special attention to poisoning of the soil under trees in the vicinity of smelters due to sulfurous acid and other substances dissolved in rain water. This poisoning of the soil produces premature autumnal coloration of the leaves, especially in the beech. Other articles deal with seed testing and with fermentation.—H. HASSELBRING.

THE SECOND PART of Grout's[8] *Mosses with a hand-lens and microscope* well sustains the promise of its predecessor, as we judge from advance sheets with which we have been favored. The issue completes the Dicranaceae, Grimmiaceae, and Ephemeraceae, and presents a good part of the Tortula-

[4] ADERHOLD, R., Der heutige Stand unseres Kenntnisse über die Wirkung und Verwert und der Bordeauxbrühe als Pflanzenschutzmittel. Jahresb. Vereinig. Vert. angew. Bot. 1: 12–36. 1903.

[5] SCHULZE, C., Einige Beobachtungen über die Einwirkung der Boden-sterilization auf die Entwickelung der Pflanzen. *ibid.* 37–44.

[6] NESTLER, A., Untersuchungen über das Thein der Theepflanze. *ibid.* 54–61.

[7] WIELER, A., Wenig beachtete Rauchbeschädigungen. *ibid.* 62–78.

[8] GROUT, A. J., Mosses with a hand lens and microscope. Part II. Imp. 8vo. pp. 87–166. *figs. 36–76. pls. 11–35.* Brooklyn: The author. $1.00. 1904.

ceae. The plates are remarkably good reduced reproductions of those of the *Bryologia Europaea*, as are most of the figures, which sometimes cover a half page or more. The figures original in this work are well drawn and illustrate critical features of various species. The comments of the author will also be very helpful to those for whom the book is intended. All in all, the work is admirable both in conception and in execution. It is difficult to understand how it can be sold profitably at the very low price asked.—C. R. B.

THE FACT that an unhealthy or wounded tree is neither ornamental nor serviceable dominates every page of the little volume entitled *The tree doctor*.[9] The titles of the three sections into which the book is divided are : tree surgery; ornamental; landscaping and floriculture. In the first part, where, how, and when to prune a tree are discussed, while the two latter titles deal with the problems of landscape gardening. The book is written in a somewhat sensational and extravagant style, and it contains numerous statements in regard to the physiology and pathology of plants that will seem queer to the scientific reader. The volume is intended, however, for the layman, and it will doubtless stimulate him to a better care of his fruit-bearing and ornamental trees. — C. D. HOWE.

C. F. MILLSPAUGH[10] has issued the Compositae of his flora of Yucatan. In addition to the plates, there are numerous excellent cuts from drawings by Miss Agnes Chase, showing a portion of the inflorescence or a single head natural size, the achene magnified, and a cross-section of the achene at its greatest diameter. The display of the family is somewhat remarkable in that there are no large genera among the 58 enumerated. The new species in old genera are only three in number (Parthenium, Salmea, Encelia), and a new genus (*Plagiolophus*) of Verbesinae is described by J. M. Greenman.— J. M. C.

THE SIXTH FASCICLE of Dalle Torre and Harms's *Genera Siphonogamarum*[11] has just appeared, including genera from Gentianaceae (6492. Geniostemon) to Acanthaceae (7937. Mimulopsis).— J. M. C.

NOTES FOR STUDENTS.

IWANHOFF[12] finds that proteids are not destroyed in the course of alcoholic fermentation, because the decomposition of the sugar forms substances which inhibit the action of the proteolytic enzymes.— C. R. B.

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[9] DAVEY, JOHN, The tree doctor, a book on tree culture illustrated profusely with photographs. 8vo. pp. 88. *figs. 167*. Akron, Ohio: Published by the author. 1902. $1.00.

[10] MILLSPAUGH, C. F., Plantae Yucatanae (regionis antillanae). Plants of the insular, coastal, and plain regions of the peninsula of Yucatan, Mexico. Fasc. 2. Compositae (with Agnes Chase). Pp. 85–151. *pls. 9* and numerous text cuts. Field Columb. Mus. Bot. Series 3: no. 2. April 1904.

[11] DALLA TORRE, C. G. DE, and HARMS, H., Genera Siphonogamarum ad systema Englerianum conscripta. Fasc. 6, pp. 401–480. Leipzig: Wilhelm Engelmann, 1904. *M*4.

[12] IWANHOFF, L., Ueber das Verhalten der Eiweissstoffe bei der alkoholischen Gärung. Ber. Deutsch. Bot. Gesells. **22**: 203–206. 1904.

BENECKE[13] has presented a concise review and discussion of several of the more recent researches upon the influence of metallic salts upon organisms. He well points out that what is most needed now is a study of the effect of a large number of salts upon the same organism, so that comparison may be instituted. He also calls attention to the fact that the effect of salts upon other processes than growth (*e. g.*, photosynthesis, transpiration, etc.) will need to be studied.—B. E. LIVINGSTON.

OLIVER,[14] in studying certain unreferred seeds of the Permocarboniferous, has found that those named Trigonocarpus and Polylophospermum, both being of the radially symmetrical type (Radiosperms), agree essentially in structure with Stephanospermum and the Trigonocarpons of the English Coal Measures, having the broad pollen-chambers, the tracheal mantle, and the differentiated testa. The probabilities are becoming stronger that many of these numerous unreferred seeds belonged to that anatomically differentiated group Cycadofilices, and it remains to be seen how much of it will pass over into the recently proposed group Pteridosperms.[15]—J. M. C.

ILTIS[16] has investigated the influence of light and darkness on the rate of growth of the adventitious roots of a number of water plants. His results show that the growth of the roots observed is decidedly accelerated by darkness. The mean result of experiments on the roots of five water plants, viz: *Myriophyllum proserpinacoides*, *M. verticillatum*, *Lysimachia nummularia*, *Ranunculus aquatilis*, and *Elodea canadensis*, though varying considerably among themselves, shows the growth in length in darkness is approximately twice that of similar roots in the light. This is a greater acceleration for darkness than has been obtained for soil roots.—W. B. MACCALLUM.

APOGAMOUS PROTHALLIA[17] of Nephrodium, showing remarkable nuclear changes that appear to be related to the apogamy in question, are described in a preliminary note by Farmer, Moore, and Miss Digby. Binucleate cells are frequently present in young prothallia and in such cases at least one contiguous cell is destitute of a nucleus. Nuclei were also seen passing from one cell into another and a fusion of nuclei may then take place, though the two nuclei often remain separated for some time. Mitoses in apogamous

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[13] BENECKE, W. VON, Einige neuere Untersuchungen über den Einfluss von Mineralsalzen auf Organismen. Bot. Zeitung **62**^{2}: 113–126. 1904.

[14] OLIVER, F. W., Notes on *Trigonocarpus* Brongn. and *Polylophospermum* Brongn., two genera of palaeozoic seeds. New Phytol. **3**: 96–104. *pl. 2.* 1904.

[15] See BOT. GAZ. **37**: 236–238. 1904.

[16] ILTIS, HUGO, Ueber den Einfluss von Licht und Dunkel auf das Längenwachstum der Adventivwurzel bei Wasserpflanzen. Bei. Deutsch. Bot. Gesells. **21**: 508–517. 1903.

[17] FARMER, J. B., MOORE, J. E. S., and DIGBY, MISS L., On the cytology of apogamy and apospory. I. Preliminary note on apogamy. Proc. Roy. Soc. London **71**: 453–457. 1903.

regions show a much larger number of chromosomes than those of the ordinary cells of the prothallium. The whole process is regarded as a kind of irregular fertilization and the young plantlet as an homologously differentiated embryo.—C. J. CHAMBERLAIN.

A CYTOLOGICAL STUDY[18] of malignant growths known as "carcinomata" and "sarcomata" has shown nuclear details resembling those in normal reproductive cells. The cells of the diseased tissue for a time resemble those of early stages in sporogenous tissue; then a varying number of cells, situated behind the advancing edge of the diseased tissue, enlarge and undergo the heterotypic mitosis, showing the loops or rings characteristic of the heterotypic mitosis of normal reproductive cells, and in several cases the numbers were approximately halved. Subsequent divisions behind this zone show homœotypic mitoses, but the reduced number of chromosomes is retained. This paper is a preliminary note and does not attempt to make a full application of the results.—C. J. CHAMBERLAIN.

FARMER and MOORE[19] are reinvestigating the reduction of chromosomes and believe they can reconcile such divergent views as those of Häcker and Brauer. They claim that observers, with the exception of Schaffner, have not apprehended the mode of formation of the heterotypic chromosomes. They believe that synapsis is a phase specially intercalated in the reproductive cycle, and that in it the number of chromosomes is reduced by their adhesion in pairs. The longitudinal division following synapsis is that characteristic of ordinary somatic division, the separation of the halves being deferred until the next mitosis. They believe that the heterotype division is different in kind from ordinary mitoses. The full paper, now in preparation, will give the evidence upon which their conclusions rest.—C. J. CHAMBERLAIN.

THE VASCULAR SYSTEM of *Pteris aquilina*, though examined by every elementary student, has been very generally misunderstood. DeBary followed Hofmeister in considering the peripheral ring of strands to be cortical bundles, but Jeffrey[20] pointed out that these represent the stele, while the two central or medullary strands are of late origin. The petiolar strands are derived from both inner and outer strands of the rhizome. In a recent paper by Tansley and Lulham[21] the exact connection of the petiolar strands with

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[18] FARMER, J. B., MOORE, J. E. S., and WALKER, C. E., On the resemblances exhibited between the cells of malignant growths in man and those of normal reproductive tissues. Proc. Roy. Soc. London **72**: 499–504. 1903.

[19] FARMER, J. B., and MOORE, J. E. S., New investigations into the reduction phenomena of animals and plants. Proc. Roy. Soc. London **72**: 104–108. *figs. 6.* 1903.

[20] JEFFREY, E. C., The morphology of the central cylinder in the angiosperms. Trans. Canadian Inst. **6**: 1–40. *pls. 7–11.* 1900.

[21] TANSLEY, A. G., and LULHAM, R. B., The vascular system of the rhizome and leaf-trace of *Pteris aquilina* and *Pteris incisa integrifolia*. New Phytologist **3**: 1–17. *figs. 59.* 1904.

those of the rhizome has been traced. The writers derive the condition seen in *P. aquilina* from the simpler one presented by *P. incisa integrifolia*, in which the infoldings of the petiolar stele are continued down into the rhizome as infoldings, while in *P. aquilina* the infoldings become medullary strands in the rhizome.—M. A. CHRYSLER.

THE STIMULATION OF GROWTH by poisons has been studied by Kanda.[22] He finds that seedlings of *Pisum sativum* in water culture are not stimulated by $CuSO_4$ at any concentration. The salt is toxic at a concentration of $M/1,000,000,000$. When these seedlings are grown in water which contains traces of $ZnSO_4$ they are stimulated to greater growth, the optimum concentration lying between $M/10,000,000$ and $M/1,000,000,000$. This salt is toxic at $M/1,000,000$ concentration. In a similar way NaF is found to stimulate Pisum seedlings when at a concentration of $5M/10,000$ to $5M/100,000$. NaF is toxic at about $5M/1,000$ concentration. When grown in pots of soil and watered with solutions of $CuSO_4$ and ZnSO , seedlings of *Vicia Faba* and *Pisum sativum* show a marked stimulation at a certain concentration. Of course the amount of salt cannot here be measured; the fact of stimulation alone is noted.—B. E. LIVINGSTON.

ACCORDING TO RESEARCHES OF GRÜSS,[23] it is possible to demonstrate in yeast cells, and in a glycerin extract of them, a substance which splits free oxygen from such molecules as hydrogen peroxid, potassium permanganate, and the oxidation products of di- and tetramethylparaphenylendiamin chlorid, etc. It is possible to destroy the oxidase in yeast by treatment with aceton, after which treatment the power to split oxygen from the above bodies is still exhibited to a marked degree. The author was able to separate oxidase from this new body (which he terms peroxidase) by their unequal rates of diffusion. If into a mixture of yeast cells rubbed up in glycerin strips of filter paper are hung, it is found that the peroxidase ascends in the paper much faster than does the oxidase, so that the paper at a certain level is found to give no reaction for the latter enzyme, while the presence of peroxidase was easily demonstrated. Grüss thinks the new body is probably a true enzyme, of opposite action to that of oxidase.—B. E. LIVINGSTON.

THE NOTABLE LENGTHENING which takes place in the stipe of Taraxacum during the ripening of the seed has often been commented upon, especially by the older ecologists. Miyake[24] has made daily measurements of the growing stipe in numerous specimens of several varieties of Taraxacum.

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[22] KANDA, MASAYASU, Studien über die Reizwirkung einiger Metallsalze auf das Wachsthum höherer Pflanzen. Jour. Coll. Sci. Imp. Univ. Tokyo **19**: [article 13]. pp. 37. *pl. 1.* 1904.

[23] GRÜSS, J., Peroxydase, das Reversionsenzym der Oxydase. Ber. Deutsch. Bot. Gesell. **21**: 356–364. 1903.

[24] MIYAKE, K., Ueber das Wachstum des Blütenschaftes von Taraxacum. Beihefte Bot. Centralbl. **16**: 403–414. *pl. 1.* 1904.

He finds three well-marked stages in the development: (1) a period of accelerating growth extending from the appearance of the stipe to the middle of the flowering period, 7–10 days; (2) a period of slow growth including the last half of the flowering and the development of the seeds, 6–8 days; (3) a second period of active elongation reaching its maximum 1–2 days before the dispersal of the seeds and continuing for a day or two thereafter, 7–10 days. The greatest daily growth noted in the first stage was 8.9^{cm}, and in the third stage 10^{cm}. The curve representing the "grand period of growth" thus presents the anomaly of having two well-marked maxima. There seems to be no indication that external factors are responsible, as every individual measured, both in Japan and America, gave essentially the same results.—G. H. SHULL.

THE MEMOIR OF F. W. OLIVER[25] "On the structure and affinities of Stephanospermum," read before the Linnean Society in February of 1903, has just appeared. In consequence of the fact that during this long interval between the reading of the paper and its publication a remarkable number of discoveries have been made bearing upon the matters of general morphological interest presented by this paper, its information is not so fresh and striking as it would have been a year ago.[26] In addition to the details in reference to the two species of Stephanospermum considered, attention is called to the fact that the presence of a pollen chamber is a remarkably uniform character of paleozoic seeds. That this pollen chamber was associated with fertilization by means of swimming sperms seems to be no less evident, and it "reached its zenith in Permo-Carboniferous times. Its decline Professor Oliver correlates "with the evolution of pollen-tubes;" but it must be remembered that there is every reason to believe that pollen-tubes were not originally developed as sperm-carriers. The whole paper is full of interesting details to the morphologist interested in the phylogeny of seed-plants. —J. M. C.

BOWER[27] has published the results of a study of a single specimen of the very interesting Sumatran *Ophioglossum simplex*, only three plants of which were found by Ridley in 1897. "The almost complete suppression of any trace of a sterile portion of the frond, and the consequent reduction of the plant to the very simplest elements, is the most peculiar feature in this species" is a statement from Ridley's description. Bower found that an external examination revealed no part which could be compared with the sterile lobe or sporophyll of other Ophioglossaceae, and this was confirmed by

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[25] OLIVER, F. W., On the structure and affinities of *Stephanospermum* Brongniart, a genus of fossil gymnosperm seeds. Trans. Linn. Soc. London. Bot. II. **6**: 361–400. *pls. 41–44.* 1904.

[26] See BOT. GAZ. **37**: 236. 1904.

[27] BOWER, F. O., *Ophioglossum simplex* Ridley. Annals of Botany **18**: 205–216. *pl. 15.* 1904.

sections. Accordingly, in his judgment, the "sterile lobe" is completely suppressed. It seems to follow either that the plant never had a subtending sporophyll or that the sporophyll is entirely abortive. The former alternative would support the view of the primitive character of the Ophioglossaceae, proposed by Campbell in comparing the "spike" of Ophioglossum with the sporogonium of Anthoceros. Bower is inclined to accept the second alternative, and to see in *O. simplex* an abortion of the sterile lamina, regarding the Ophioglossaceae as derivatives from a lycopod type. He finds a descending series in the related *O. pendulum*, *O. intermedium*, and *O. simplex*, in which there is a decrease of the sterile leaf, and the extreme condition of *O. simplex* he thinks "may be attributed to the presence of mycorhiza, which makes nutrition of the large spike still possible in the dense, wet forest in which it grows, notwithstanding that the usual assimilating organ is functionally non-existent."—J. M. C.

HANNIG[28] has studied the growth of embryos in nutrient solutions outside of the embryo sac. The embryos used were those of *Raphanus sativus*, *R. Landra*, *R. caudatus*, and *Cochlearia danica*, and were isolated at various stages in their development from the one-celled condition. The object was to determine their ability to utilize various organic foods. In the cell-sap squeezed out of the plant and sterilized the embryos refused to grow. In nutrient salt solutions they also failed to live, despite the fact that all possess plenty of chlorophyll. In cultures of 10 per cent. cane sugar in a nutrient salt solution embryos consisting of a single cell at the end of the suspensor soon die, but much older embryos grow well. These never assume the curved position that they present in the embryo sac but always remain straight. They soon lose their chlorophyll, but make and store in their leaves large amounts of starch, but are unable to form proteid. Young plants taken from this sugar solution and planted in sand and watered with a nutrient salt solution at once become green and grow and fruit normally, which brings out the interesting fact that the embryo is not hindered from its normal development by removal from the embryo-sac. In solutions of 1 per cent. sugar and varying amounts up to 10 per cent. of peptone the embryos are unable to produce proteid and the protoplasm finally disappears, as does also the chlorophyll. With asparagin as a source of nitrogen only the older embryos of Cochlearia came to maturity; all the rest died, as they also did in leucin. With glycocoll, which is a favorable source of nitrogen for fungi, no growth was obtained, nor on tyrosin. In a decoction of Raphanus plants only a temporary growth was obtained. Several other nitrogen compounds were used, but in no case could any increase in the total amount of nitrogen in the embryos be obtained.—W. B. MACCALLUM.

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[28] HANNIG, E., Zur Physiologie pflanzlicher Embryonen. I. Ueber die Cultur von Cruciferen-Embryonen ausserhalb des Embryosacks. Bot. Zeitung **62**^{1}:45–80. *pl. 3.* 1904.

WILLIAMS,[29] in continuing his studies in the Dictyotaceae, has described the gametophyte generation of *Dictyota dichotoma*, dealing with the development of egg and sperm, fertilization, segmentation of the fertilized egg, and parthenogenesis. The oogonia and antheridia are developed simultaneously in fortnightly crops, each crop being initiated a little before the lowest neap tide, and reaching maturity about the period of the highest succeeding spring tide. A regular succession of crops continues thus from July to the end of October. The eggs are liberated for fertilization, and those not fertilized within half or three-quarters of an hour become invested by walls and give rise to parthenogenetic embryos. The oogonium and antheridium are produced by the increased growth of surface cells, and after cutting off a stalk-cell they form respectively a single egg and over 1500 sperms. All the divisions of the antheridium are homotypic, and there are sixteen chromosomes. The sperm has a lateral cilium, and there may be a second very much reduced cilium, but it is difficult to demonstrate. The eye-spot is very small, and instead of being at the base of the cilium is generally near the anterior end of the beak. After fertilization thirty-two chromosomes appear, and in the segmentation of the egg there is at first a single centrosome which divides, and as the two centrosomes separate the two spindle cones also diverge, until finally they form a normal spindle. In parthenogenesis the nucleolus breaks up into chromosomes, leaving no residual nucleolar matter to be extruded into the cytoplasm, as occurs in other mitoses. The mitotic figure is very irregular and multipolar; there is no nuclear membrane, and a cluster of nuclei is formed, each containing one or several chromosomes. These separate into two or more groups, and walls are formed between them. The process may go on a little further, but very soon it stops and the embryos die. Comparing normal germination with parthenogenesis, it is concluded that the entrance of the sperm into the egg causes a centrosome and radiations to appear in the cytoplasm, renders the metabolism of the nucleus far more active, introduces into the mitosis a directive influence that is completely absent from the parthenogenetic figure, and prevents the early disappearance of the nuclear membrane.—J. M. C.

MASSEE[30] has published an extremely interesting and suggestive paper on the origin of parasitism in fungi. The author refers to the experiments of Pfeffer and of Miyoshi on chemotaxis, and then shows by his own experiments that the germ tubes of parasitic fungi in general are attracted by decoctions of their respective host plants. Thus *Macrosporium Tomato* and *Cladosporium fulvum* are attracted by decoctions of tomato leaves, *Cercospora melonis* is attracted by a decoction of cucumber leaves, etc. Obligate parasites are attracted only by the cell sap of the plants upon which they are

[29] WILLIAMS, J. LLOYD, Studies in the Dictyotaceae. II. The cytology of the gametophyte generation. Annals of Botany **18**: 183–204. *pls. 12–14.* 1904.

[30] MASSEE, G., On the origin of parasitism of fungi. Phil. Trans. Roy. Soc. London B. **197**: 7–24. 1904.

parasitic; while facultative parasites are attracted by substances, such as sugar, common to many plants. That a facultative parasite does not attack all plants containing sugar is probably due to the presence of some other negatively chemotactic substance in the plant. A state of immunity, therefore, is determined by the presence or absence of chemotactic substance. This was actually shown to be the case with an immune cucumber plant growing among a number of plants attacked by *Dendryphium comosum*. All efforts to inoculate this plant failed. The germ tubes of the fungus also failed to respond chemotactically to a decoction of the leaves of the plant. Miyoshi has shown that by injecting leaves with a sugar solution the germ tubes of *Penicillium glaucum* could be made to penetrate the leaf and grow in its tissues. By a similar method Massee has succeeded in growing *Trichothecium candidum* on begonia leaves injected with 2 per cent. sugar solution. The spores produced in the first instance were sown on another injected leaf and so on for fifteen generations. Sowings from some of the later generations of spores were made on leaves not injected, and it was found that the fungus grew and fruited on the leaf; in other words, it had been changed into a true parasite in twelve to fifteen generations. In several other instances similar experiments were successfully carried out with other fungi and other hosts, and several illustrations are given where a similar transition was observed in nature. The transition from a saprophytic to a parasitic mode of life is thus shown to take place with comparative ease. The possibility of wide application of the suggestion embodied in Massee's work will at once appear evident, not only in its relation to parasitism among fungi, but also as an explanation of the curious phenomena of heteroecism and symbiosis.— H. HASSELBRING.

STRASBURGER[31] has made a careful investigation of the origin of the embryo sac and development of the prothallium in *Taxus baccata*. The work was undertaken not with the expectation of making new discoveries, but rather in the hope of establishing a firmer basis for comparison with the problematical structures of the embryo sac of angiosperms. Each embryo sac mother-cell in Taxus is the inner cell of a row resulting from repeated divisions of an outer cell of the periblem of the nucellus. The sporogenous cells in the nucellus form a group of from three to five contiguous embryo sac mother-cells only slightly marked off from the surrounding tissue, which in a physiological sense may be designated as a tapetum. The mother-cells are formed in October and the winter is passed in this condition, but by the end of February they have elongated so that they are readily distinguishable. The spring of 1903, when the material was collected, was unusually early, so that the pollen was shed by the last of February, and about the same time

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[31] STRASBURGER, EDUARD, Anlage des Embryosackes und Prothalliumbildung bei der Eibe nebst anschliessenden Erörterungen. Reprint from Festschrift zum siebzisten Geburtstage von Ernst Haeckel. pp. 1–18. *pls. 1–2.* Jena, Gustav Fischer. 1904.

divisions appeared in the embryo sac mother-cell. Cold weather followed and all stages of development in the nucellus were suspended until the end of April. The mother-cell gives rise to four megaspores arranged in a row, though other arrangements are sometimes found, due presumably to the shape of the mother-cell. The four megaspores correspond to the four microspores formed by a pollen mother-cell. Usually only one of the megaspore mother-cells reaches the synapsis stage. The mitotic figure at the first division of the mother-cell is plainly heterotypic and the number of chromosome pairs seems to be eight. The expected sixteen chromosomes were counted repeatedly in vegetative tissues, but a smaller number was sometimes found. The second division is homotypic. The lowest of the four megaspores is almost invariably the one to germinate, but any of the others may develop, and in one case two contiguous megaspores of one row were observed with several free nuclei. Frequently more than one megaspore in the nucellus may begin to develop. The mitotic figure at the first division in the germinating megaspore is heterotypic, and generally eight chromosomes could be counted. This number was also counted at the second division. When the eight-nucleate stage is reached the nuclei have begun to assume a peripheral position in the sac, but there is no polar grouping as in angiosperm sacs.

Strasburger calls attention to the fact that *Ceratozamia mexicana* also has eight to sixteen chromosomes, while other gymnosperms, so far as determined, have twelve and twenty-four. Many embryo sacs nearly filled with tissues were examined to see whether any nuclear fusions occurred which could be compared with the fusion of polar nuclei in embryo sacs, but no fusions were found. The archegonium initials appear as soon as the embryo sac is filled with tissue.

After discussing the development of prothallia and fertilization in Gnetum, the conclusion is reached that it is not possible to derive the embryo sac of angiosperms from that of Gnetum, the resemblances being only phylogenetic parallels. The densely staining areas in the embryo sac mother-cells of Casuarina and of various gymnosperms were studied in Taxus. Though denser, they have the same general structure as the trophoplasm. It is suggested that these structures may be useful in determining the position of Casuarina.

The nuclear fusions which initiate the formation of endosperm in angiosperms are not found in gymnosperms and show no indication of their origin. They are not to be regarded as sexual fusions, although, under some conditions, the fusion of sister nuclei may be a process of fertilization.— C. J. CHAMBERLAIN.

NEWS.

DR. HENRY H. DIXON has succeeded Professor E. Percival Wright as professor of botany in Trinity College, Dublin.

MARY PERLE ANDERSON, a graduate student of The University of Chicago, has been appointed instructor in botany in Mt. Holyoke College.

DR. H. H. BEHR, professor of botany in the California College of Pharmacy, died in San Francisco March 6, in his 86th year. He was the author of the "Flora of the vicinity of San Francisco," published in 1888.

IN HIS ACCOUNT of the forest fires in the Adirondacks in 1903, H. M. Suter, of the Bureau of Forestry, reports that over 600,000 acres of timberland in northern New York were burned over, culpable carelessness having been responsible for the largest part of the fires.

IN A RECENT NUMBER of *Ber. Deutsch. Bot. Gesells.* (Generalversammlungs-Heft **21**: 9–66. 1904) the following biographical sketches are published: L. J. ČELAKOVSKÝ, by B. Němec; FRANZ BENECKE, by W. Wieler; ALBERT MATZ, by P. Graebner; MICHAEL WORONIN, by S. Nawaschin; EUGEN ASKENASY (with portrait), by M. Möbius.

PROFESSOR E. L. GREENE has resigned his position at the Catholic University of Washington. His very valuable herbarium and library will be deposited in the U. S. National Herbarium for a period of ten years. It will be moved during June and will be accessible for reference at once. Professor Greene will be an Associate in Botany in the National Museum and will have an office in the building.

THE ANNUAL REPORT of the New York Botanical Garden for 1903 gives some conception of the varied interests and great activity of that growing establishment. The herbarium is reported to have received an accession of 84,163 specimens. The privileges of the laboratories, library, and herbarium have been granted during the year to forty-six students, including graduates of forty different colleges and universities; and the investigations have covered a wide range. The work of exploration has been carried on by members of the staff and others with remarkable activity, especially among the West Indies, collections having been obtained from Cuba, Porto Rico, Jamaica, Dominica, Haiti, and Honduras. The Philippine Islands have also been invaded, and special collections were made in Arizona and peninsular Florida.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties are printed in **bold-face** type; synonyms in *italics*.

THE HILL OF TARIK IN AMERICA,

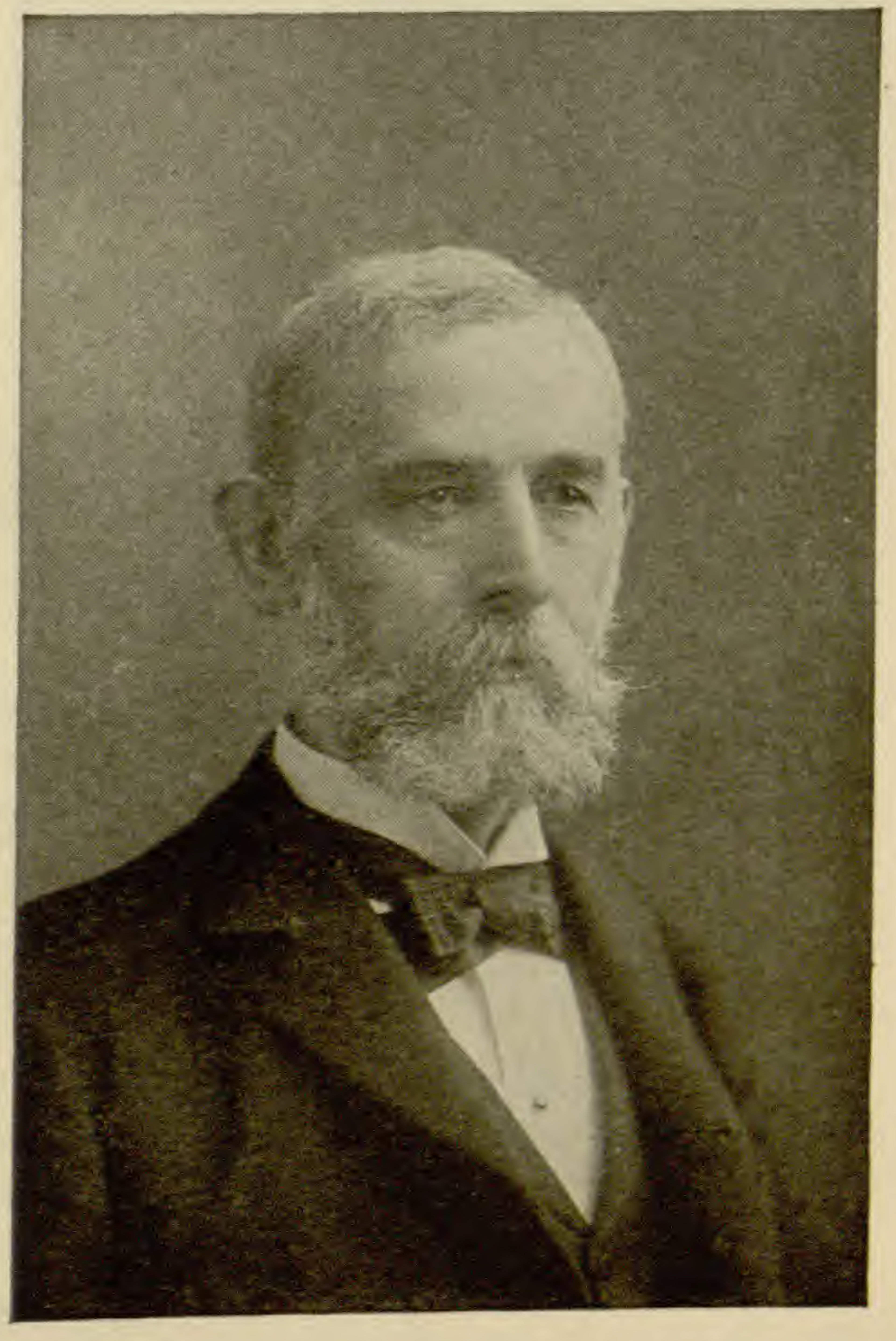
By HERBERT S. HOUSTON.

(*With Photographic Illustrations by Arthur Hewitt.*)

FROM Madeira the ship's course was straight for the Mediterranean. Among those on board, bound for the Orient, were a New York publisher and a bright boy from the West, eager for all the new sights of the Old World ahead. As the land breezes caught the pennant at the masthead, the boy scanned the eastern horizon and he kept it up for hours.

"What are you looking for so hard?" inquired the publisher.

"Oh, I want to see that big sign of the Prudential on Gibraltar," and the boy still peered into the east. When at last the great rock, the Hill of Tarik the Saracen, lifted its head above the ocean, the boy searched in vain for the sign he was sure he would see. For him, as for all other Americans who read the magazines, the Prudential was inseparably associated with Gibraltar. And this association has made the rock and the insurance company almost interchangeable terms, simply because each suggested strength. But the American Gibraltar achieved its strength in a few years by dauntless human endeavor, while the slow accretions of ages gave strength to its namesake, the mighty Hill of Tarik.



U. S. SENATOR JOHN F. DRYDEN,
President of the Prudential.

Ten years after the close of the Civil War—a period so recent that its history has scarcely been written—the Prudential was established in Newark. As if foreknowing the great rock to which it would grow, it began its foundation in a basement office. It was like the beginning of the New York *Herald* by Bennett, the elder, in a basement on Ann Street. But it would be an idle play with words to make a basement office the real foundation of the Prudential. It was something much deeper down than that—nothing else than the bed-rock American principle of democracy. The Prudential applied the democratic principle to life insurance. As Senator Dryden, of New Jersey, the founder of the company, has said: "Life insurance is of the most value when most widely distributed. The Prudential and the companies like it are cultivating broadly and soundly among the masses the idea of life-insurance protection. To them is being carried the gospel of self-help, protection, and a higher life."

HOME OFFICES, PRUDENTIAL INSURANCE CO., NEWARK, N. J.

And what has been the result of the democratic American principle worked out in life insurance? In 1875 the first policy was written in the Prudential. At the end of 1903 there were 5,447,307 policies in force on the books of the company, representing nearly a billion dollars. The assets in 1876 were $2,232, while twenty-seven years later, in 1903, they were more than 30,000 times greater, or $72,712,435.44, the liabilities at the same time being $62,578,410.81. This is a record of growth that is without precedent in insurance and that is hard to match in the whole range of industry. The rise of the Prudential to greatness reads like a romance in big figures, but, in fact, it is a record of business expansion that has been as natural as the growth of an oak. To say that, in ten years, the company's income grew from something more than $9,000,000 a year to more than $39,000,000 last year is amazing as a general statement, but when made in relation to the broad principles on which that growth has been based, there is no mystery about it; but there is in it, from the day when the principles were planted in Newark until these great harvest days, the genuine American spirit of achievement, strong, hopeful, and expansive.

The Prudential Insurance Company of America is a national institution. It was founded to provide insurance for the American people on the broadest possible basis, consistent with strength and safety.


ENTRANCE TO MAIN OFFICES.

Just as Grant and Lee organized their armies, or as Kouropatkin and Yamagata plan their campaigns in Asia, so does the Prudential work out its national insurance propaganda. The company's organization is essentially military. It is a wonderful combination of big grasp and outlook, with the most painstaking thoroughness and system in details. And, as is always the case in every organization that throbs throughout with intelligent energy, there is a man at the center of it. This man has a constructive imagination lighting up a New England brain. To business prudence there is added the large vision which sweeps the horizon for opportunity. Naturally, to such a vision the application of the democratic idea to insurance was an opportunity of the first magnitude. When seen, it was grasped and developed. The Prudential was founded. Year after year the company added to its number of policy-holders. And all the time the company was working out a more liberal basis for its democratic idea. But each time a more liberal policy was offered, it was fully tested. "Progress with strength" is the way President Dryden describes the company's principle of growth—the results, clearly, of vision and prudence. At the end of ten years of this method of growth, the company reached the point where, it was believed, insurance could be safely offered for any amount with premiums payable on any plan, either in weekly instalments or at longer periods. Within the five years, 1886 to 1890 inclusive, the company's assets increased nearly fivefold, from $1,040,816 to $5,084,895, and the amount of insurance in force from $40,266,445 to $139,163,654.

The Prudential had found itself. The idea of democratic insurance had been fully tested and adjusted to the needs and conditions of the American people. Then, with a boldness which only large vision could have quickened, the plan was formed to make the Prudential's idea known in every section of the country. Gibraltar was chosen as the symbol of the company's strength, and advertising—the telling of the Prudential idea to the people—was begun.

There is no place where one feels the greatness of the Prudential quite so much as in the vast granite piles which have been raised for the company's home buildings. They rise above the Jersey meadows as Gibraltar does above the sea, a convincing witness, surely, to the growth and to the strength of the Prudential. But they are not a cold, gray rock, but a living organism throbbing from vital contact with millions of policy-holders. There are now four of these great buildings, all occupied by the company.

Today the Prudential is paying over 300 claims a day, or about forty each working hour. On many policies settlement is made within a few hours by the superintendent of the district; on the large policies a report is sent immediately to the home office and settlement authorized by telegraph. And on over 45 per cent. of the claims more money is paid than the policy calls for. From the beginning the Prudential has followed lines of great liberality.

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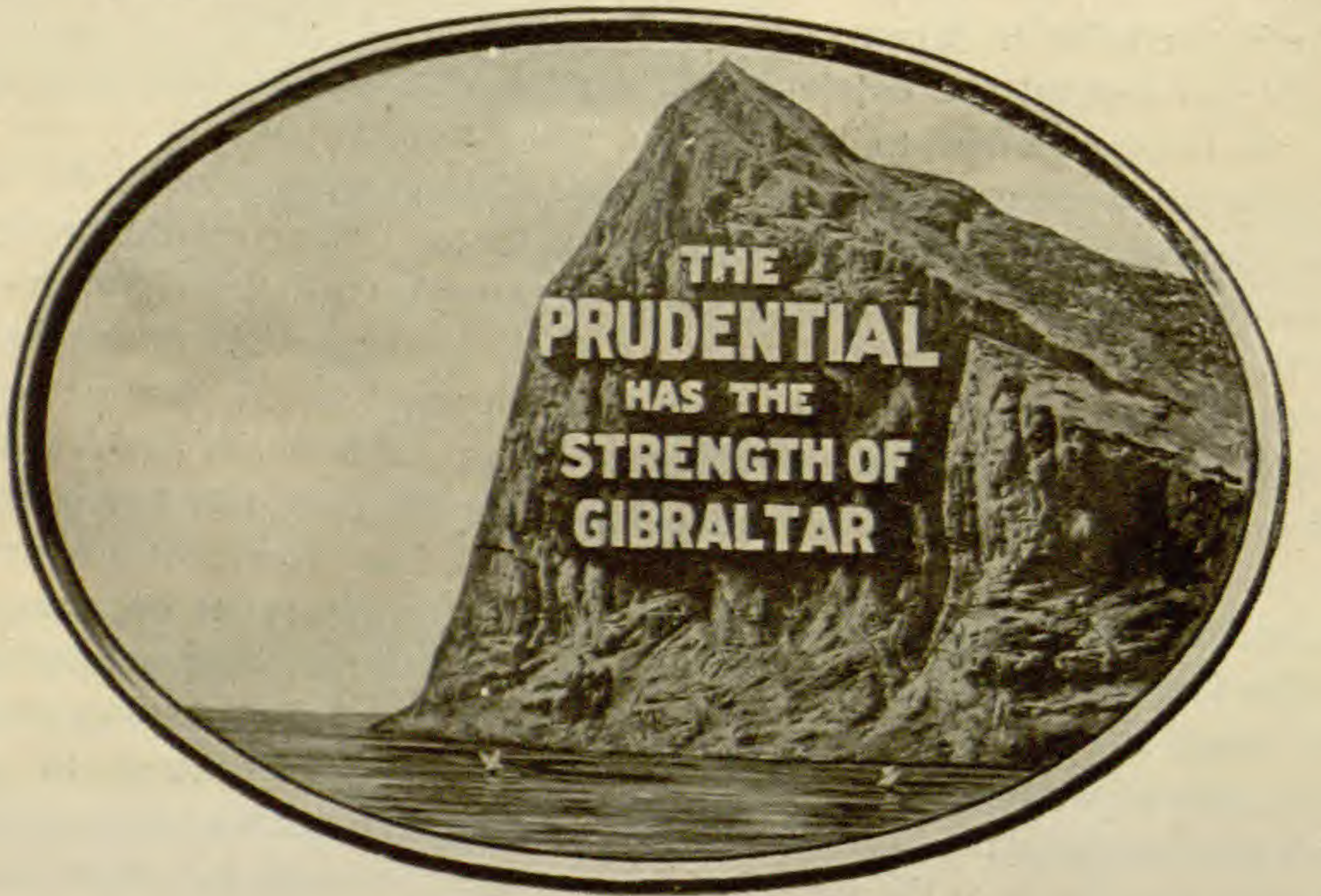

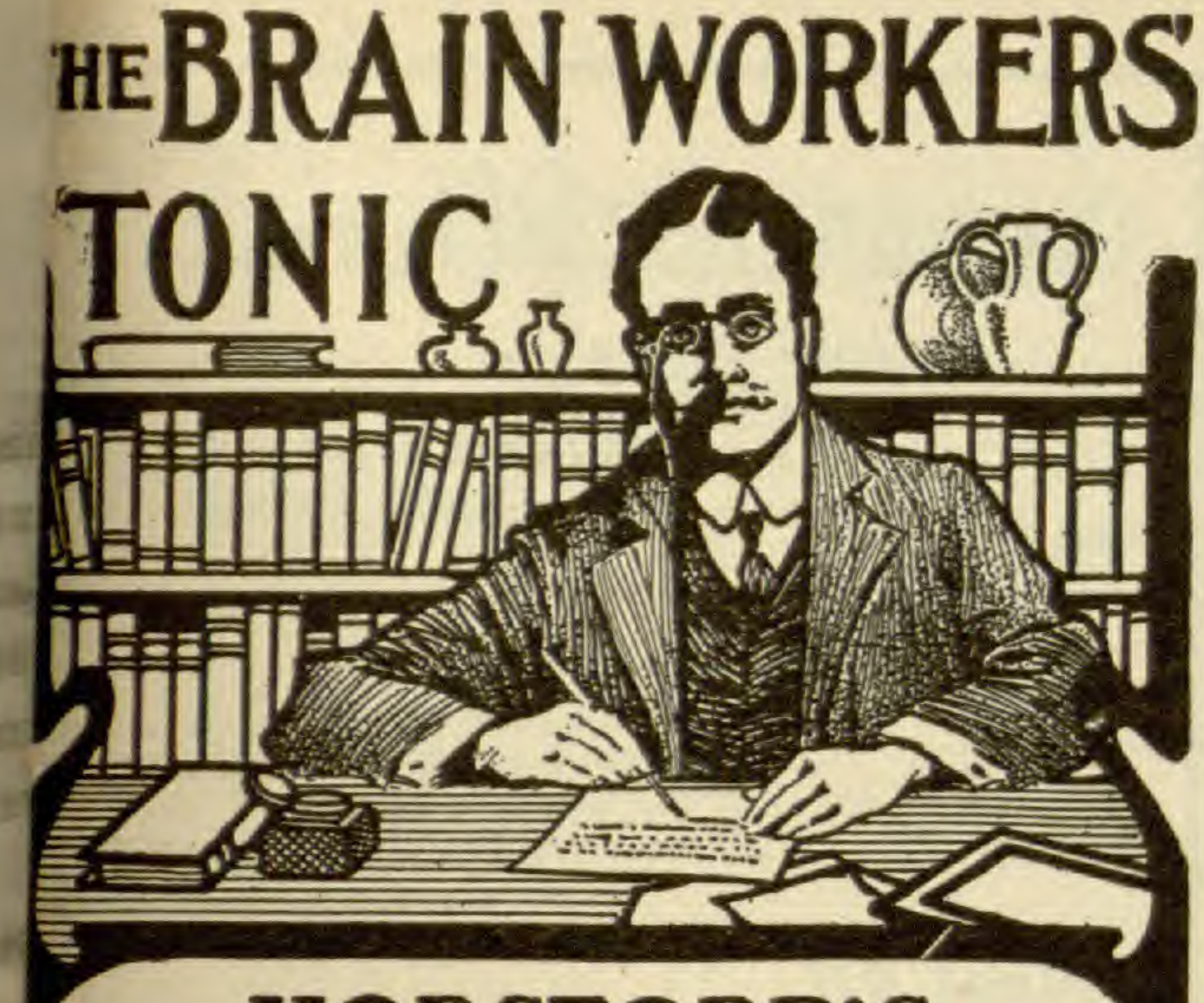
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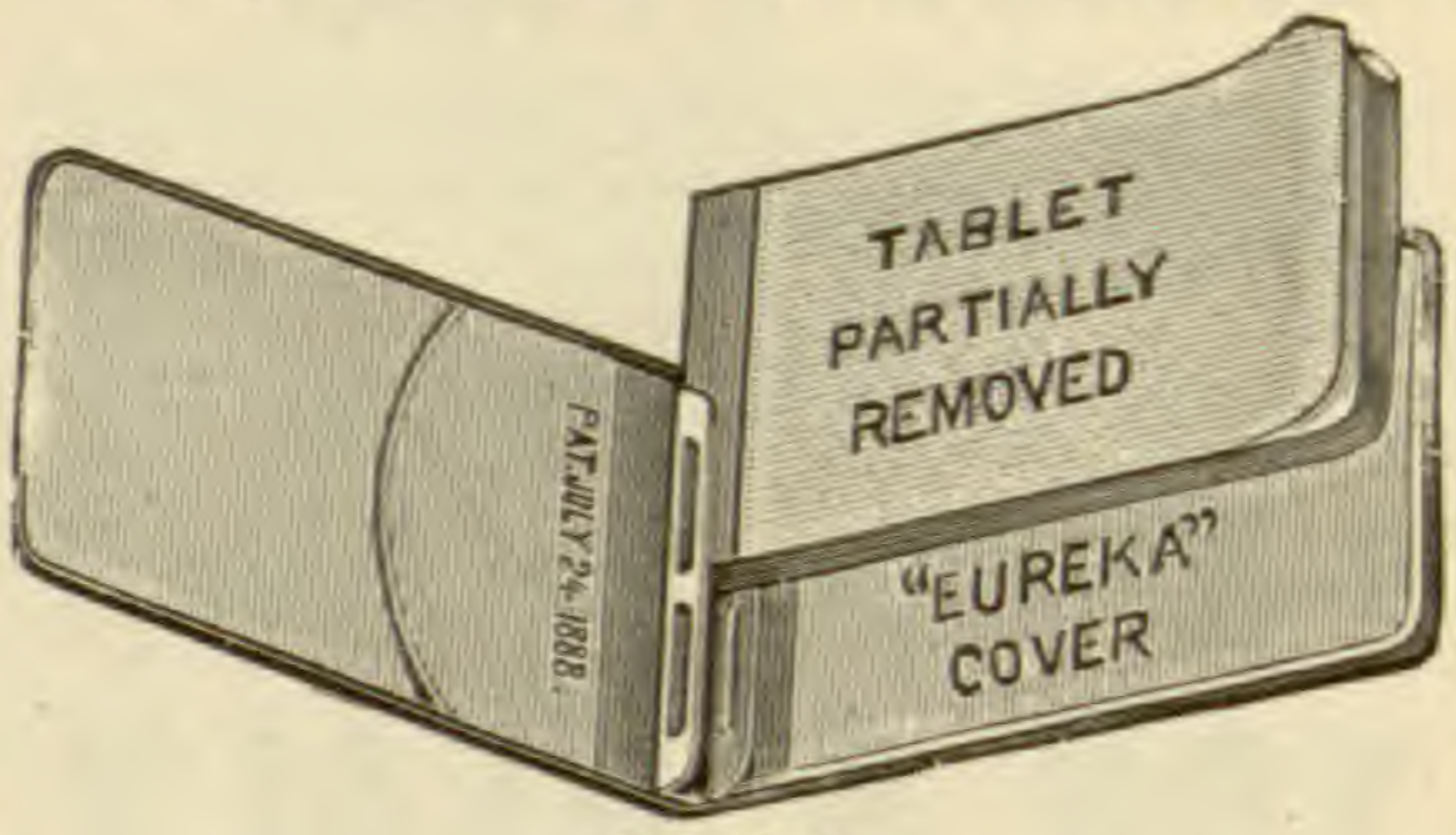

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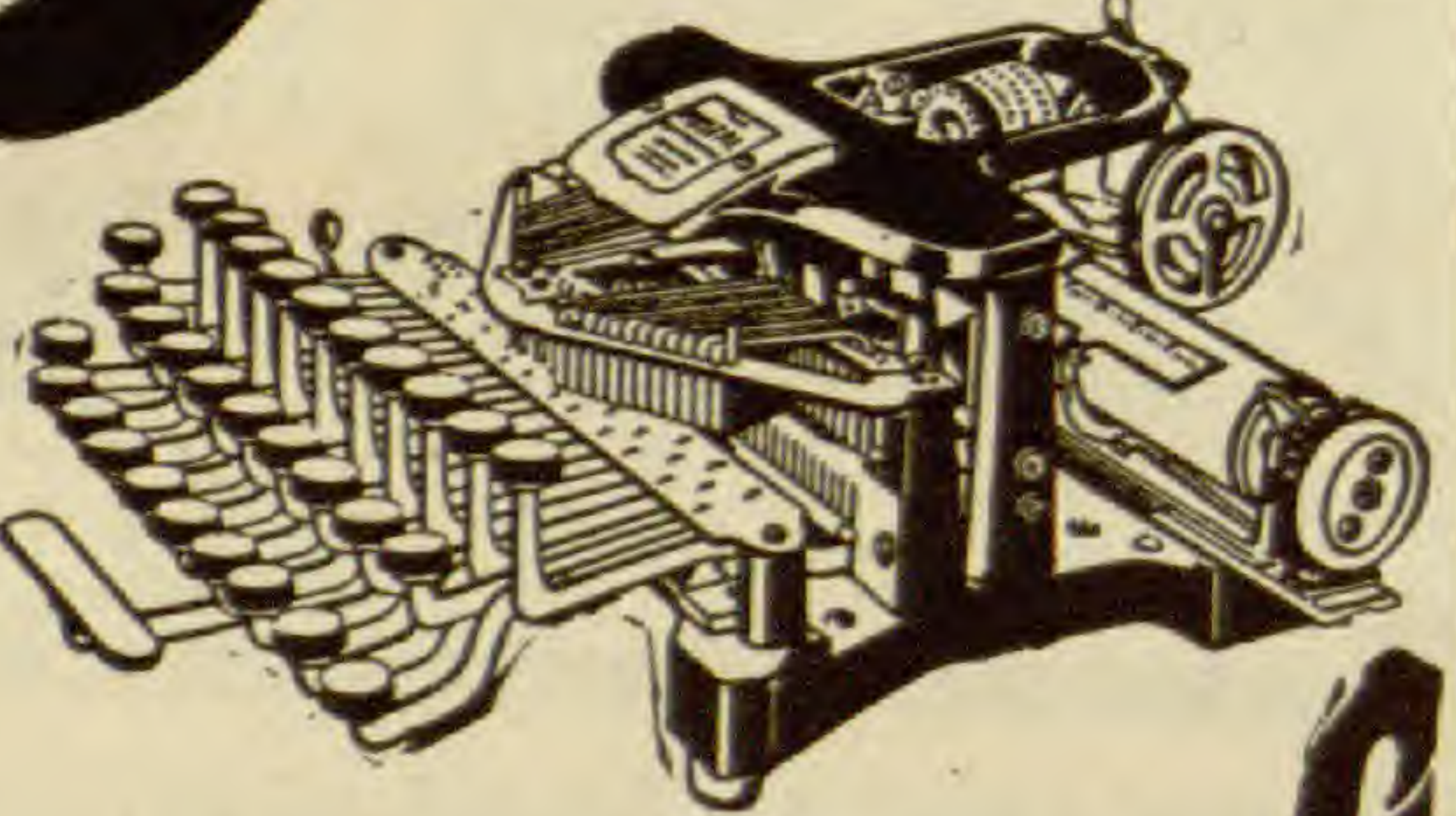

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